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STRUCTURAL ANALYIS AND DESIGN OF A BOX CULVERT ALONG ISUANIOCHA, MGBAKWU ROAD IN AWKA-NORTH LOCAL GOVERNMENT AREA, ANAMBRA STATE USING BS-8110

BY

AKPA NNAMDI OYO

NAU/2016224005

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NNAMDI AZIKIWE UNIVERSITY, AWKA

SUPERVISOR: ENGR. PROF. C.H. AGINAM

FEBRAURY 2022

CERTIFICATION

This is to certify that this project work is done by Akpa Nnamdi Oyo, Reg no: 2016224005 has been approved in partial fulfillment of the requirement for the award of bachelor degree in Engineering in civil engineering.

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Akpa Nnamdi Oyo   Date

(Student)

APPROVAL

This design work has been assessed and approved by the department of Civil Engineering, Nnamdi Azikiwe University, Awka.

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Engr.Prof. C.H. Aginam Date

Supervisor

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Engr. Dr. C. A. Ezeagu Date

(Head of Department)

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Engr. Prof. D.O. Onwuka Date

(External examiner)

DEDICATION

This project work is dedicated to God Almighty whom his infinite grace and mercy has led me to the successful completion of my project. I equally dedicate this work to my late Dad Oyo Akpa and to my entire family at large for their support and encouragement towards the success of this work.

ACKNOWLEDGEMENTS

The help of God Almighty throughout my life and stay in this university is highly acknowledged.

Many thanks to the entire staff of Civil Engineering Department especially my project supervisor Engr. Prof. C.H. Aginam for his instruction, patience and understanding in guiding me through this project. The effort of our Head of Department, Engr. Dr. C. A. Ezeagu in organizing the department is also highly acknowledged and also my lecturers, Engr. Prof Ekenta, Engr. Prof. Chidolue, Prof. C.M.O Nwaiwu. Prof. N.E. Nwaiwu, Engr. Nwajuaku .A.I, Engr. Dr. Adinna, Engr. Ezewamma, Rev. Dr Nwkaire, Engr. Dr. P. Onodagu, Engr. Dr. Odinka, Engr.B. Njotae, Engr.N. Nwokdiko, I really appreciate your efforts towards impacting me the requisite knowledge needed for my excelling in this department and beyond.

I will also in no small way appreciate my lovely parents, Mr. and Mrs. Akpa for their love, and continuous support throughout my stay in this graeat institution and to my uncle Engr. Nwakpa Oyoyo, you all make me feel blessed for having you all as a family.

All my friends and course mates are well appreciated for their love and support. God bless you all.

SYMBOLS AND ABBREVIATION

Q = Discharge

L = Culvert length

S = Culvert slope

Ke = Entrance loss coefficient

V = Velocity

D = Height box

Dc = Critical depth

N = Manning’s roughness coefficient

B = Culvert width

A = Cross sectional area

M = Moment

M_A = Moment at point A

T_{as} = unit weight of asphalt

W = Wheel load

H = Depth of earth fill

∅ = Angle of repose

U.D.L = uniformly distributed load

ϵMA = Summation of moment about point A

E = Modulus of elasticity

I = Second moment of area

Q = Shear force

N = Axial forces

f_{CU} = Characteristics strength of concrete

fs = Service stress in reinforcement (deflection requirement)

As = Area of steel

AS_{prov} = Area of steel provided

As min = Minimum area of steel

M.F = Modification factor

V = Shear stress

Vc = Concrete shear stress

c/c = centre to centre

k_a = Coefficient of active pressure

p_a = Active earth pressure

X = Level arm

M_r = Resisting moment

Mnet = Net moment

q = Earth bearing pressure

N_f = Near face

FHWA = Federal highway authority

RCD = Reinforced concrete design

AASHTO = America Association of state highway and transportation officials

μ = Coefficient of friction

Fo = Factor of safety for overturning

e = Eccentricity

ABSTRACT

This project is the analysis design of Box culvert along Isuaniocha/ Mgbakwu road in Awka North Local Government Area. The sequence of execution commenced with a site investigation, collection of data and information for the hydraulic design, which gives the adequate dimension of the culvert. The hydraulic design was carried out in line with federal highway authority (FHWA) design guidelines. Then, the structural analysis and design was done based on the result of the hydraulic design. The culvert was analyzed and designed as a rigid frame under different load combination of dead load, live load, water pressure and literal earth pressure. The method of analysis used was force method for triple and single cell box culvert was designed for both ultimate limit state and serviceability limit state. The wing walls and headwalls were designed as cantilever retaining walls. Detailing was done according to BS8110. Having satisfied all necessary checks the proposed culvert is fit for construction and will serve its purpose under the worst condition.

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CHAPTER ONE

INTRODUCTION

A culvert is a small opening of less than six meres (6m), provided to allow flow of water pass through the embankment and follow the natural channel. Since culvert pass through the earthen embankment, subjected to same traffic loads as the road carries, the structural elements are required to be designed to withstand maximum bending moments and shear forces.

The structural analysis and design of triple and single cell box culvert is therefore the determination of the stresses and strain developed by the culverts when loaded and providing the appropriate reinforcement members to suit these stresses and strains.

1.1 Statement of Problem

Inaccessibility of Isuaniocha village for conveying goods due to the absence of access road thereby preventing the location of industries in the large expanse of land in the interior parts of Isuaniocha village and thus impeding the development of the area.

1.2 Aim & Objective

The aim of this project is to produce adequate design of a triple and single cell box culvert across a natural drainage channel at Isuaniocha road, Awka North to easy vehicular movement.

The main objective is to provide a design that is structural stable, based upon appropriate hydraulic principles, economy and minimized effects.

1.3 Scope of Study

The study is limited to the hydraulic and structural analysis, design and detailing a triple and single cell box culvert with each cell having an opening dimension of 2.8m X 2.8m and is to be located along Isuaniocha-Mgbakwu road, Awka North local government area based on the data obtained from the MINISTRY OF WORKS, inlet and outlet nomograph will be used for the hydraulic design of the culvert. The structure will be designed using BS8110 and the structural detailing will also be in accordance with BS8110.

The detailing of the hydraulic design is in accordance with Federal Highway Authority (FHWA)

1.4 Significance of the Design

The natural channel at Isuaniocha road has been an impediment to the flow of traffic and pedestrians between Mgbakwu Town, the design of a triple cell box will direct drainage of accumulated stream water runoff from roads.

Thus, this design will help recognize the need to allow natural movement of surface water where fill roads would otherwise adversely affect the natural flow and alter the hydrology of the area.

1.5 Classification Of Culverts

Culverts can be classified as:

i. pipe Culvert
ii. Arch Culvert
iii. Pipe Arch Culvert
iv. Box Culvert
v. Slab/bridge culvert
vi. Metal Box Culvert

1.6 Factors Affecting Choice Of Culverts

Some factor to be considered in choosing the type of culvert to be used are as follows:

i. Road profiles.
ii. Channel characteristics.
iii. Flood damage evaluations.
iv. Construction and maintenance cost.
v. Estimates of service life.

1.7 Material For Construction

The following materials can be used in construction:

i. Concrete (Reinforced and non-reinforced)

ii. Galvanized steel (Smooth and corrugated)

iii. Aluminium (Smooth and corrugated)

vi. Plastic (Smooth and corrugated)

V. High density polyethylene.

1.8 Factors Affecting Choice Of Materials For Construction

The selection of the construction materials for a culvert depends on several factors that can vary considerably with location. They include:

i. Structure strength, considering filling height, loading condition a foundation condition
ii. Hydraulic efficiency, considering manning roughness, cross section area and shape.
iii. Installation, local construction practices ,availability of pipe embedment material and point tightness requirement
iv. Durability, considering water and soil environment (PH and resistivity), corrosion (Metallic coating selection) and abrasion.
v. Cost, considering availability of materials

1.9 Functions of Culvert.

i. Culverts are provided to allow water flow freely across the embankment without causing failure of the road.
ii. They are provided to balance the water level on both sides of embankment during floods.
iii. It provides a platform for road construction to ensure its continuity over the water course without obstructing the flow of the water course.

1.10 Application Of Culverts

Culverts are applied in surface water drainages, stream diversion, conveyor tunnels, storage tanks, pedestrian subways, vertical shafts and walls, vehicle access and cattle creeps, installation of thrust bore techniques and so on.

1.11 Culvert Flow

The flow is usually non-uniform with regions of both gradually varying flow. Outlet velocity can range from 3mls for culverts on mild slope to 9mls for those on steep slopes

1.11.1 Types Of Control Flow

a) Inlet Control:

A culvert flowing in inlet control has shallow, high velocity flow categorized as “supercritical”. For supercritical flow the control section is at the upstream and the barrel (inlet).

b) Outlet Control:

A culvert flowing in outlet control will have relatively deep, lower velocity flow termed "subcritical" flow. For subcritical flow the control is at the down stream end of the culvert (the culvert).

1.12 Concrete Box Culvert

One of the most common types of culverts used today is the concrete box culvert. It is made up of cement, fine aggregate, coarse aggregate and water with reinforcement. A box culvert has a top slab, vertical walls and a bottom slab which may or may not be present. When present, it provides a lined channel for the water and a base for the walls. It could also be left out in order to allow the stream crossing to maintain its natural streambed. In such a case the side walls are supported on concrete footings.

The dimensions of the box culvert are determined by the hydraulic requirements, forces it would be subjected to, bearing capacity of in-situ soil and so on. Box culverts are used in a variety of circumstances for both small and large channel openings and are easily adaptable to a wide range of site condition. In cases where the required size of the opening is very large, a multi-cell box culvert can be used. It is important to note that although a box culvert may have multiple barrels (cells), it is still a single structure. The internal walls are provided to reduce the unsupported length of the top slab.

1.13 Types of Construction

There are two main types of concrete box culverts. They are

i. **Cost-in-place box culverts:** They are constructed at the site using form work as mould and pouring concrete into it (casting) so that the liquid concrete takes the shape of the mould when it solidifies. Reinforced cast-in-place (CIP) concrete culverts are typically rectangular (box) shaped. The major advantage of cast in place box culverts is that the culvert can be designed to meet the specific geometric requirement of the site.

ii. **Pre-cast box culverts:** They are fabricated in a controlled environment at the factory and then conveyed to the site where they are to be installed. They are designed for various depths to cover and various live loads and are manufactured in a wide range of sizes. Standard box sections are available with spans as large as 3.7 meters. Some advantages of precast box culverts are;

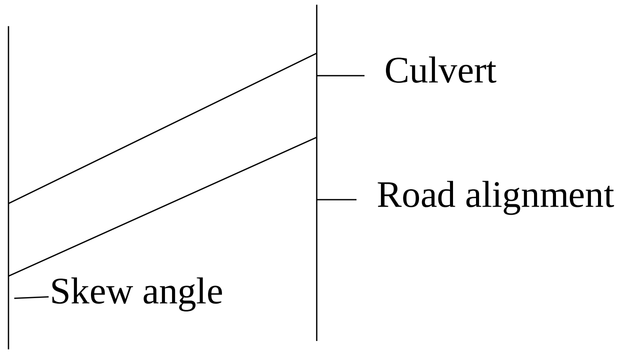
i. High quality

ii. Reduced water control cost

iii. Quick and easy on-site installation
iv. High durability and so on.

1.14 Skew Culvert

Sometimes the road alignment may cross a stream at an angle other than a right angle. In such situation a skew culvert may be provided. Thus



1.15 Cushion

A box culvert can be placed such that the lop slab is almost at road level. Here the culvert is said to be placed within the embankment such that the top slab is few meters below the surface. Such culverts are said to be with cushion. Thus, cushion refers to the material which fills the gap between the top slab and the road surface.

1.16 Advantages Of Box Culverts

i. The box culvert is structurally strong, stable and safe.
ii. It is easy to construct
iii. It can be placed at any elevation within the embankment with varying cushion which is not possible with other types.
iv. It does not require separate elaborate foundation and can be placed on soft soil by providing suitable base slab projection to reduce base pressure within the safe bearing capacity of the foundation soil.
v. Bearings are not needed
vi. It can be conveniently extended in future without any problem of design and/or construction.

CHAPTER TWO

2.1 Literature Review

The design of a culvert is divided into two parts. Namely; the hydraulic design and the structural design. The hydraulic design has to do with the estimation of the culvert size and the choice of culvert shape after due consideration of several factors such as design discharge, allowable headwater depth, slope of stream bed, allowable outlet velocity, and the culvert and son on.

According to Adekola (1990), structural design is concerned with estimating as accurately as possible the loads the structure is likely to be subjected to during service and the use of an appropriate method of analysis to evaluate the reactions and internal stresses generated in the structure after which the dimensions of the component parts of the culvert with appropriate strength grade would be chosen to safely resist such stresses under the worst condition.

2.2 Hydraulic Design

Hydraulic design precedes structural design. According to Ross (1988), “Before any attempt is made to design a culvert for a given site, certain field investigations are necessary. The required information is usually taken along with the survey work. Data relevant to center line location, skew of structure, and suggested possible channel changes are recorded along with the field survey. This data should be sufficient to provide cross section and profile, estimate a roughness factor, run off factor and so on. Hydraulic design determines whether the culvert flow is governed by inlet control or outlet control. According to a research sponsored by the Federal Highway Administration (FHWA), Norman, et al (1985), explained that culvert operation is governed at all times by one of two conditions: inlet control or outlet control. Inlet control is the common governing situation for culvert design characterized by the fact that the tail water or barrel conditions allow more flow to be passed through the culvert than the inlet can accept. The inlet itself acts as a controlling or governing section of the culvert, restricting the passage of water into the main barrel”

The ultimate objective of determining the hydraulic requirements for any highway drainage structure is to provide a suitable structure size that will economically and efficiently dispose of the expected runoff.

Certain hydraulic requirement should also be met to avoid erosion and sedimentation in the system.

The main factors considered in culvert deign are the location of the culvert, economy and the type of flow control.

It is the best to locate the culvert in the existing channel bed such that the center line and slope of the culvert coincides with that of the channel.

The design flow rate is based on the storm with an acceptable return period (frequency), culverts are designed for the peak flow rate.

The control section of the culvert is used to classify different culvert flows. The control section is the location at which a unique relationship exists between the flow rate and the depth flow.

There are two procedures for the hydraulic design of culverts. They are

1. Manual use of inlet and outlet control nomographs and
2. The use of computer programs.

The use of culvert design nomographs requires a trial and error solution, the design procedure uses several design charts and nomographs developed from a combination of theory and numerous hydraulic test results.

In the design of a culvert, the headwater elevations are computed for inlet and outlet controls and the controls with the higher headwater elevation is selected as the controlling condition.

As regards estimation of design flow and flood flow, Bhattachar and Michael (2003) stated that, “No method is available by which the extact amount and intensity of the rain fall in any assigned future period can be predicted precisely. Various methods have been used for estimating floods. Some of them are based on the characteristics of the drainage and others are based on the theory of probabilities applied to the previous known flood data; lastly others are based on a study of the rain fall and run off. Various methods, which are generally used in for determining flood flows, can be classified into the following.

1. Determination by means of empirical formulae
2. Determination by envelop curves.
3. Determination by statistical or probability methods; and
4. Determination by unit hydrograph method.

According to IOWA storm water management manual, (December, 2008), the design procedure that requires the use of inlet and outlet control nomographs is as follows.

Step 1: list of design data

- Q = Discharge (M^3/S)
- L = Culvert length (M)
- S = Culvert slope (M)
- Ke = Inlet loss coefficient
- V = Velocity (M/S)
- TW = Tail water depth (M)
- HW = Allowable headwater depth for the design storm (M).

Step 2: Determine trail culvert size by assuming a trial velocity 0.9-1.5m/s and computing the culvert area, A=Q/V. Determine the culvert diameter (m).

Step 3: Find the actual HW for the trail size culvert for inlet and outlet control.

a) For inlet control, enter-control nomograph with D and Q and find HW/D for the proper entrance type. Compute HW, and if too large or too small, try another culvert size before computing HW for outlet control.
b) For outlet control, enter the outlet-control nomograph with the culvert entrance loss coefficient, and trial culvert diameter.
c) To compute HW, connect the length of the scale for the type of entrance condition and culvert diameter scale with a straight line, pivot on the turning line, and draw a straight line from the design discharge through the turning point to the head loss scale H. compute the headwater elevation HW from the following equation: HW = H +ho –LS Where ho = ½ (critical depth + D), or tail water depth, whichever is greater.

Step 4: Compare the computed headwaters and use the higher HW nomograph to determine if the culvert is under inlet or outlet control. If outlet control governs and the HW is unacceptable, select a larger trail size and find another HW with the outlet control nomographs.

Step 5: Calculate exit velocity and expected streambed scour to determine if an energy dissipater is needed.

Creamer (2007) stated that “the FHWA has standardized the manner by which culverts are examined and designed. The design approach involves first computing the headwater elevation up stream of the culvert assuming that inlet control governs. The two headwater values are compared and the higher of the two is selected as the basis of the culvert design. The procedure described above is repeated for different types of culvert shapes, sizes and entrance condition. The least expansive culvert that produces an acceptable headwater elevation is typically chosen for the final design”.

2.3 Structural Analysis and Design

2.3.1 Structure of The Box Culvert

A box culvert is made up of several parts. According to Punmia, Jain and Jain (1992), “A box culvert is a continuous rigid frame of rectangular section in which the abutment and the top and bottom slabs are cast monolithic”. Sinha and Sharma (2009) also stated that, “the box is one which has its top and bottom slabs monolithically connected up of the three major elements. Namely: top slab, walls and bottom slab. These element have various loads acting on them.

Structural analysis involves the identification of the loads acting on the culvert as well as their magnitude and direction in order to ascertain their effects on the structure. These effects refer to the bending moments, shear and axial stresses, deflection and so on.

Design is the process of selecting the appropriate dimension of the structural elements with respect to the strength characteristics of the construction material (concrete in this case) that will adequately resist the stresses generated by the loads:

2.3.2 Loading

A box culvert is subjected to various loads. These loads could be vertical or lateral loads which can be classified as dead loads or live loads and can be estimated in the different ways under different circumstances.

According to Reynolds and Steedman (1988), "The loads on a box culvert can be conveniently divided as follows:

1) A uniformly distributed load on the top slab and an equal reaction from the ground below the bottom slab.
2) Concentrated imposed load on the top slab and an equal reaction from the ground below the bottom slab.
3) An upward pressure on the bottom slab due to the weight of the walls.
4) A uniformly distributed horizontal pressure on each wall due to the increase in earth pressure in the height of the culvert.
5) A uniformly distributed horizontal pressure on each wall due to pressure from the earth and any surcharge above the level of the roof of the culvert.
6) The internal horizontal and possibly vertical pressures from water in the culvert.

Where a trench has been excavated in firm ground for the construction of a culvert and the depth from the surface of the ground to the roof of the culvert exceeds, say, three times the width of the culvert, it may be assumed that the maximum earth pressure on the culvert is that due to a depth of the earth equal to three times the width of the culvert. Although a culvert passing under a newly filled embankment may be subjected to more than the full weight of the earth above, there is little reliable information concerning the actual load carried and therefore any reduction in the load due to arching of the ground should be made with discretion. If there is no filling and wheels or other concentrated loads can bear directly on the culvert, the load should be considered as carried on a certain length of the culvert. The concentration is modified if there is any filling above the culvert and, if the depth of the filling is h1, a concentrated load F can be considered as spread over an area of $4h_1$. When h_1 equals or slightly exceeds half the width of the culvert, the concentrated load is equivalent to a uniformly distributed load of $F/4H_1^2$ in units of force per unit area over a length of culvert equal to $2h_1$.

The weight of the walls and top (and any load that is on them) produce an upward reaction from the ground. The weights of the bottom slab and the water in the culvert are carried directly on the ground below the slab and thus do not produce bending moments, although these weights must be taken into account when calculating the maximum pressure on the ground. The horizontal pressure due to the water in the culvert produces an internal triangular or a trapezoidal load if the surface of the water outside the culvert is above the top slab. The magnitude and distribution of the horizontal pressure due to the earth against the sides of the culvert can be calculated in accordance with the formulae given in the table 16-20, consideration being given to the possibility of the ground becoming water logged with consequent increased pressures and possibility of floatation."

Oyenuga (2001) stated that "A box culvert consists of three elements that is, top slab, walls and bottom slab and the loads on each component are as follows:

Top slab: The load will include slab own weight, imposed load and weight of earth fill. In cases where the depth of the earth fill is greater than three times the width of the culvert, the earth load can be assumed to be equal to earth loads of height three times the culvert width. Should be based on tyre width. For a wheel load of height, h, the load should be spread over an area of $4h^2$,that is 2h by 2h. When h equals or slightly exceeds one half of the width of the culvert, the wheel load can be assumed as equivalent to a uniformly distributed load of $W/4h^2$ where W is the wheel load. Wheel loads are given in units of 2.5KN and the most common HB loads are 30 and 45units equivalent to 75KN and 112.5KN respectively. Critical culverts should be designed for 45 units HB loads and the number of wheels that incident on the culverts noted.

Walls: Loads on walls include own weight, effect of active earth pressure, the effect of any the inside wall and the wall should be designed to resist this pressure and assuming no back fill.

Bottom slab: the top slab and its imposed load, the walls and the pressures on them produce an upward pressure (reaction) from the ground and causes moments. The weight of the water in the culvert and the weight of the bottom slab should be considered when determining the maximum pressure on the ground but since they borne by the ground directly, they do not generate moment.

According to ASSHTO specification section 12, "When the depth of fill exceeds 2.4m, live load is ignored."

Punmia, Jain and Jain (1992) stated that, A box culvert is subjected to soil load from outside and water load from inside. The vertical walls are subjected to earth pressures from outside and water pressure from inside. Similarly, the bottom slab will be subjected to soil pressure from outside and water pressure from inside. The top slab will, however, be subjected to embankment weight and traffic loads, if any." The weight of bottom slab of a box culvert will be resisted by equal and opposite soil pressure without bending in the bottom slab.

2.3.3 Factor of Safety

Factors of safety are usually applied to cater for unforeseen circumstances and uncertainties in the calculation method.

LRFD concrete box culverts from Engineering Policy Guide (2007) gives load factors for box culvert design thus.

Load Description	**Load Designation**	**Strength 1**		**Service 1 factor**
		Max. Factor	Min. factor	
Dead load of members	DC	1.25	0.9	1.0
vertical earth pressure	EV	1.30	0.9	1.0
Horizontal earth pressure	*EH(barrel)	1.35	1.0	1.0
	EHH(wings)	1.50	NA	1.0
water pressure	WA	1.0	0.0	1.0
Live load	LL	1.75	0.0	1.0
Dynamic load allowance	IM	1.75	0.0	
live load surcharge	*LS	1.75	1.0/0.0	1.0

` Table 2 Load Factors for Box Culvert Design

The maximum factor should be applied with the maximum equivalent fluid, pressure, and the minimum factor should be applied with the minimum fluid pressure. Live load surcharge, LS, is neglected when live load is neglected.

In this project, a factor of safety of 1.40 and 1.60 will be applied to culvert own weight, wheel load and earth load respectively.

2.3.4 Load Cases

According to Oyenuga (2001), “Two conditions should be considered as follows;

a. **Culvert Empty**: full load on top of the slab, surcharge load and earth pressure on the walls.
b. **Culvert full**: minimum load on top of the slab (eg own weight), minimum earth pressure (if possible, none), on walls and maximum lateral water pressure on the walls should the area be water logged, the pressure on the wall will be trapezoidal and they will be upward water pressure (equal to the weight of water above the surface of the top slab) on the top slab and should be taken into consideration”. After analyzing both load cases he stated that, “these loads are less than case 1 loads excepts for the wall loads and practically speaking if the culvert is flooded with water would be on both side of the walls cancelling the net water pressure on the walls. The case 1 loads can therefore be used for design purposes”. In the above equation, “these loads” refer to culvert full while “case 1” refers to culvert empty.

Sinha and Sharma (2009) stated that, “mainly three load cases govern the design. These are given below;

a. Box empty, live load surcharge on top slab of box and superimposed surcharge load on earth fill.
b. Box inside full with water, live load surcharge on top slab and superimposed surcharge load in earth fill.
c. Box inside full with water, live load surcharge on top slab and no superimposed surcharge on earth fill.”

   In this project two load cases will be considered. That is, culvert empty and culvert full as stated by Oyenuga(2001).

2.3.5 Analysis and Design

Box culverts shall be analyzed as closed rigid frames. The dead and superimposed earth loads, the lateral earth pressure, and the live and impact load are to be analyzed separately. The result of these separate loading conditions shall be assembled in various combination to give maximum moment and shear at the critical points. That is, the corners and the positive moment areas. Appropriate load positions shall be used to produce maximum positive and minimum moments. A maximum of one half of the moment caused by lateral earth pressure, including any live load surcharge may be used to reduce the positive moment on top and bottom slabs."

There are several methods of analyzing rigid frames. They include;

1. Displacement method.
2. Method of force.
3. Moment distribution method.

Oyenuga stated that, "a box culvert should be analyzed as a rigid structure with moment occurring at the corners. The hardy cross method of moment distribution is best suited for culvert analysis or the kani's method of moment distribution."

According to AASHTO specification section 12, (1998), Buried structures and tunnel liners, shall be analyzed and designed as rigid frames."

Reynolds and Steedman (1988) stated that, "the bending moments produced in monolithic rectangular culverts may be determined by considering the floor slabs as a continuous beam of four spans with equal bending moments at the end support. But, if the bending of the bottom slab tends to produce a downward deflection, the compressibility of the ground and the consequent effect on the bending must be considered.

Oyenuga (2001), further stated that, "due to the interconnections of the members, the shear in the walls introduces axial forces in the slabs and vice. Hence each element must be designed for moment and axial pull (just as a column that is subjected to bending and axial pull."

In this project, the structural members will be designed as columns subject to bending and axial pull.

2.3.6 Reinforcement

Oyenuga (2001) stresses that the designer should, "should note the u-bars provided at the corner to carter for torsional effects". He also stated that a minimum steel reinforcement of 0.4%bh be provided in the structural members. Where b= 1000mm length of the culvert and h= depth of the member.

2.3.7 Dimensions and specifications

According to AASHTO specification section 12, “the minimum top and bottom slab thickness is 200mm. All cells of multiple cell reinforced concrete box (RCB) culvert shall be the same size. The minimum height of RCB culvert is 1.25 vertical clearance to allow for inspection. Four sided boxes can typically be used for spans up to 3.5m span length from 3.4m to 7.5m are typically bridges using three sided rigid frames.”

The thickness of walls and slabs of a box culvert shall be not less than 250mm for members with reinforcement in both faces.

If the top slab is to be used as the road way wearing surface, then it shall have a 50mm-75mm concrete top reinforcement cover. Additionally, the top slab concrete shall be 4500 psi minimum strength, and the top math of reinforcing steel shall be epoxy coated. When the top slab is not the riding surface, the earth cover provided hall be not less than 22.86cm (in addition to paving) at the minimum point.

Construction joints shall be provided at approximately 9m. Expansion joints shall be provided at approximately 27m intervals. Reinforcement shall be stopped two inches clear of joints. Head walls shall be provided at the exposed ends of culverts to retain the earth embankment and to act as edge distribution beams.

In other to provide for the effect of scour, cut- off walls in a minimum of 0.9m deep shall be provided at the exposed end of the culverts.

Wing wall footing shall be set at the elevations of the cut-off walls and securely toed to them with reinforcement.”

In this project, the slabs and walls are 350mm thick and the top slab has a concrete cover 50mm although it carries an embankment of 2m.

CHAPTER THREE

3.0 Methodology

The proposed culvert to be designed is located at Awka North Local Government Area of Anambra State. Awka North comprises of several villages but as mandated by this design, focus will be on Isuaniocha along Mgbakwu road. Isuaniocha is a populated area in Awka and its climatic type is tropical savannah, wet with latitude of $6^{o}16^{I}$ 20^{II} N.

Chainage point for triple cell box culvert = 0+750 m

Chainage point for single cell box culvert = 0+525 m

Length of the road = 16 m

Design discharge (Q) = 62.43 m^3/s

Slope, (S) = 0.0092

The design of a box culvert take into account many different engineering and technical aspects at the site and adjacent areas. The following criteria are considered for box culvert design as applicable.

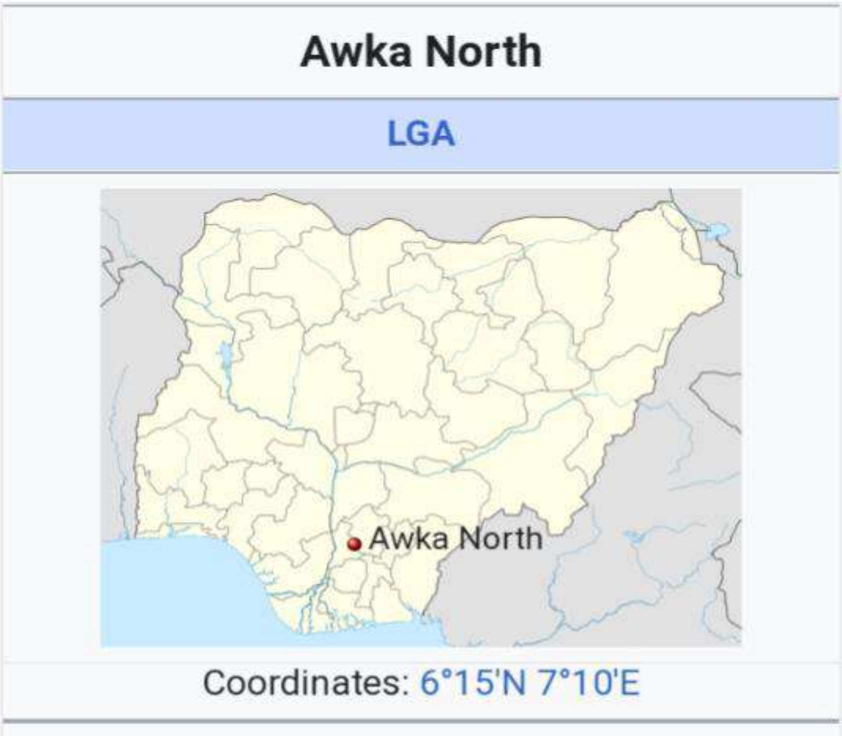


Figure 1: Map of Awka North

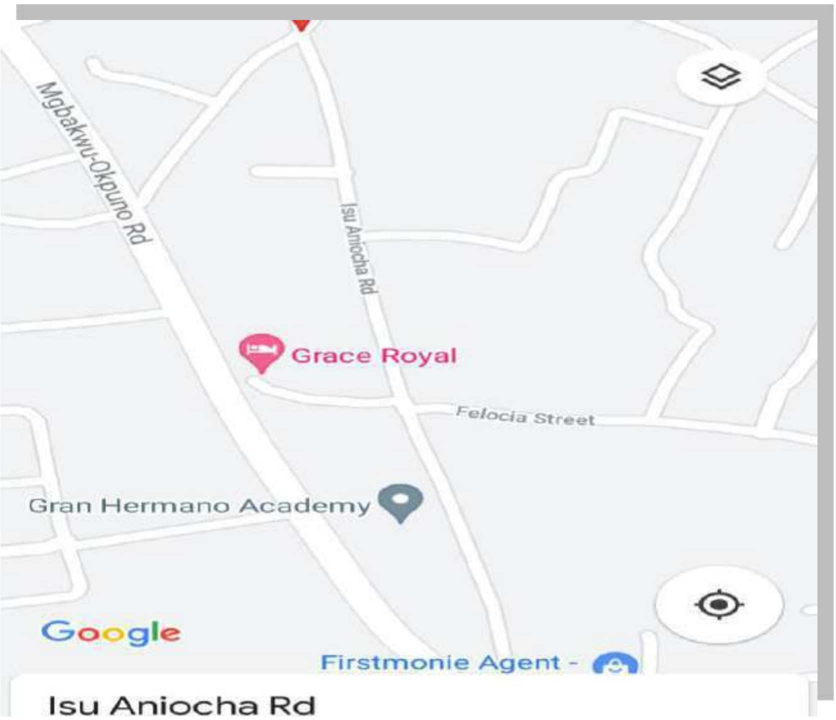


Figure 2: Map showing Isuaniocha Road

3.1 Site Investigation

For a safe and economic design of an engineering project, it is necessary to carry out investigations at the site of the proposed structure. Proper design of a box culvert structure calls for adequate knowledge of the sub-soil and hydraulic condition of the catchment area.

The main objectives of site investigations are:

1. To assess the general suitability of the site for the proposed work.
2. To enable adequate and economic design to be prepared.
3 To foresee and provide against difficulties that may arise during construction due to ground and local conditions.
4 To investigate the occurrence of causes of natural or created changes in the soil conditions and the result arising there from.
5 To get the chainage of the proposed culvert.

3.2 Ground Profile Survey

The design of a culvert must take into account the physical survey of the catchment area of the proposed project, Hydraulic studies of the stream flood, slope, soil type and bearing capacity of the soil.

3.3 The Hydraulic Design

According to Garber and Hoel (2000) ‘the ultimate objectives in determining the hydraulic requirements for any highway drainage structure is to provide a suitable structure size that will economically and efficiently dispose of the expected runoff’. Thus, the hydraulic requirement must be met to avoid erosion and sedimentation in the system.

The most appropriate location of a culvert is in the existing channel bed, with centre line and slope of the culvert bed coinciding with that of the channel, therefore parameters used in the hydraulic design (proposed culvert) were obtained from the site investigations and Hydrology and Hydraulics of Box Culvert, alongside the application of information gotten from Ministry of works, Awka.

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DATE: JANUARY 2022 **SHEET NO : 01 OF 01**

MEMBER REF	**CALCULATIONS**	**OUT PUT**
T1.2Hydrology On hydraulics of box culvert	**DESIGN DATA** Chainage point for triple cell culvert = 0 +750 m Chainage point for single cell culvert = 0 + 525 m Design discharge (Q) = 6s2.43 m^3/sec Length of culvert = 16m Slope = 0.0092 Inlet loss coefficient ,Ke = 0.5 Allowable outlet velocity = 2.74m/s Tail water depth, tw = 2.62 m Allowable headwater depth = 3.36 m Manning's roughness coefficient, n = 0.012 Several sizes of culvert were until the size that satisfy the limitations of head water elevation and outlet velocity was formed to be triple cell box culvert with each cell having a dimension of 2.8 x2.8 m. Dimension = 2.8m Width of culvert, B = 8.4m Cross sectional area per cell = 2.8 x 2.8 = 7.84 $\frac{Q}{B} = \frac{62.43\ m,^3/s}{8.4\ m} = 7.43m,^2/s$ Angle of wing wall flow =30^0 Fig 3.3 inlet control nomograph $\frac{HW}{D}$ = 1.02	

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MEMBER REF	CALCULATIONS	OUT PUT
	Hw =1.02 x 2.8 m = 2.89m	
	Using outlet control nomograph (fig 3.4)	
	Ke= 0.5	
	Cross sectional area of a single cell = $7.84m^2$	
	Design discharge per cell = $\frac{62.43\ m,^3/s}{3} = 20.81m,^3/s$	
	Height = 0.567m	Q per cell = $20.81m^3/s$
	$Hw = Hw_{+} h_o – l_s$	
	But Hw = $\frac{D_{C+D}}{2}$ or Tw whichever is greater	
	From fig 3.5 critical depth box culvert and	
	$\frac{Q}{B} = 7.432m^3/s$	
	Critical depth (DC) = 1.753m	
	Thus Hw = $\frac{D_{C+D}}{2}$ = $\frac{1.753+2.8}{2}$ = 2.277m	
	Tw = 2.62m	
	Tw > hw =2.277	Dc = 1.753m
	H_o = Tw = 2.62m	
	Hw = 0.569 +2.625 – 16 x 0.000914 = 3.1733m	
	Outlet control Hw > 2.886m (inlet control)	
	Therefore outlet control governs the culvert design	Velocity = 2.65m/s
	Outlet velocity check ,	
	V = $\frac{Q}{A} = \frac{62.43}{8.4x\ 2.8} = \frac{2.65m}{s} < 2.74m$/s…………………....ok	V_{min} = 1.02 m/s
	For minimum flow (Qm) = $24.07m^3/s$	
	V_{min} = $\frac{24.07}{8.4\ x2.8} = 1.02m/s$……………………………ok	Provide a triple cell box culvert of 2.8 x 2.8m
	This complies with the recommended non socuring and silt velocity of between 0.914m/s and 3m/s	Each cell
	Thus the outlet velocity is ok	

CHAPTER FOUR

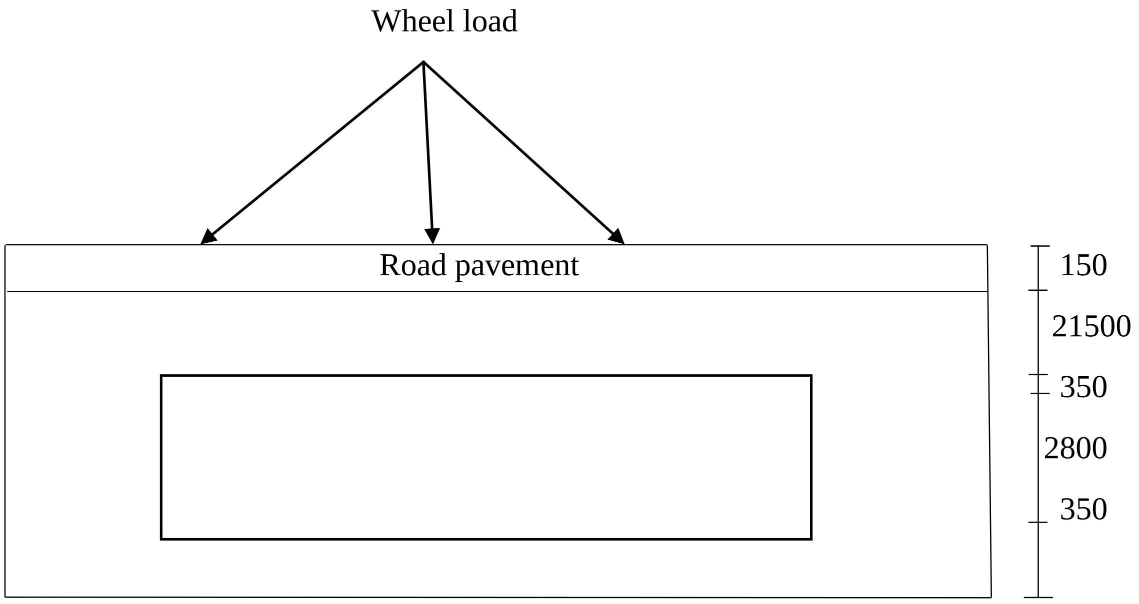
4.0 STRUCTURAL ANALYSIS

Loading Analysis

Having obtained the dimension (size) of the proposed box culvert through the hydraulic design carried out in the previous chapter.

Chainage point for the triple cell box culvert = 0+750 m

The figure below show a section of a triple box culvert with the various loads the culvert are likely to be subjected to.



Chainage point = 0 + 750

Fig 3. Triple cell box culvert

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MEMBER REF	**CALCULATIONS**	**OUT PUT**
T.2 Reynold and Steadman	All the design information used for each of the triple cells are applicable for the single cell culvert , CASE 1(culvert when empty) for triple cell box culvert -Top slab **Dead load** Self weight = 0.35 x24x1.4 =11.76KN/m^2 Thickness of road pavement = 0.15m Unit weight of asphalt, vs = 23 KN/m^3 Weight of road pavement = 0.15x23x1.4 =5.52KNm^2 Unit weight of earth fill =18 kN/m^3. Depth of earth fill = 2m, Weight of earth fill = 18 x 2 x 1.6 = 57.67KN/m^2 Total dead load = self weight of slab + weight of road pavement +weight of earth fill = (11.76 +5.52 +57.6)KN/m^2= 74.88KN/m^2 **Live load** Using abnormal HB loading Load per wheel = 112.5KN Since the height of the is more than one half of the culvert,each wheel load is equivalent to $\frac{w}{4h^2} = \frac{112.5}{4\ x\ 2^2} = 7.03\ KN$ Number of wheels that can incident on the culvert = 8(4wheels per axle),since each wheel load is spread over an area of $4h^2$= 4*2^2 = 16m	

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MEMBER REF	**CALCULATIONS**	**OUT PUT**
O.V. Oyenuga Pg 335	The area of influence of the four wheel of the first axle will over-lap with the area of influence of those of the second axle. Total live load = 8*7.03*1.3 =73.112KN/m^2 Total u.d.l on top slab of culvert = total dead load + live load. =(74.88 + 73.112) KN/m^2 **Walls:** Earth pressure Angle of response Ø =30 Coefficient of active earth pressure Ka = $\frac{1-\sin Ø}{1+\sin \quad Ø}$ $= \frac{1-\sin 30}{1+\sin \quad 30}$ = 0.333 Earth pressure at any depth = kayz P(2.175) = 0.33 * 18 *2.175* 1.6 = 20.86KN/m^2 Earth pressure at bottom edge of the wall P(5.325) =0.333 * 18 *5.325 *16) = 51.07 KN/m^2 Horizontal surcharge pressure = surcharge due to traffic + surcharge due to pavement = (73.112 + 5.52) 0.33 = 26.18 KN/m^2 Total lateral pressure at top edge of wall =20.86+26.18 =47.04KN/m^2 **Bottom slab** Load from the slab = 147.99KN/m^2 Wall load = weight of each wall per meter x no of walls = (24 x 0.35 x 2.8 x1.4)x 4 = 131.71KN/	Total live load = 73.112KN/m^2 Total slab u.d.l = 147.99KN/m^2 Ka = 0.333

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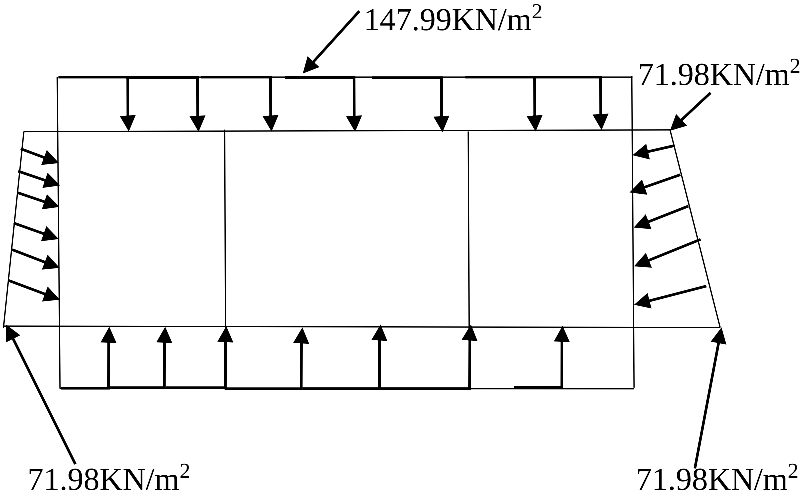
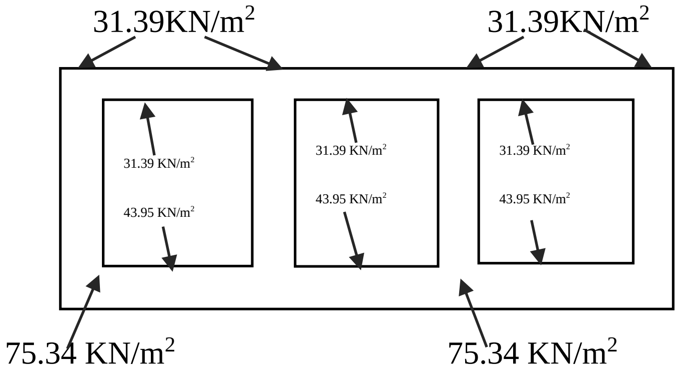
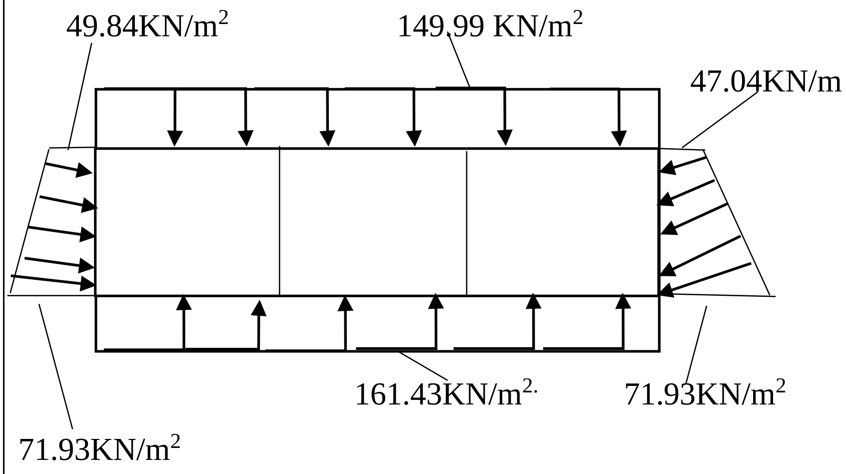
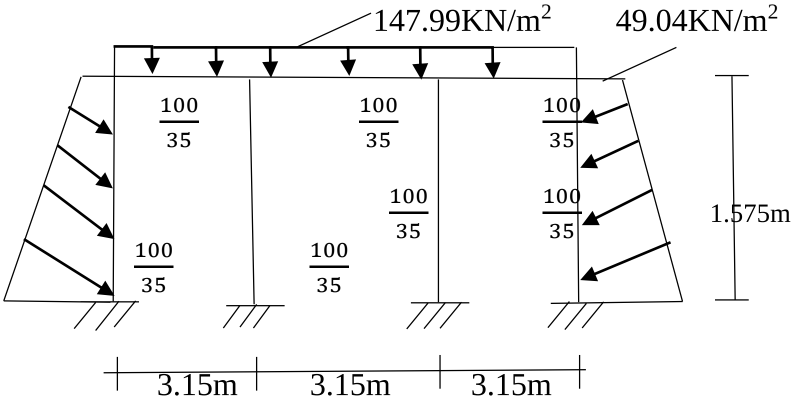
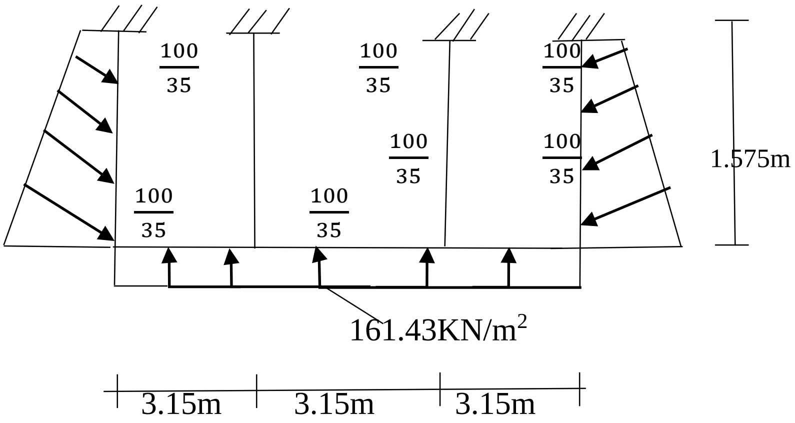
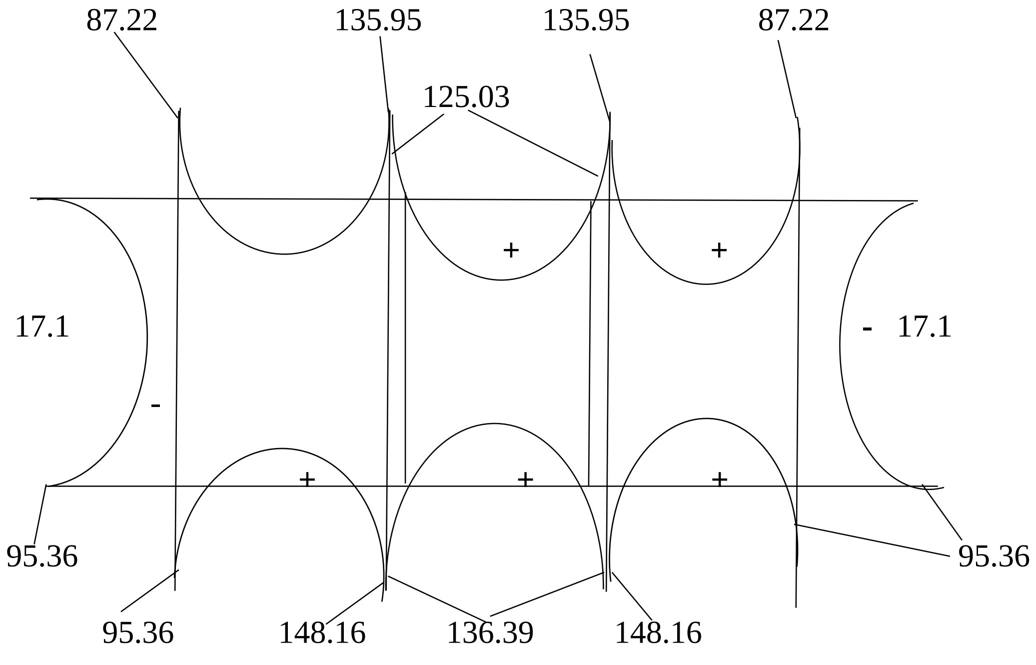
MEMBER REF	**CALCULATIONS**	**OUT PUT**
	Distributing weight of wall over bottom slab as UDL=$\frac{131.71\text{KN/m}}{9.8m}$ = 13.44KN/m^2 Total UDL on bottom slab = load from top slab + wall load = (147.99 +13.44)KN/m^2 = (147.99 +13.44) KN/m^2 = 161.43KN/m^2  **CASE 2**:Assuming the culvert is full of water and over flooded to maximum of 2m **Top Slab:** There will be an upthrust underneath the top slab equal to the weight of the water disposed by the 2m depth of culvert embarkment structure water load = 2x 9.81x1.6 = 31.39KN/m^2 walls due to water pressure only at top edge of wall = 2 x 9.81 x 1.6 =31.39KN/m^2	Bottom slab UDL= 161.43 KN

MEMBER REF	**CALCULATIONS**	**OUT PUT**
	At bottom edge of wall = 48 x 9.81x 1.6 = 75.34 KN/m^2 Bottom slab = 2.8 x 9.81 x 1.6 = 43.95 KN/m^2  The case two loads are less than the case 1 loads ,seeing that the water pressure on the top slab and walls act in the opposite direction to the loads outside .Thereby producing a resultant pressure of less value on the members in practice, there will be water on both sides of the walls at flooding and the net pressure will be zero. On the Bottom slab, the water generates an equal and opposite reaction and no moment is generated. Thus the case 1 loads will be used for the design because they cortical. **4.2 Moment and shear analysis**  	

MEMBER REF	**CALCULATIONS**	**OUT PUT**
	Using method of force Break the structure into two equal halves across the walls and analyse separately. assuming fixed support at the base  	

Below depicts Bending moment diagram after all the calculations done



M_{def} all values in KNm

MEMBER REF	CALCULATIONS	OUT PUT

Design Of Structural Elements

The culvert is design to adequately resist the maximum bending moment and shearing forces. It is subjected to as obtained from the loading analysis in the previous chapter due to interconnections of the members, the shear in the cracks introduce axial forces in the slab and vice versa .

Hence each member is designed for the moment and axial forces (just as a column that is subjected to loading and axial pull)

From the analysis the following maximum stresses were obtained

Element	Max support moment (KNm)	Max span moment (KNm)	Max axial pull (KNm)	Max shear (KN)
Top slab	135.95	72.04	1112.02	248.51
Bottom slab	148.19	78.47	131.7	271.01
Side wall	95.36	17.1	239.49	131.01
Internal walls	11.77	9.67	271	11.21

Design information

Client	Mgbakwu ,isuaniocha ,Awka, L.G.A
Architect,	Akpa Nnamdi Oyo
Site	Isuaniocha Awka – north, LGA, Anambra state.
Design engineer	Akpa Nnamdi oyo

MEMBER REF	**CALCULATIONS**	**OUT PUT**
Supervising engr	Engr. Prof. Aginam Chukwurah	
Intended of structure	Transportation	
Relevant code	Bs 8110 :part 1:1997 and part 2 :1985	
Design stress	Concrete grade fcu =25N/mm^2 and grade of steel = 460 N/m^2	
Soil condition	Firm gravely laterite clay – 180 KN/m^2	
Concrete cover	50mm	
Several loading	Unit wheel load = 112. 5 KN/m^2	T.10, Reynold
	Unit weight of soil cover = 18KN/m^3	and Steedman
	Angle of internal friction Ø = 30^0	T.17 ,,
	Unit weight of concrete = 24KN/m^3	T.17,
		T.2
Design data	$K=\frac{m}{fcub\ d^2}$	
	As $=\frac{m}{0.95fylad}$	
	$La = 0.5 + \sqrt{(0.25 - \frac{k}{0.9})} \leq 0.95$	
	$M.f = 0.55 + \frac{(477-fs)}{(120\left(0.9+\frac{m}{bd^2}\right))}$	
	h =350mm	
	$d = h - c - \frac{Ø}{2} = 350 - 50 - \frac{16}{2} = 292mm$	
	$\frac{d}{h} = \frac{292}{300} = 0.83mm$	
	Design of Top slab	
	Support moment	
	M = 135.95KNm	
	N = 112.02KN	
	$\frac{N}{fcubh} = \frac{112.02 \times 10^3}{25\ x\ 1000x350} = 0.01$	

MEMBER REF	**CALCULATIONS**	**OUT PUT**
From design chart 10.2 v.Oyenuga pg 306 T.10.3 RCD Oyenuga pg 344	$\frac{M}{fcubh} = \frac{135.95.\text{x}\,10^6}{25\,x\,1000x350^2} = 0.04$ $\propto = 0.01$ As = 0.0026 x fcubh = 0.0026 x 0.1 x 25 x 1000 x 350 = 2275mm^2 AS$_{min}$ = $\frac{0.4bh}{100} = \frac{0.4\text{ x }1000\text{ x}350}{100}$ = 1400mm^2 Provide Y25 @ 200mm c/c top (As$_{prov}$=2450mm^2) Provide Y12 @ 150mm c/c distribution	Y25@ 200 c/c top Y12 @ 150mmc/c dist.
	Mid span reinforcement M= 72.04KN/m N = 112.02KN $\frac{N}{fcubh} = \frac{112.02\text{ x }10^3}{25\,x\,1000x350} = 0.01$ $\frac{M}{fcubh^2} = \frac{72.04.\text{x}\,10^6}{25\,x\,1000x350^2} = 0.2$ $\propto = 0.04$	
T.10.2 v.Oyenuga pg 356 T.10.3 RCD v.Oyenuga pg 344	As = 0.0026 x 0.04 x 25 x1000 x350 = 910mm^2 AS$_{min}$ = $\frac{0.4bh}{100} = \frac{0.4\text{ x }1000\text{ x}350}{100}$ = 1400mm^2 Prov Y20 @ 200mm c/c btm (As$_{prov}$=1570mm^2) Prov Y12 @ 150mm c/c distribution	Y20@ 200 c/c btm Y12 @ 150mmc/c dist

MEMBER REF	**CALCULATIONS**	**OUT PUT**
	Check For Deflection Fs = $\frac{2}{3} fy \ \frac{\text{ASreq}}{ASprov}$ $= \frac{2}{3}\ x\ 460\ x\ \frac{1400}{1570} = 273.46$ M.F = 0.55 +$\frac{(477-fs)}{(120\left(0.9+\frac{m}{bd^2}\right))}$ = 0.55 +$\frac{(477-273.46)}{(120\left(0.9+\frac{72.04\ x10^6}{1000x296^2}\right))}$	Mf = 1.52
	M.F = 1.52 < 2 ………………………..ok Since thee slab is continuous ,the span effective depth ratio is 23 $d_{req} = \frac{span}{23xMF} = \frac{3.15\ X\ 10^3}{230X\ 1.52} = 90.10mm$ $d_{req} <$ dprov	Deflection ok
	maximum shear ,v = 248.51 kN but the culvert is chamfered 550mm at the joints. therefore deflection is satisfied Check for Shear is reduced is reduced to V = 243.51 – (0.55 x 147.99) = 167.12KN Shear stress ,V = $\frac{167.12\ x10^3}{1000x\ 292}$ =0.572N/mm^2 Concrete shear stress $V_c = 0.632(\frac{(100AS)^{\frac{1}{3}}}{bd}(\frac{(400)^{\frac{1}{4}}}{d})$ $= 0.632(\frac{(100x2450)^{\frac{1}{3}}}{1000x292}(\frac{(400)^{\frac{1}{4}}}{292})$ = 0.645N/mm^2 $V < V_c$ ……………………………………..ok	Shear ok

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DATE: JANUARY, 2022 SHEET NO: 07 of 04

MEMBER REF	CALCULATIONS	OUTPUT

5.2 DESIGN OF BOTTOM SLAB

Support reinforcement

$M = 148.19 KNm$

$N = 131.7 KN$

$$\frac{N}{f_{cu}bh} = \frac{131.7\times10^3}{25\times1000\times350}$$

$$= 0.02$$

$$\frac{M}{f_{cu}bh^2} = \frac{148.19\times10^6}{25\times1000\times350^2}$$

$$= 0.05$$

chart 10.2 RCD V.O Oyenuga Pg 356

$\alpha = 0.1$

$A_s = 0.0026\alpha f_{cu}bh$

$= 0.0026\times0.1\times25\times1000\times350$

$= 2275 mm^2$

$$As_{min} = \frac{0.4bh}{100}$$

$$= \frac{0.4\times1000\times350}{100}$$

$$= 1400 mm^2$$

T.10.3 RCD Oyenuga Pg 344

provide Y25mm @200mm c/c Btm

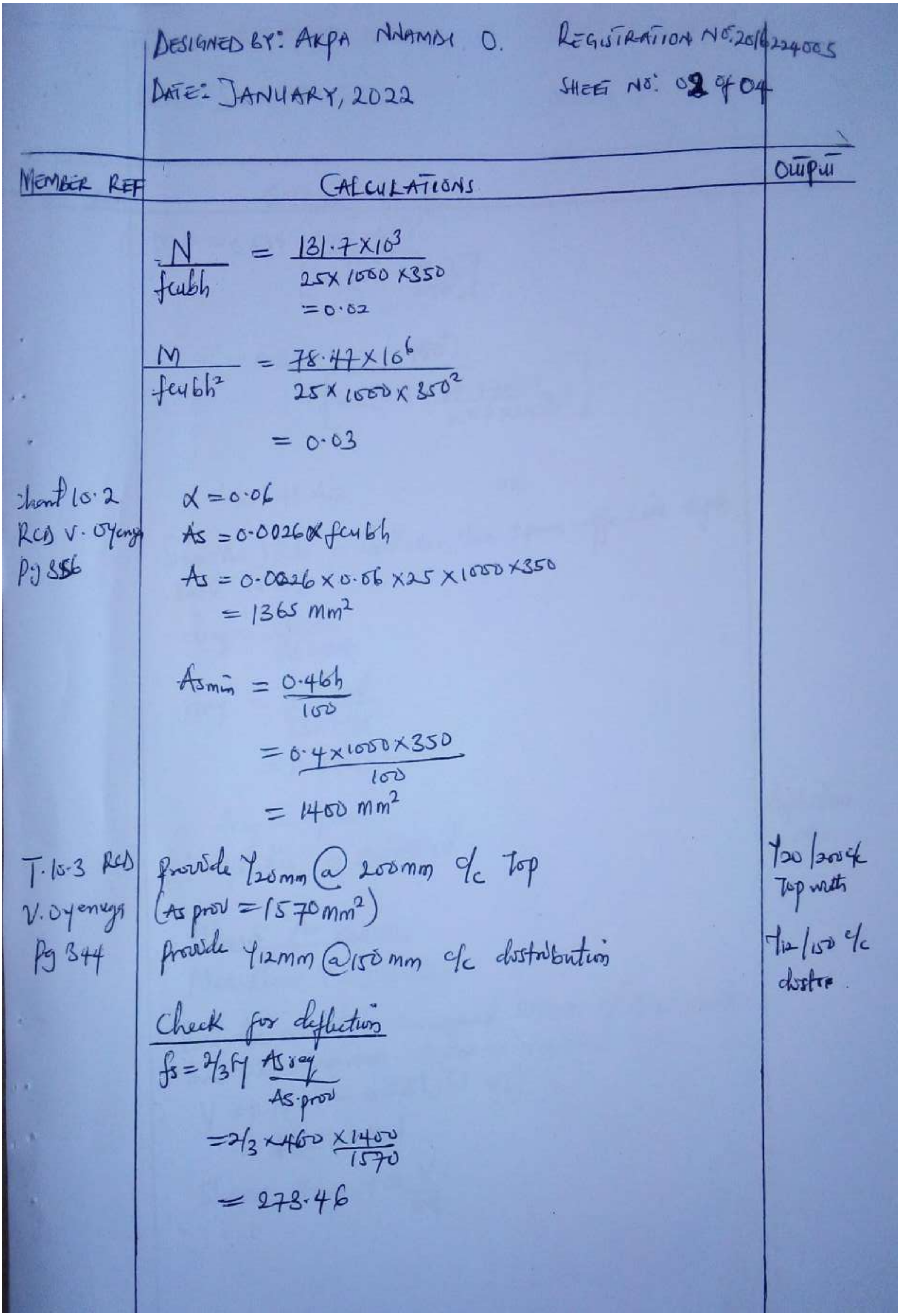
provide Y12mm @ 150mm c/c distribution

Output: Y25/200 c/c Bttm with Y12/150 c/c distribution

Midspan Reinforcement

$M = 78.47 KNm$

$N = 131.7 KN$



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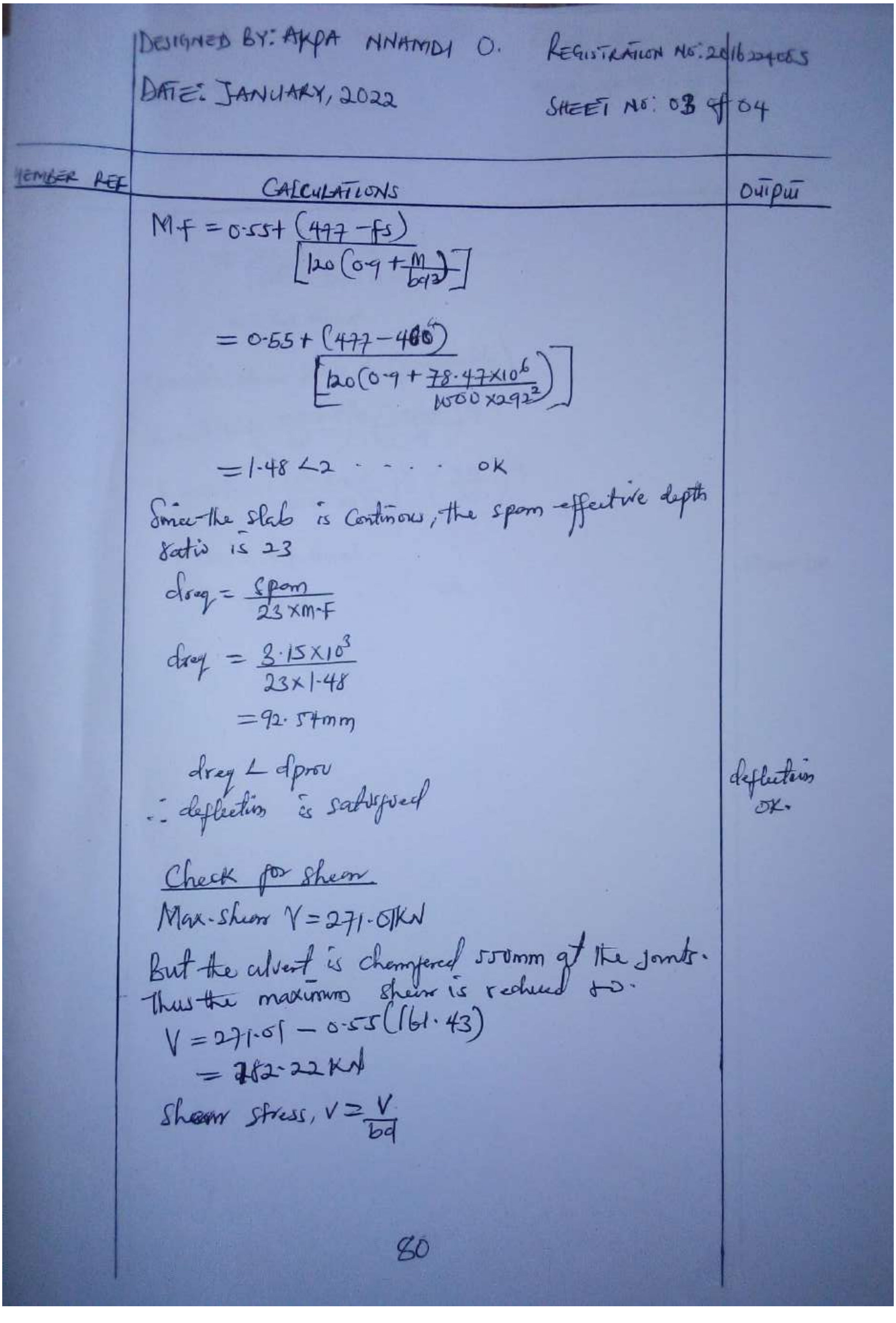
DATE: JANUARY, 2022 SHEET NO: 02 of 04

MEMBER REF	CALCULATIONS	OUTPUT
	$\frac{N}{f_{cu}bh} = \frac{131.7 \times 10^3}{25 \times 1000 \times 350}$ $= 0.02$	
	$\frac{M}{f_{cu}bh^2} = \frac{78.47 \times 10^6}{25 \times 1000 \times 350^2}$ $= 0.03$	
Chart 10.2 RCD V. Oyenuga Pg 356	$\alpha = 0.06$ $A_s = 0.0026 \alpha f_{cu} bh$ $A_s = 0.0026 \times 0.06 \times 25 \times 1000 \times 350$ $= 1365 \text{ mm}^2$	
	$A_{s\,min} = \frac{0.4bh}{100}$ $= \frac{0.4 \times 1000 \times 350}{100}$ $= 1400 \text{ mm}^2$	
T.10.3 RCD V. Oyenuga Pg 344	Provide Y20mm @ 200mm c/c Top (A_s prov $= 1570 \text{mm}^2$) Provide Y12mm @150 mm c/c distribution	Y20/200 c/c Top width Y12/150 c/c distr.
	Check for deflection $f_s = \frac{2}{3} f_y \frac{A_{s\,req}}{A_{s\,prov}}$ $= \frac{2}{3} \times 460 \times \frac{1400}{1570}$ $= 273.46$	



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DATE: JANUARY, 2022 SHEET NO: 03 of 04

MEMBER REF	CALCULATIONS	OUTPUT

$$M.F = 0.55 + \frac{(477 - fs)}{\left[120\left(0.9 + \frac{M}{bd^2}\right)\right]}$$

$$= 0.55 + \frac{(477 - 460)}{\left[120\left(0.9 + \frac{78.47\times10^6}{1000\times292^2}\right)\right]}$$

$$= 1.48 < 2 \quad \ldots\ldots \quad ok$$

Since the slab is Continous, the span-effective depth ratio is 23

$$d_{req} = \frac{span}{23 \times m.f}$$

$$d_{req} = \frac{3.15\times10^3}{23\times1.48}$$

$$= 92.54mm$$

$d_{req} < d_{prov}$

∴ deflection is satisfied

deflection OK.

<u>Check for shear</u>

Max. shear $V = 271.05KN$

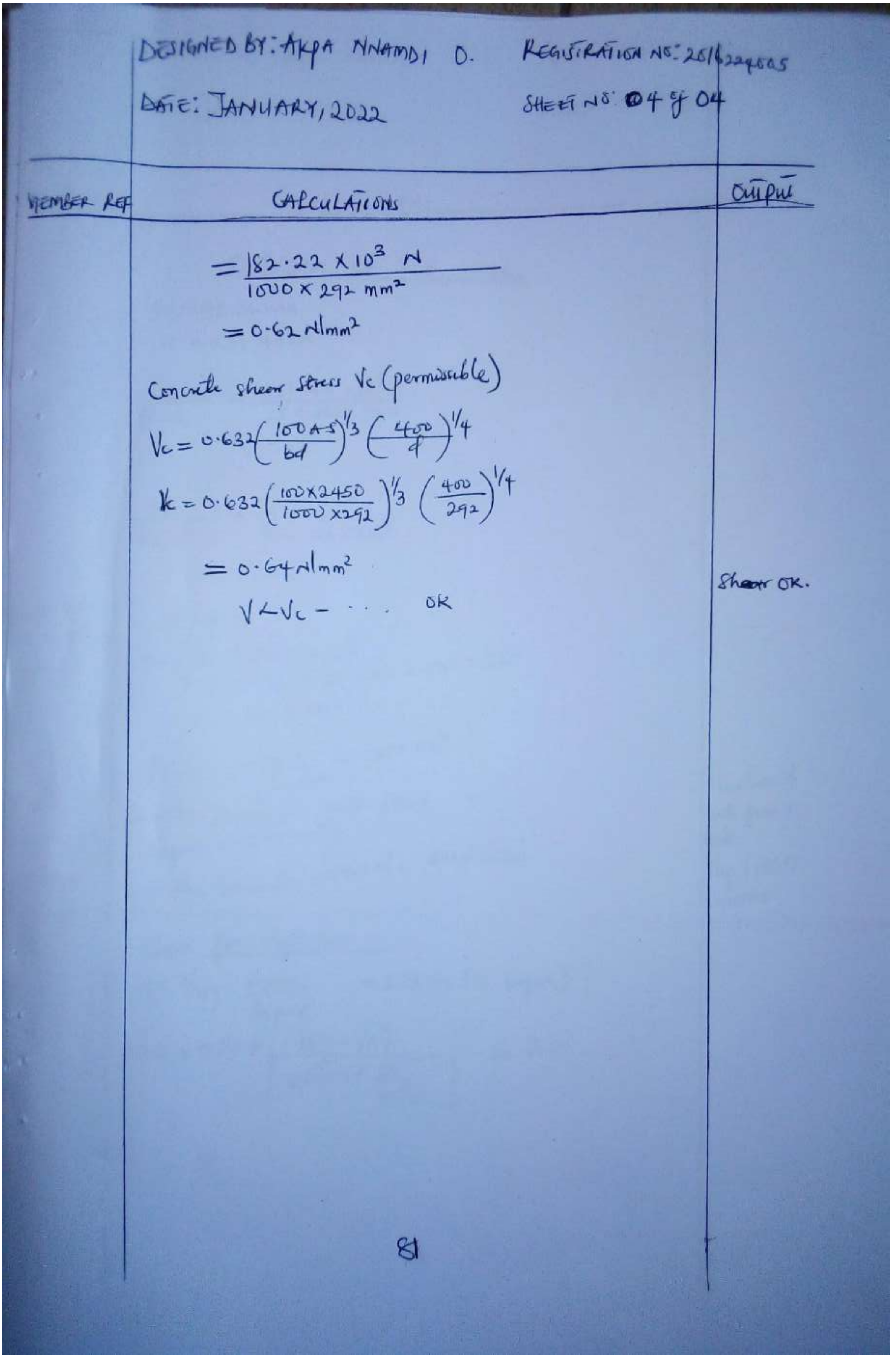
But the culvert is chamfered 550mm at the joints. Thus the maximum shear is reduced to.

$$V = 271.05 - 0.55(161.43)$$

$$= 182.22KN$$

Shear stress, $v = \frac{V}{bd}$

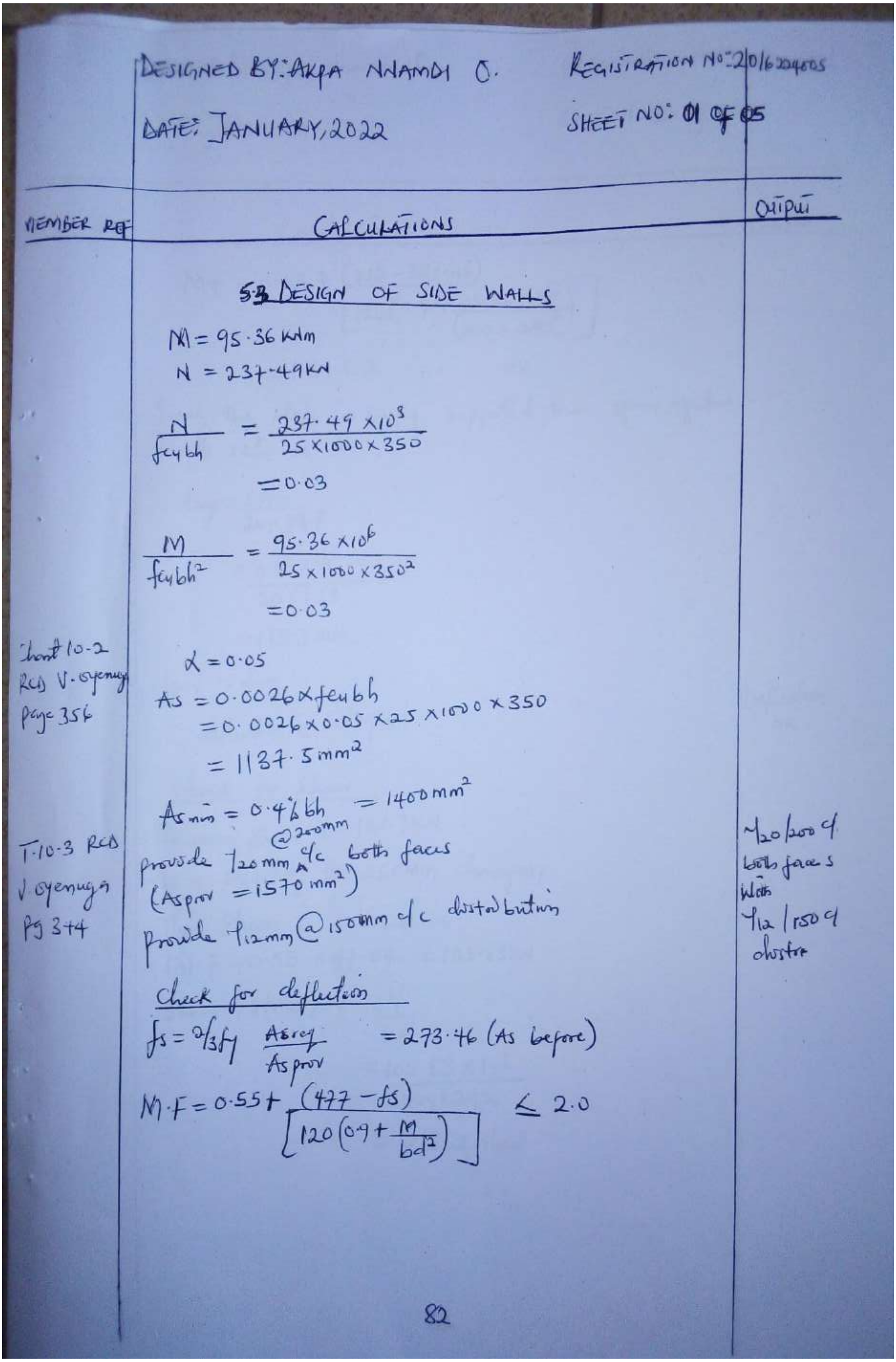
80



DESIGNED BY: AKPA NNAMDI O.
REGISTRATION NO: 2016224505
DATE: JANUARY, 2022
SHEET NO: 04 of 04

MEMBER REF	CALCULATIONS	OUTPUT
	$= \frac{182.22 \times 10^3 \ N}{1000 \times 292 \ mm^2}$	
	$= 0.62 \ N/mm^2$	
	Concrete shear stress Vc (permissible)	
	$V_c = 0.632\left(\frac{100 A_s}{bd}\right)^{1/3}\left(\frac{400}{d}\right)^{1/4}$	
	$V_c = 0.632\left(\frac{100 \times 2450}{1000 \times 292}\right)^{1/3}\left(\frac{400}{292}\right)^{1/4}$	
	$= 0.64 \ N/mm^2$	Shear OK.
	$V < V_c$ - . . . OK	

81



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DATE: JANUARY, 2022 SHEET NO: 01 OF 05

MEMBER REF	CALCULATIONS	OUTPUT

5.3 DESIGN OF SIDE WALLS

$M = 95.36\ kNm$

$N = 237.49kN$

$$\frac{N}{f_{cu}bh} = \frac{237.49 \times 10^3}{25 \times 1000 \times 350}$$

$$= 0.03$$

$$\frac{M}{f_{cu}bh^2} = \frac{95.36 \times 10^6}{25 \times 1000 \times 350^2}$$

$$= 0.03$$

Chart 10-2 RCD V. Oyenuga Page 356

$\alpha = 0.05$

$$A_s = 0.0026 \alpha f_{cu} bh$$

$$= 0.0026 \times 0.05 \times 25 \times 1000 \times 350$$

$$= 1137.5mm^2$$

$A_{s\,min} = 0.4\% bh = 1400mm^2$

T.10.3 RCD V Oyenuga Pg 344

provide Y20mm @200mm c/c both faces

($A_{s\,prov} = 1570\ mm^2$)

provide Y12mm @150mm c/c distribution

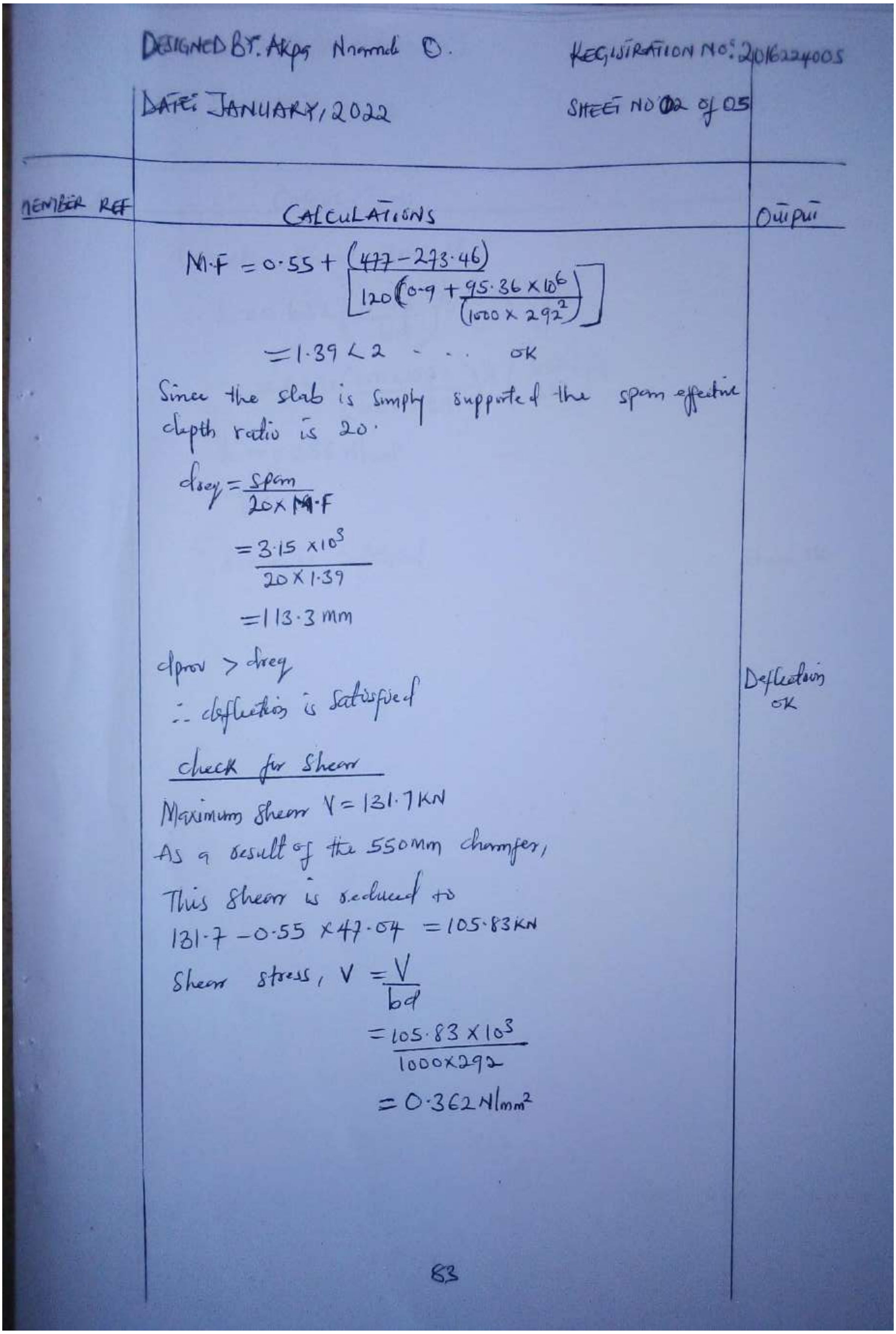
Y20/200 c/c both faces with Y12/150 c/c distr

Check for deflection

$$f_s = \frac{2}{3} f_y \frac{A_{s\,req}}{A_{s\,prov}} = 273.46 \text{ (As before)}$$

$$M.F = 0.55 + \frac{(477 - f_s)}{\left[120\left(0.9 + \frac{M}{bd^2}\right)\right]} \le 2.0$$

82



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MEMBER REF CALCULATIONS OUTPUT

$$M.F = 0.55 + \frac{(477 - 273.46)}{\left[120\left(0.9 + \frac{95.36 \times 10^6}{(1000 \times 292^2)}\right)\right]}$$

$$= 1.39 < 2 \quad \ldots \quad ok$$

Since the slab is simply supported the span effective depth ratio is 20.

$$d_{req} = \frac{span}{20 \times M.F}$$

$$= \frac{3.15 \times 10^3}{20 \times 1.39}$$

$$= 113.3\,mm$$

$d_{prov} > d_{req}$

$\therefore$ deflection is satisfied

Deflection OK

check for Shear

Maximum Shear $V = 131.7\,KN$

As a result of the 550mm chamfer,

This Shear is reduced to

$131.7 - 0.55 \times 47.04 = 105.83\,KN$

$$\text{Shear stress, } v = \frac{V}{bd}$$

$$= \frac{105.83 \times 10^3}{1000 \times 292}$$

$$= 0.362\,N/mm^2$$

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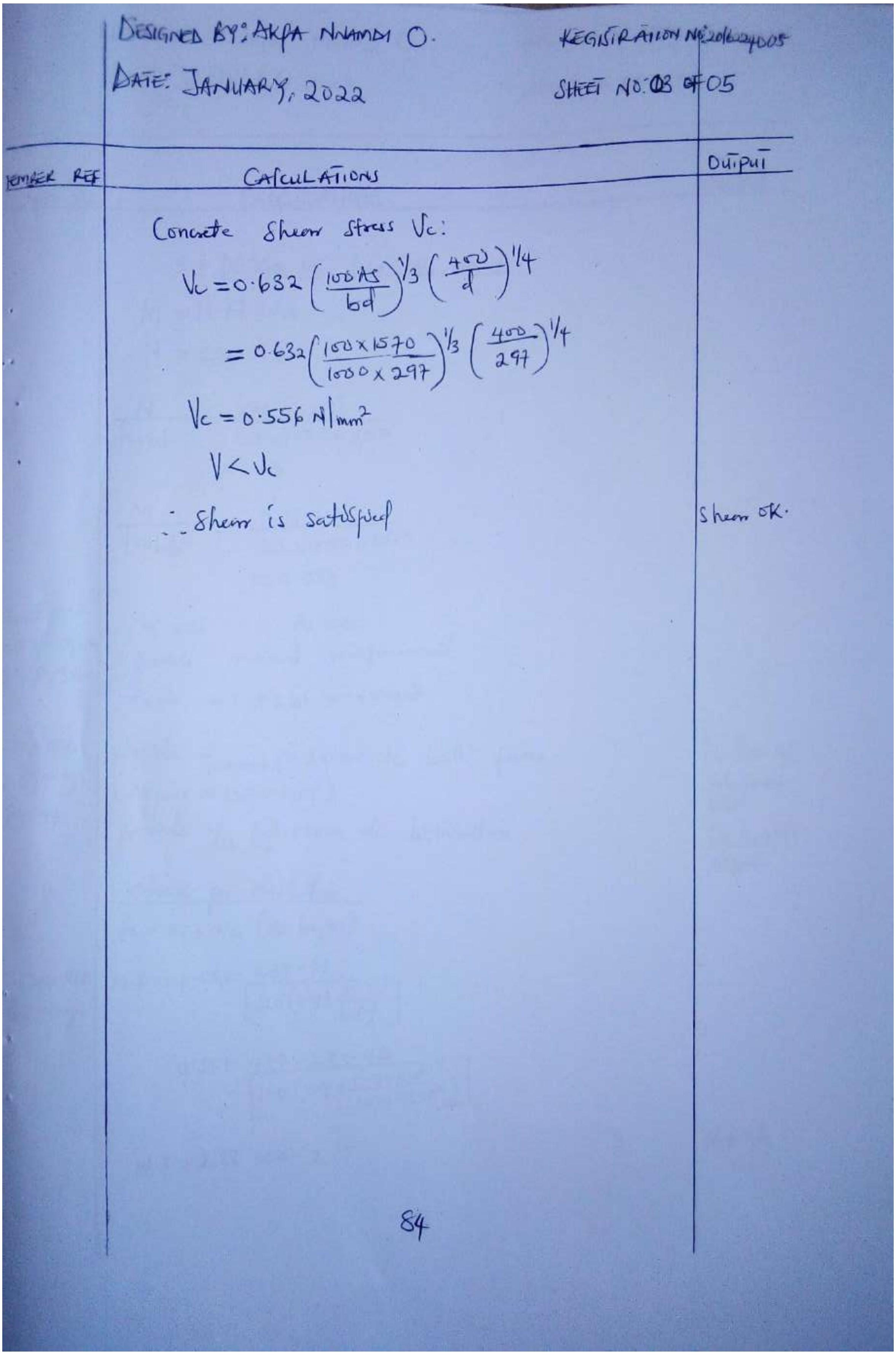

DESIGNED BY: AKPA NNAMDI O.
REGISTRATION NO: 20/[illegible]4005
DATE: JANUARY, 2022
SHEET NO: 03 OF 05

MEMBER REF	CALCULATIONS	OUTPUT
	Concrete Shear Stress V_c:	
	$V_c = 0.632\left(\frac{100A_s}{bd}\right)^{1/3}\left(\frac{400}{d}\right)^{1/4}$	
	$= 0.632\left(\frac{100 \times 1570}{1000 \times 297}\right)^{1/3}\left(\frac{400}{297}\right)^{1/4}$	
	$V_c = 0.556\ N/mm^2$	
	$V < V_c$	
	$\therefore$ Shear is satisfied	Shear OK.

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DESIGNED BY: AKPA NNAMDI O.
DATE: JANUARY, 2022

REGISTRATION NO: 2016224005
SHEET NO 01 OF 06

MEMBER REF	CALCULATIONS	OUTPUT

5.4 DESIGN OF INTERNAL WALLS

$M = 11.77$ kNm

$N = 271.01$ kN

$$\frac{N}{f_{cu}bh} = \frac{271.01 \times 10^3}{25 \times 1000 \times 350} = 0.03$$

$$\frac{M}{f_{cu}bh^2} = \frac{11.77 \times 10^6}{25 \times 1000 \times 350^2} = 0.004$$

Chart 10.2 RCD V. Oyenuga 199 Pg 354

$\alpha = 0 \quad \therefore A_s = 0$

provide nominal reinforcement

$A_{c\,min} = 0.4\%bh = 1400\,mm^2$

T 10.3 RCD V. Oyenuga Pg 344

provide Y_{20}mm @ 200mm c/c both faces
($A_{s\,prov} = 1570\,mm^2$)
provide Y_{12} @ 150mm c/c distribution

$Y_{20}/200$ c/c both faces walls
$Y_{12}/150$ c/c distrb

Check for deflection

$f_s = 273.46$ (as before)

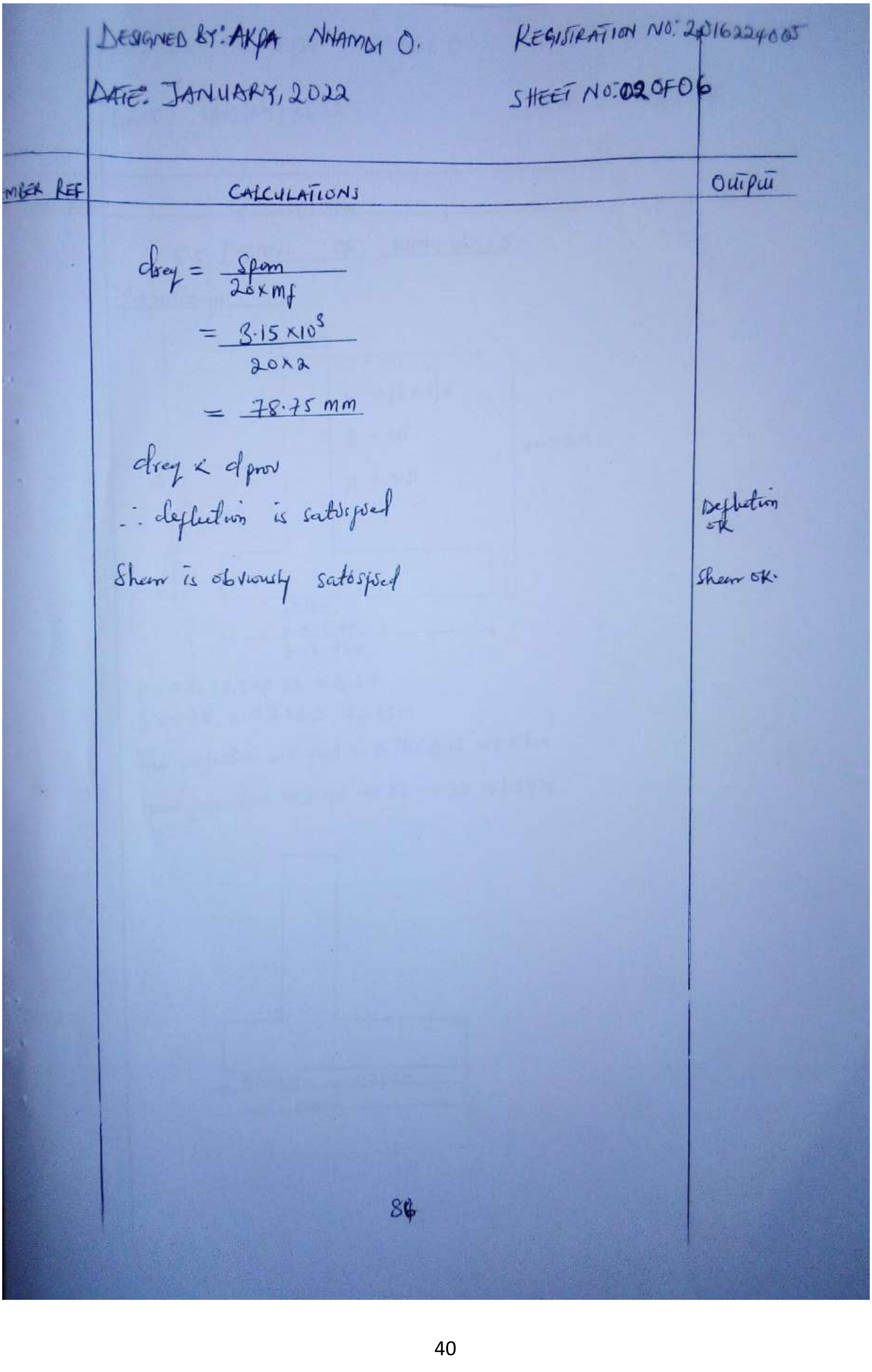
Pg 347 RCD V. Oyenuga

$$M.F = 0.55 + \frac{477 - f_s}{\left[120\left(0.9 + \frac{M}{bd^2}\right)\right]}$$

$$0.55 + \frac{477 - 273.46}{\left[120\left(0.9 + \frac{11.77 \times 10^6}{1000 \times 350^2}\right)\right]}$$

$M.F = 2$

$M.F = 2.18$ use 2



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DATE: JANUARY, 2022 SHEET NO: 02 OF 06

MBER REF	CALCULATIONS	OUTPUT
	$d_{req} = \frac{Span}{20 \times mf}$ $= \frac{3.15 \times 10^3}{20 \times 2}$ $= 78.75\ mm$	
	$d_{req} < d_{prov}$ ∴ deflection is satisfied	Deflection ok
	Shear is obviously satisfied	Shear ok.

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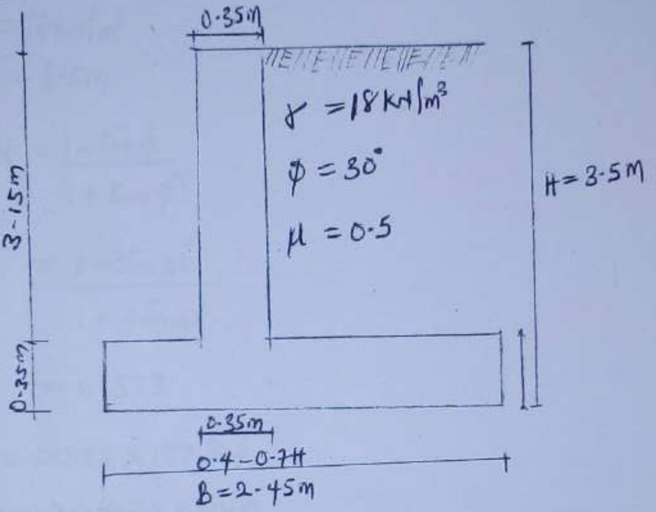
DATE: JANURY, 2022 SHEET NO: 03 OF 04

EMBER REF | CALCULATIONS | OUTPUT

5.5 DESIGN OF WING WALLS

Proportioning

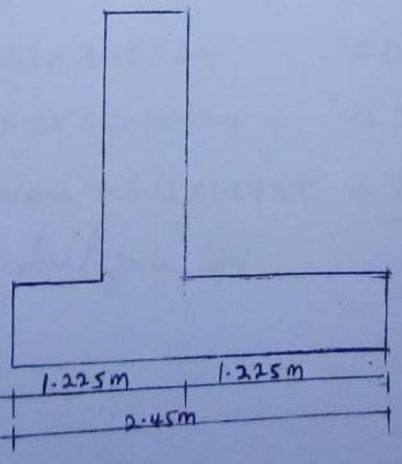


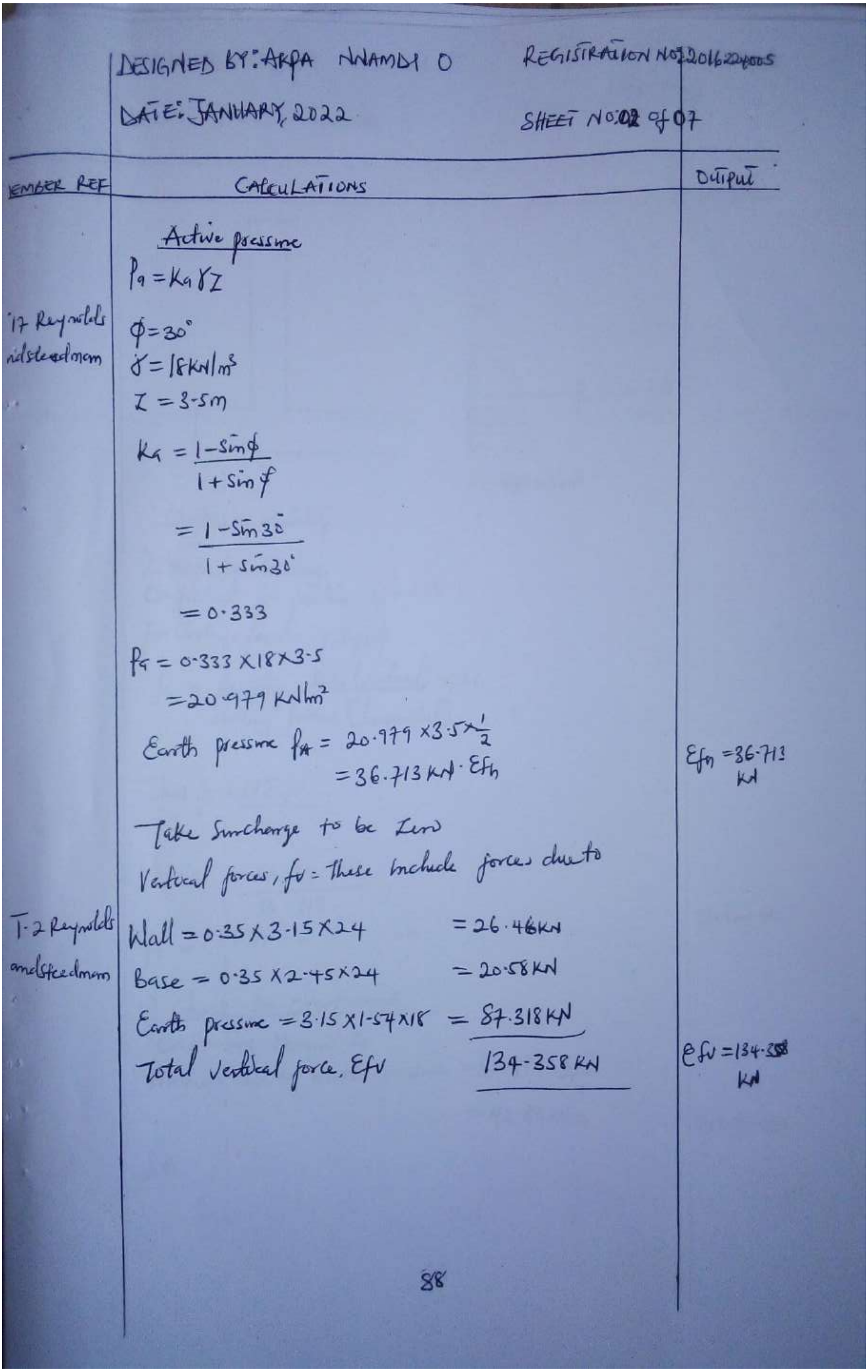
$H = 0.35 + 2.8 + 0.35 = 3.5m$

$B = 0.7H = 0.7 \times 3.5 = 2.45m$

The projection $= 0.16H = 0.16 \times 3.15 = 0.56m$

heel projection $= 2.45 - 0.56 - 0.35 = 1.54m$





DESIGNED BY: AKPA NNAMDI O REGISTRATION NO: 2016224005

DATE: JANUARY, 2022 SHEET NO: 02 of 07

MEMBER REF	CALCULATIONS	OUTPUT

Active pressure

$P_a = K_a \gamma Z$

17 Reynolds
ndsteedman — $\phi = 30^\circ$

$\gamma = 18 kN/m^3$

$Z = 3.5m$

$K_a = \frac{1 - \sin\phi}{1 + \sin\phi}$

$= \frac{1 - \sin 30^\circ}{1 + \sin 30^\circ}$

$= 0.333$

$P_a = 0.333 \times 18 \times 3.5$

$= 20.979 kN/m^2$

Earth pressure $P_A = 20.979 \times 3.5 \times \frac{1}{2}$

$= 36.713 kN \cdot Ef_h$ — $Ef_h = 36.713$ kN

Take Surcharge to be Zero

Vertical forces, f_v = These include forces due to

T.2 Reynolds and steedman

Wall $= 0.35 \times 3.15 \times 24$ $= 26.46 kN$

Base $= 0.35 \times 2.45 \times 24$ $= 20.58 kN$

Earth pressure $= 3.15 \times 1.54 \times 18$ $= 87.318 kN$

Total vertical force, Ef_v 134.358 kN — $Ef_v = 134.358$ kN

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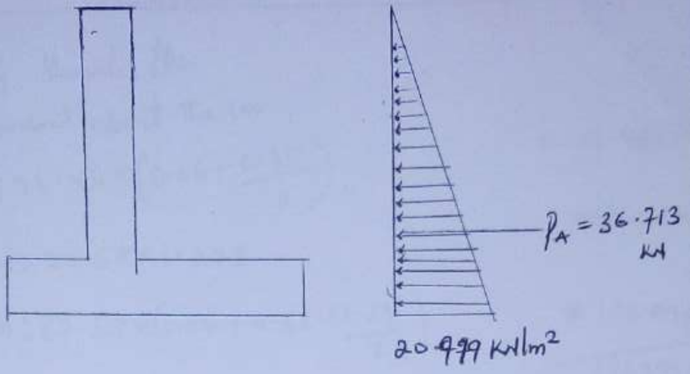
DATE: JANUARY, 2022   SHEET NO: 03 OF 07

REF	CALCULATIONS	OUTPUT



Checks for stability

I) Check for Sliding;

Coefficient for friction, $\mu = 0.5$

for Sliding, factor of safety

$$f_s = \frac{\text{Resisting forces (vertical)}}{\text{Sliding forces (horizontal)}} \geq 1.6$$

Thus $f_s = \dfrac{\mu \Sigma f_V}{\Sigma f_H}$

$$\frac{0.5 \times 134.358}{36.713}$$

$f_s = 1.83 \geq 1.6$ ... ok

Sliding ok

II) Check for Overturning

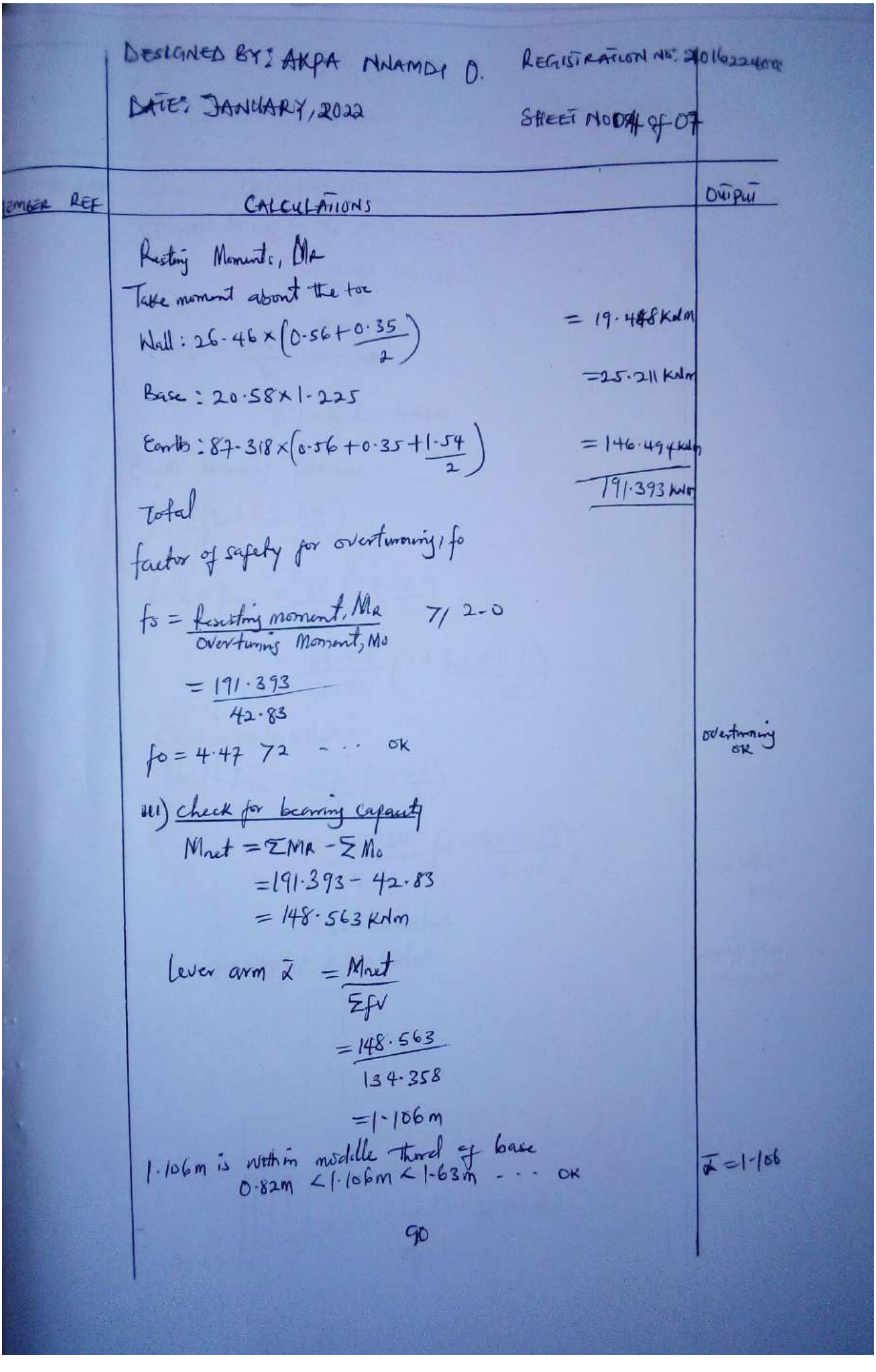
Overturning Moment, M_o

Moment due to earth pressure $= 36.713 \times \frac{3.5}{3}$

$= 42.83$ kNm

$M_o = 42.83$k

~~Res~~



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DATE: JANUARY, 2022

SHEET No 04 of 07

EMBER REF | CALCULATIONS | OUTPUT

Resting Moments, M_R

Take moment about the toe

Wall : $26.46 \times \left(0.56 + \frac{0.35}{2}\right)$ $= 19.448$ KNm

Base : 20.58×1.225 $= 25.211$ KNm

Earth : $87.318 \times \left(0.56 + 0.35 + \frac{1.54}{2}\right)$ $= 146.494$ KNm

Total 191.393 KNm

factor of safety for overturning, fo

$$f_o = \frac{\text{Resisting moment, } M_R}{\text{Overturning Moment, } M_o} \geq 2.0$$

$$= \frac{191.393}{42.83}$$

$f_o = 4.47 > 2$ . . . ok

overturning OK

iii) Check for bearing capacity

$$M_{net} = \Sigma M_R - \Sigma M_o$$

$$= 191.393 - 42.83$$

$$= 148.563 \text{ KNm}$$

$$\text{Lever arm } \bar{x} = \frac{M_{net}}{\Sigma f_V}$$

$$= \frac{148.563}{134.358}$$

$$= 1.106 \text{ m}$$

1.106m is within middle third of base

0.82m < 1.106m < 1.63m . . . OK

$\bar{x} = 1.106$

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DESIGNED BY: AKPA NNAMDI O. REGISTRATION NO: 20162240

DATE: JANUARY, 2022 SHEET NO 05 OF 07

MEMBER REF	CALCULATIONS	OUTPUT

Eccentricity, $e = B/2 - \bar{x}$

$= \frac{2.45}{2} - 1.106$

$= 0.119\text{m}$

$B/6 = \frac{2.45}{6} = 0.408\text{ m}$

$0.119\text{m} < 0.408\text{m}$

Earth bearing pressure

$$q = \frac{\mathcal{E}fv}{B}\left(1 \pm \frac{6e}{B}\right)$$

$$q_{toe} = q_{max} = \frac{\mathcal{E}fv}{B}\left(1 + \frac{6e}{B}\right)$$

$$= \frac{134.358}{2.45}\left(1 + \frac{6 \times 0.119}{2.45}\right)$$

$\mathcal{E}_{max} = 70.82\text{ kN/m}^2$

$$q_{heel} - q_{min} = \frac{\Sigma fv}{B}\left(1 - \frac{6e}{B}\right)$$

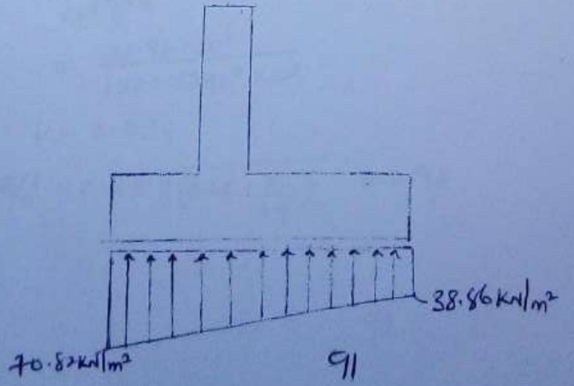
$$= \frac{134.358}{2.45}\left(1 - \frac{6 \times 0.119}{2.45}\right)$$

$= 38.86\text{ kN/m}^2$

$q_{min} = 38.$ kN/m

$70.82\text{ kN/m}^2 < 180\text{ kN/m}^2$

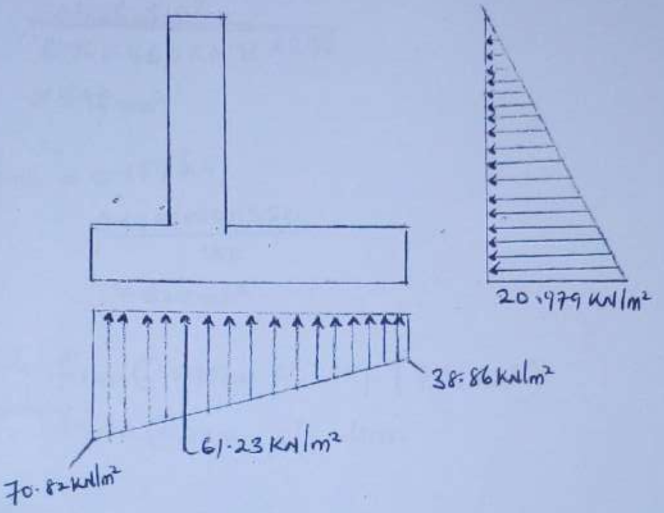
bearing pressu is adequate



DESIGNED BY: AKPA NNAMDI O.   REGISTRATION NO: 2016224005
DATE: JANUARY, 2022   SHEET NO 06 of 07

EMBER REF   CALCULATIONS   OUTPUT

5.6 DESIGN OF WALL



Bending Reinforcement
Wall

$$\text{Horizontal moment} = 36.713\left(0.175 + \frac{3.15}{3}\right)$$
$$= 44.97\ \text{kNm}$$

$$\text{Horizontal moment (u.l.s)} = 44.97 \times 1.6$$
$$= 71.96\ \text{kNm}$$

Horizontal moment = 71.9 kNm (u.l.s)

$h = 350\,\text{mm}$

$d = 350 - 50 - 10 = 290\,\text{mm}$

$$K = \frac{M}{bd^2 f_{cu}}$$
$$= \frac{71.96 \times 10^6}{1000 \times 290^2 \times 25}$$

$K = 0.034$

$$z/d = 0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)} = 0.95$$

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DATE: JANUARY, 2022　　SHEET NO [illegible]8 of 07

EMBER REF	CALCULATIONS	OUTPUT

$$A_s = \frac{M}{0.95 f_y Z}$$

$$= \frac{71.96\times10^6}{0.95\times460\times0.95\times290}$$

$$= 598\ mm^2$$

D V-Oyen- ga pg 315

$$A_{s\,min} = 0.15\%\,bh$$

$$\frac{0.15\times1000\times350}{100}$$

$$= 525\ mm^2$$

10.3 RCD .oyenuga

Provide Y16mm @ 275mm c/c N.F (731mm²) — Y16/275 c/c N.F

Provide Y12mm @ 150mm c/c distr. — Y12/150 c/c distr.

Base

Designed using pressure at Ultimate limit state.

Top Reinforcement

Hell:

Taking moment about the stem centreline for vertical loads and the bearing pressures.

$$M = 20.58\times\frac{1.715}{2.45}\times\frac{1.715}{2}\times1.0 + 87.318\times$$

$$\left(\frac{1.54}{2}+0.175\right)1.0 - 38.86\times\frac{1.715^2}{2} -$$

$$-\left(\frac{61.23-38.86}{2}\right)\times1.715\times\frac{1.715}{3}$$

$$M = 26.76\,kNm$$

$h = 350mm,\ d = 290\ mm$

$$K = \frac{26.76\times10^6}{1000\times290^2\times25}$$

$$= 0.013$$

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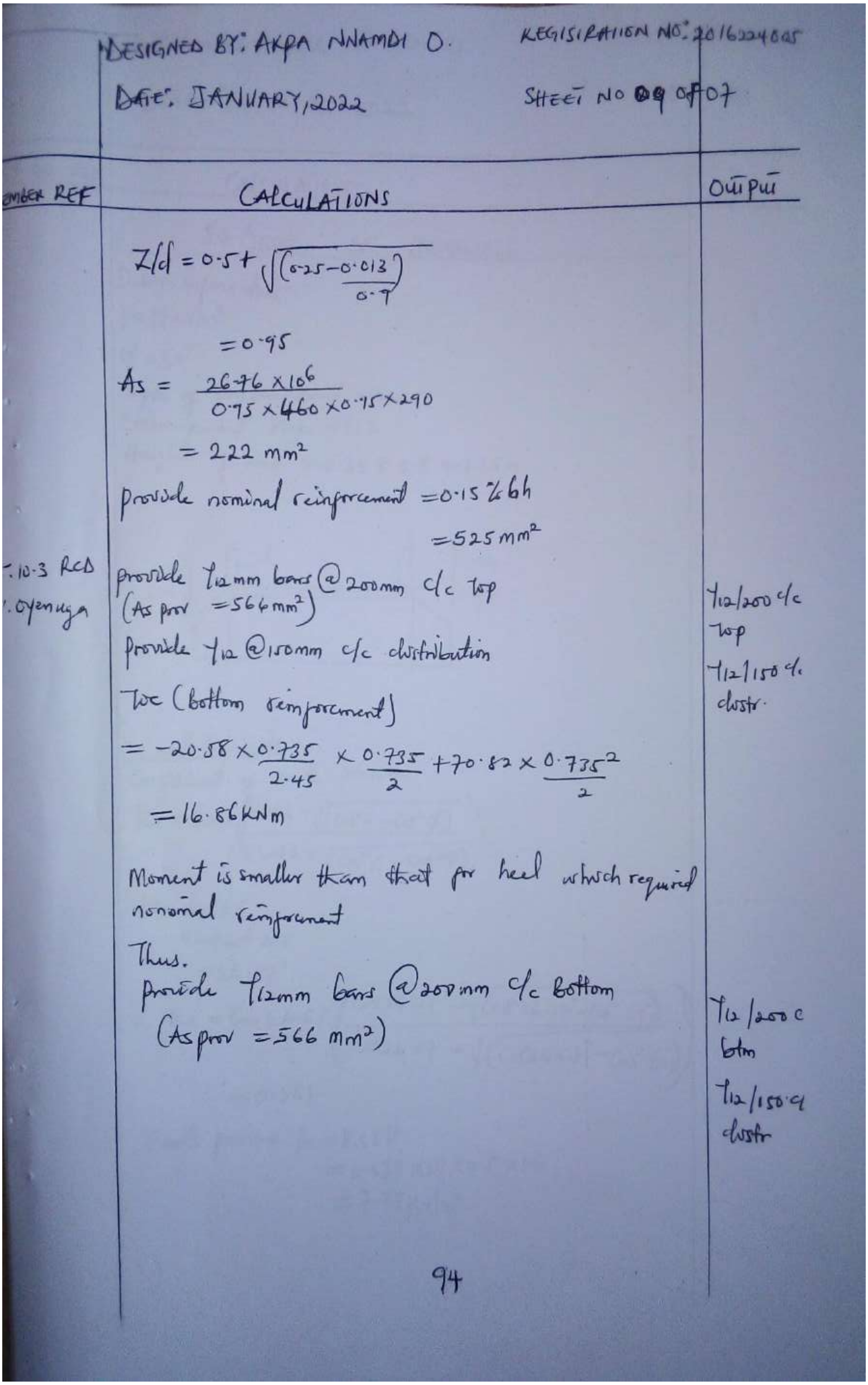
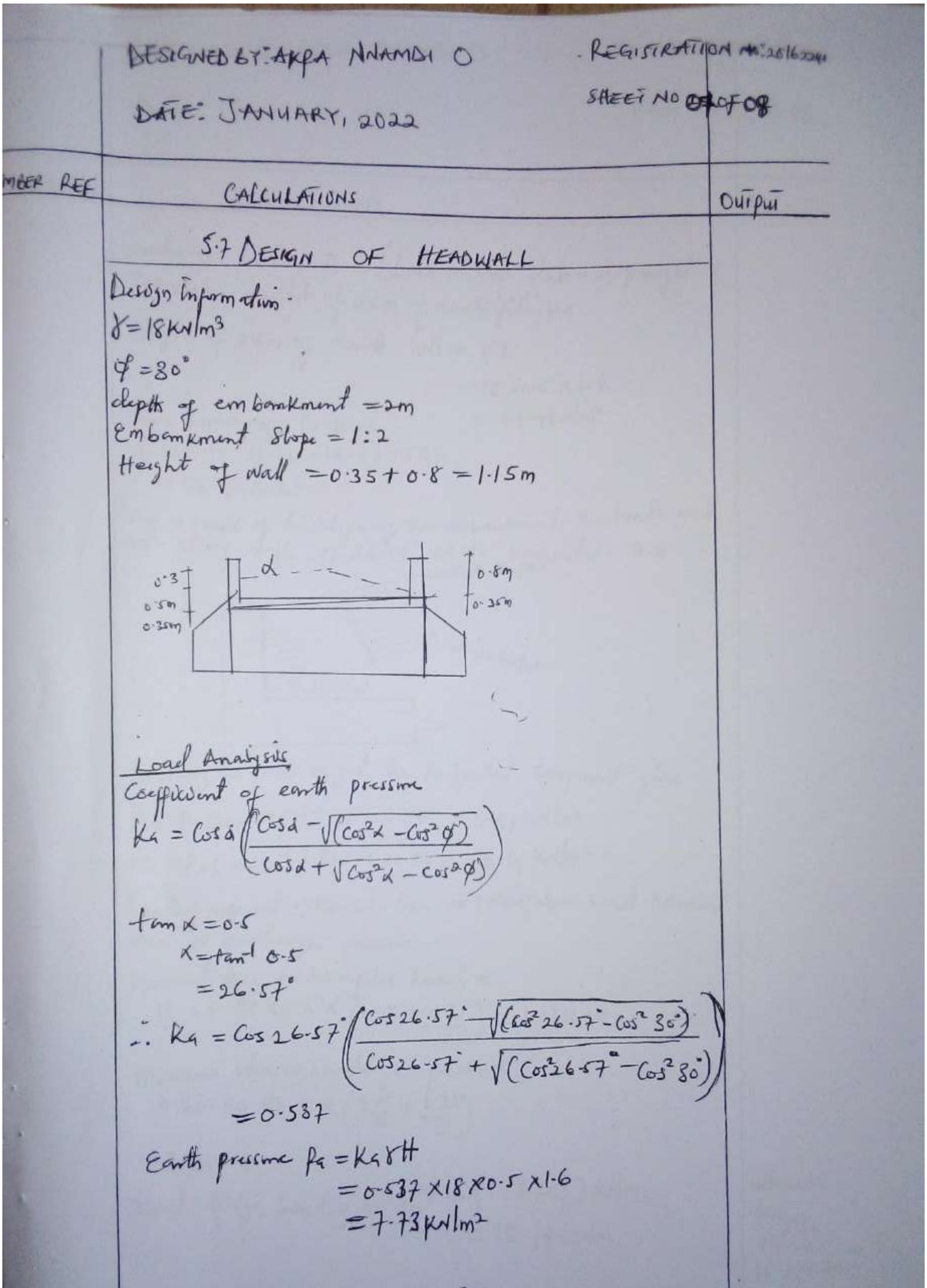


DESIGNED BY: AKPA NNAMDI O. KEGISIRATION NO: 2016224005

DATE: JANUARY, 2022 SHEET NO 09 OF 07

MBER REF	CALCULATIONS	OUTPUT
	$Z/d = 0.5 + \sqrt{\left(0.25 - \frac{0.013}{0.9}\right)}$	
	$= 0.95$	
	$A_s = \frac{26.76 \times 10^6}{0.75 \times 460 \times 0.95 \times 290}$	
	$= 222\ mm^2$	
	provide nominal reinforcement $= 0.15\%bh$	
	$= 525\ mm^2$	
.10.3 RCD .Oyenuga	provide Y12mm bars @ 200mm c/c top (As prov $= 564\ mm^2$)	Y12/200 c/c top
	provide Y12 @ 150mm c/c distribution	Y12/150 c/c distr.
	Toe (bottom reinforcement)	
	$= -20.58 \times \frac{0.735}{2.45} \times \frac{0.735}{2} + 70.82 \times \frac{0.735^2}{2}$	
	$= 16.86\ kNm$	
	Moment is smaller than that for heel which required nonomal reinforcement	
	Thus.	
	provide Y12mm bars @ 200mm c/c Bottom (As prov $= 566\ mm^2$)	Y12/200 c btm Y12/150 c/c distr



DESIGNED BY: AKPA NNAMDI O

DATE: JANUARY, 2022

REGISTRATION NO: 2016[illegible]

SHEET NO [illegible] OF 08

MEMBER REF | CALCULATIONS | OUTPUT

5.7 DESIGN OF HEADWALL

Design Information -

$\gamma = 18 kN/m^3$

$\phi = 30^\circ$

depth of embankment = 2m

Embankment Slope = 1:2

Height of wall = 0.35 + 0.8 = 1.15m

Load Analysis

Coefficient of earth pressure

$$K_a = \cos\alpha\left(\frac{\cos\alpha - \sqrt{(\cos^2\alpha - \cos^2\phi)}}{\cos\alpha + \sqrt{\cos^2\alpha - \cos^2\phi}}\right)$$

$\tan\alpha = 0.5$

$\alpha = \tan^{-1} 0.5$

$= 26.57^\circ$

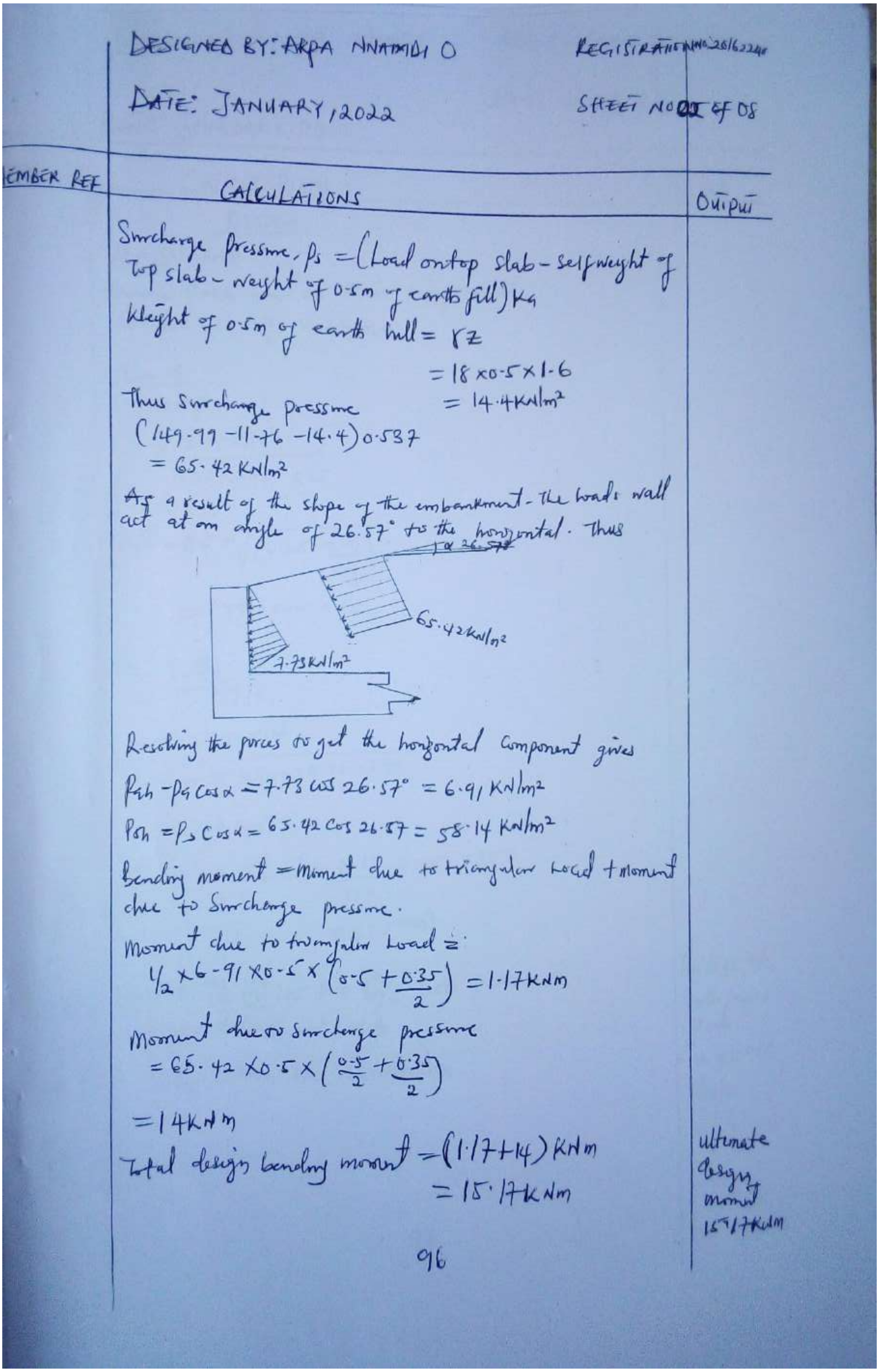
$$\therefore K_a = \cos 26.57^\circ\left(\frac{\cos 26.57^\circ - \sqrt{(\cos^2 26.57^\circ - \cos^2 30^\circ)}}{\cos 26.57^\circ + \sqrt{(\cos^2 26.57^\circ - \cos^2 30^\circ)}}\right)$$

$= 0.537$

Earth pressure $P_a = K_a \gamma H$

$= 0.537 \times 18 \times 0.5 \times 1.6$

$= 7.73 kN/m^2$



DESIGNED BY: ARPA NNAMDI O

REGISTRATION NO: 20162240

DATE: JANUARY, 2022

SHEET NO 02 OF 08

EMBER REF

CALCULATIONS

OUTPUT

Surcharge pressure, P_s = (Load ontop slab − selfweight of Top slab − weight of 0.5m of earth fill) K_a

Weight of 0.5m of earth hull = γz

$= 18 \times 0.5 \times 1.6$

$= 14.4 KN/m^2$

Thus Surcharge pressure

$(149.99 - 11.76 - 14.4)0.537$

$= 65.42 KN/m^2$

As a result of the slope of the embankment - the loads wall act at an angle of 26.57° to the horizontal. Thus

Resolving the forces to get the horizontal component gives

$P_{ah} - P_a \cos\alpha = 7.73 \cos 26.57° = 6.91 KN/m^2$

$P_{sh} = P_s \cos\alpha = 65.42 \cos 26.57 = 58.14 KN/m^2$

Bending moment = Moment due to triangular load + moment due to Surcharge pressure.

Moment due to triangular Load =

$\frac{1}{2} \times 6.91 \times 0.5 \times \left(0.5 + \frac{0.35}{2}\right) = 1.17 KNm$

Moment due to Surcharge pressure

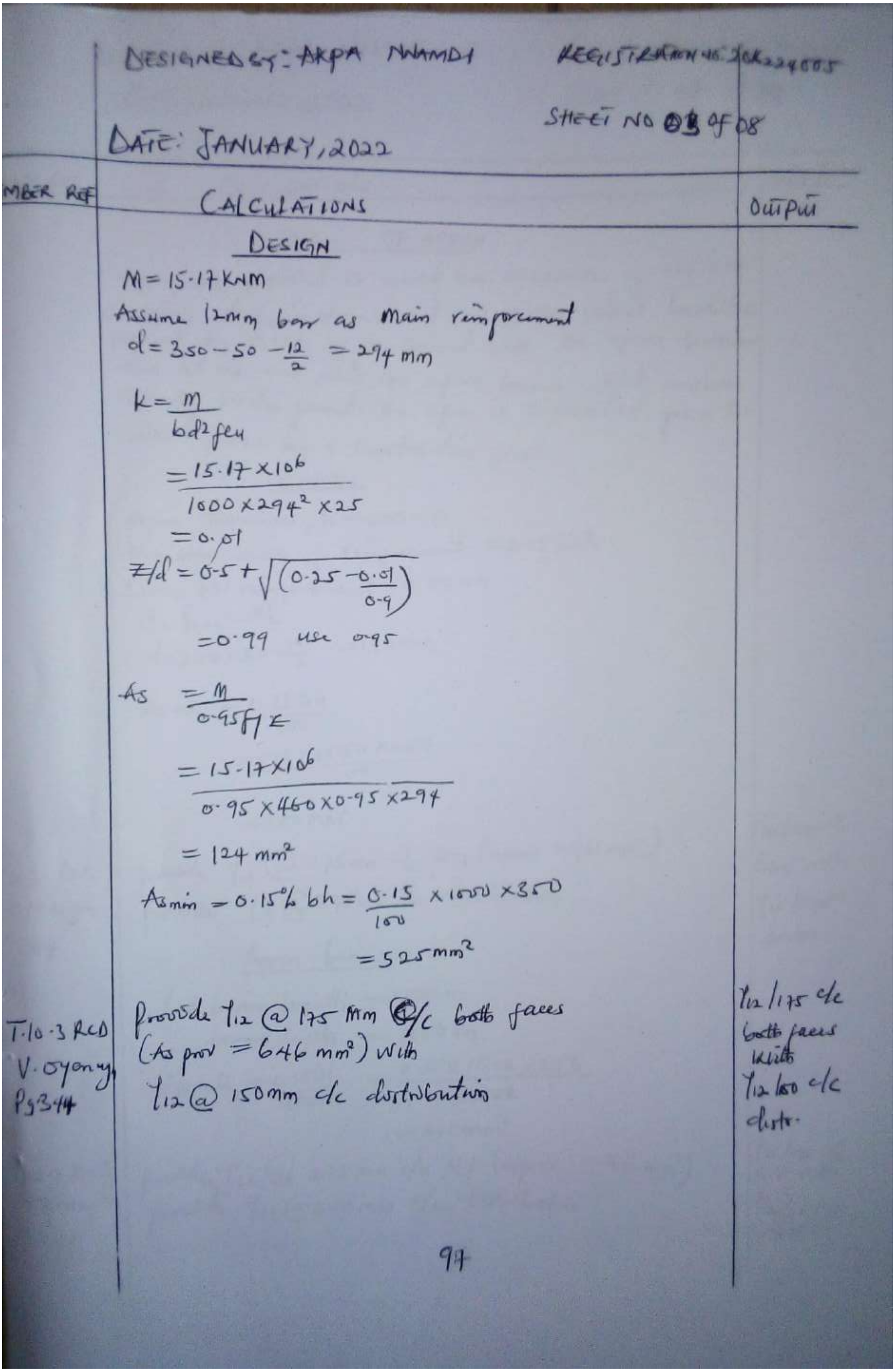
$= 65.42 \times 0.5 \times \left(\frac{0.5}{2} + \frac{0.35}{2}\right)$

$= 14 KNm$

Total design bending moment $= (1.17 + 14) KNm$

$= 15.17 KNm$

ultimate design moment 15.17KNm



DESIGNED BY: AKPA NNAMDI REGISTRATION NO: 20K224005

SHEET NO 03 OF 08

DATE: JANUARY, 2022

MBER REF | CALCULATIONS | OUTPUT

DESIGN

$M = 15.17 KNm$

Assume 12mm bar as main reinforcement

$d = 350 - 50 - \frac{12}{2} = 294\ mm$

$$k = \frac{M}{bd^2 f_{cu}}$$

$$= \frac{15.17 \times 10^6}{1000 \times 294^2 \times 25}$$

$$= 0.01$$

$$Z/d = 0.5 + \sqrt{\left(0.25 - \frac{0.01}{0.9}\right)}$$

$= 0.99$ use 0.95

$$A_s = \frac{M}{0.95 f_y Z}$$

$$= \frac{15.17 \times 10^6}{0.95 \times 460 \times 0.95 \times 294}$$

$$= 124\ mm^2$$

$$A_{s\,min} = 0.15\%\ bh = \frac{0.15}{100} \times 1000 \times 350$$

$$= 525\ mm^2$$

T.10.3 RCD V. Oyenuga, Pg 3.44 — Provide Y12 @ 175 mm c/c both faces (As prov = 646 mm²) with Y12 @ 150mm c/c distribution

Y12/175 c/c both faces with Y12/150 c/c distr.

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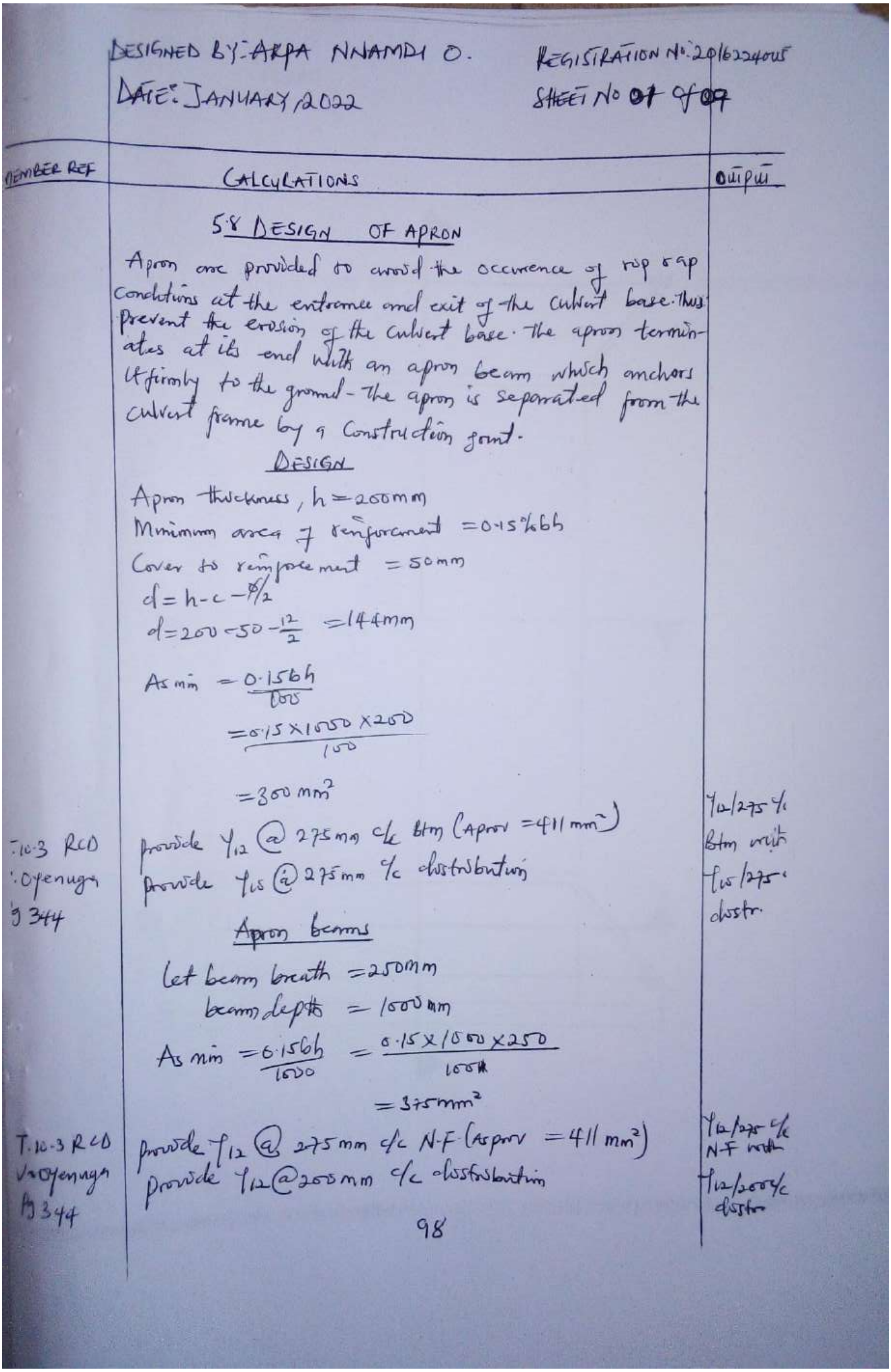

DESIGNED BY:- ARPA NNAMDI O. REGISTRATION No: 2016224005
DATE: JANUARY, 2022 SHEET No 01 of 09

MEMBER REF | CALCULATIONS | OUTPUT

5.8 DESIGN OF APRON

Apron are provided to avoid the occurrence of rip rap conditions at the entrance and exit of the culvert base. thus prevent the erosion of the culvert base. The apron terminates at its end with an apron beam which anchors it firmly to the ground. The apron is separated from the culvert frame by a Construction joint.

DESIGN

Apron thickness, $h = 200mm$

Minimum area of reinforcement $= 0.15\% bh$

Cover to reinforcement $= 50mm$

$d = h - c - \phi/2$

$d = 200 - 50 - \frac{12}{2} = 144mm$

$$As_{min} = \frac{0.15bh}{100}$$

$$= \frac{0.15 \times 1000 \times 200}{100}$$

$$= 300\ mm^2$$

:10-3 RCD
.Oyenuga
g 344

provide Y_{12} @ 275mm c/c Btm ($A_{prov} = 411\ mm^2$)

provide Y_{10} @ 275mm c/c distribution

Output: Y_{12}/275 c/c Btm with Y_{10}/275 c/c distr.

Apron beams

Let beam breath $= 250mm$

beam depth $= 1000\ mm$

$$As_{min} = \frac{0.15bh}{1000} = \frac{0.15 \times 1000 \times 250}{100}$$

$$= 375mm^2$$

T.10-3 RCD
V. Oyenuga
Pg 344

provide Y_{12} @ 275mm c/c N-F ($A_{prov} = 411\ mm^2$)

provide Y_{12} @ 200mm c/c distribution

Output: Y_{12}/275 c/c N-F with Y_{12}/200 c/c distr

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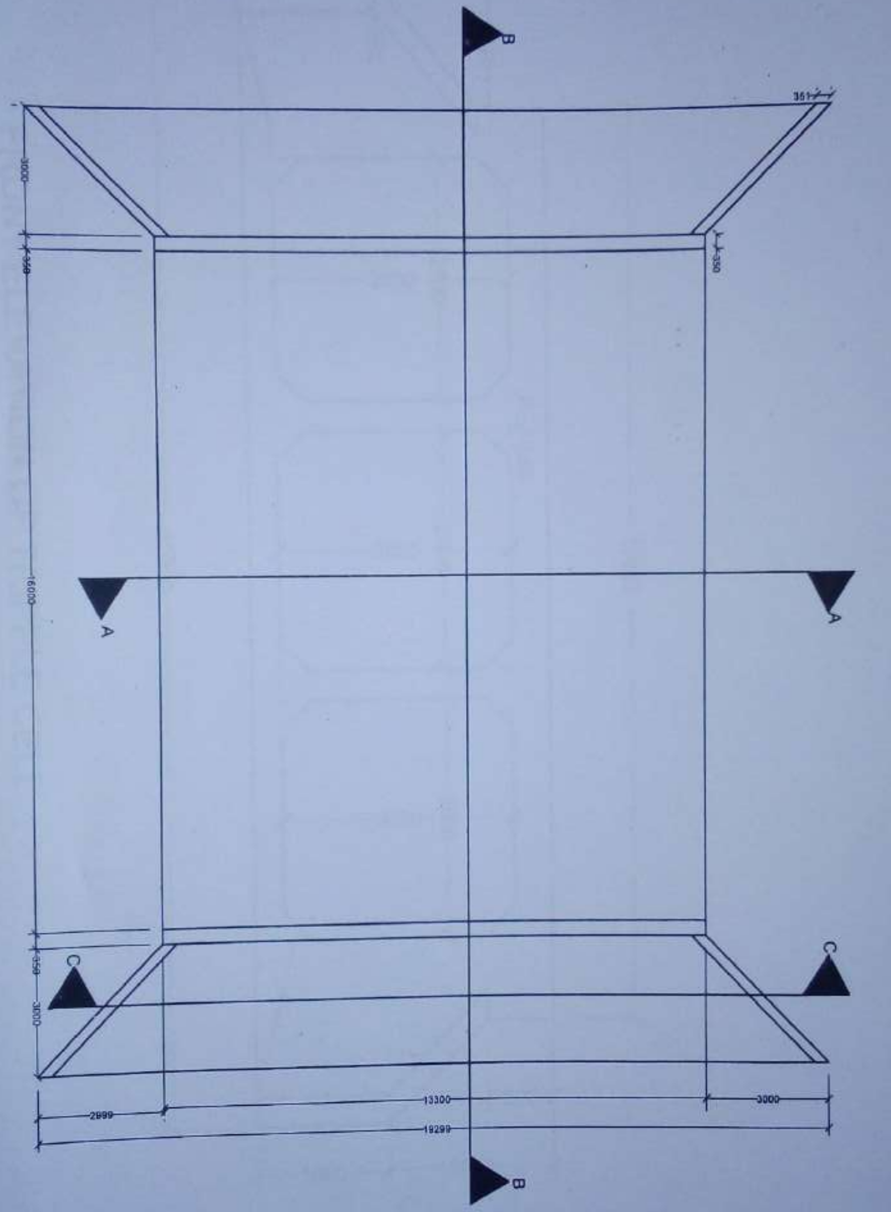
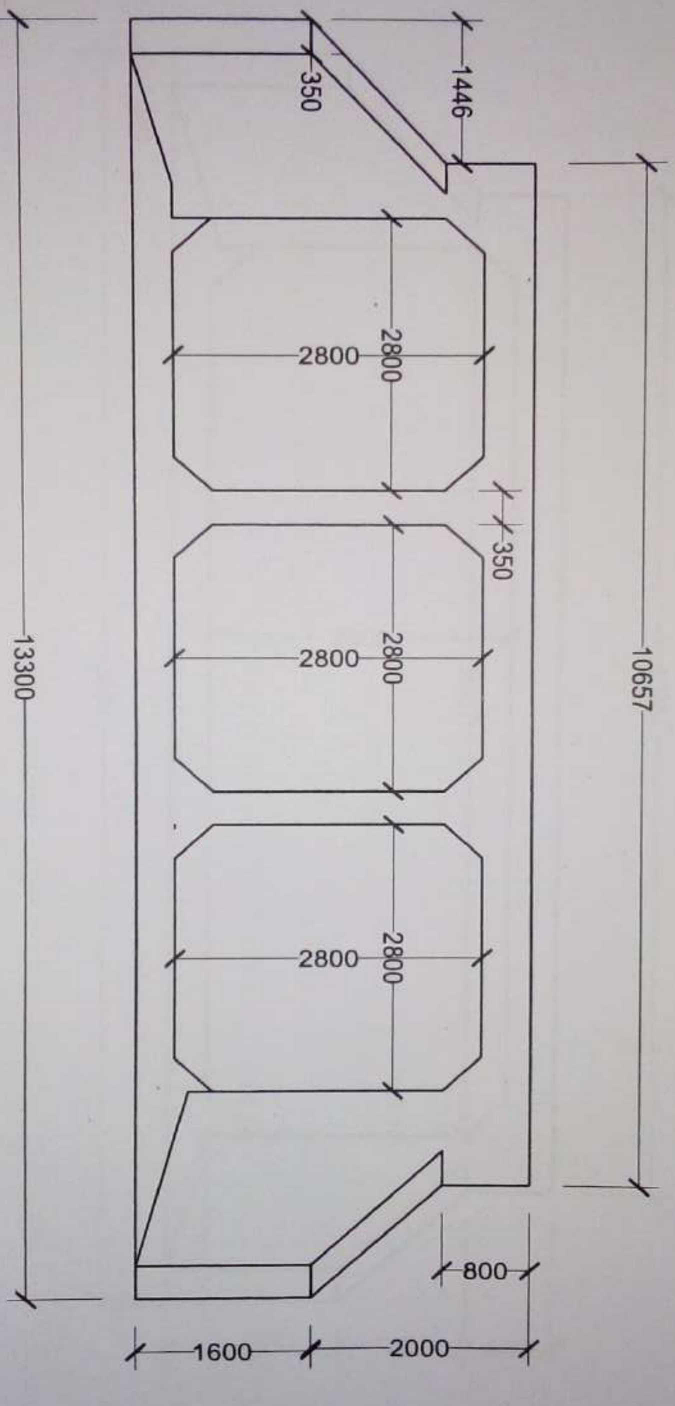
DETAILING

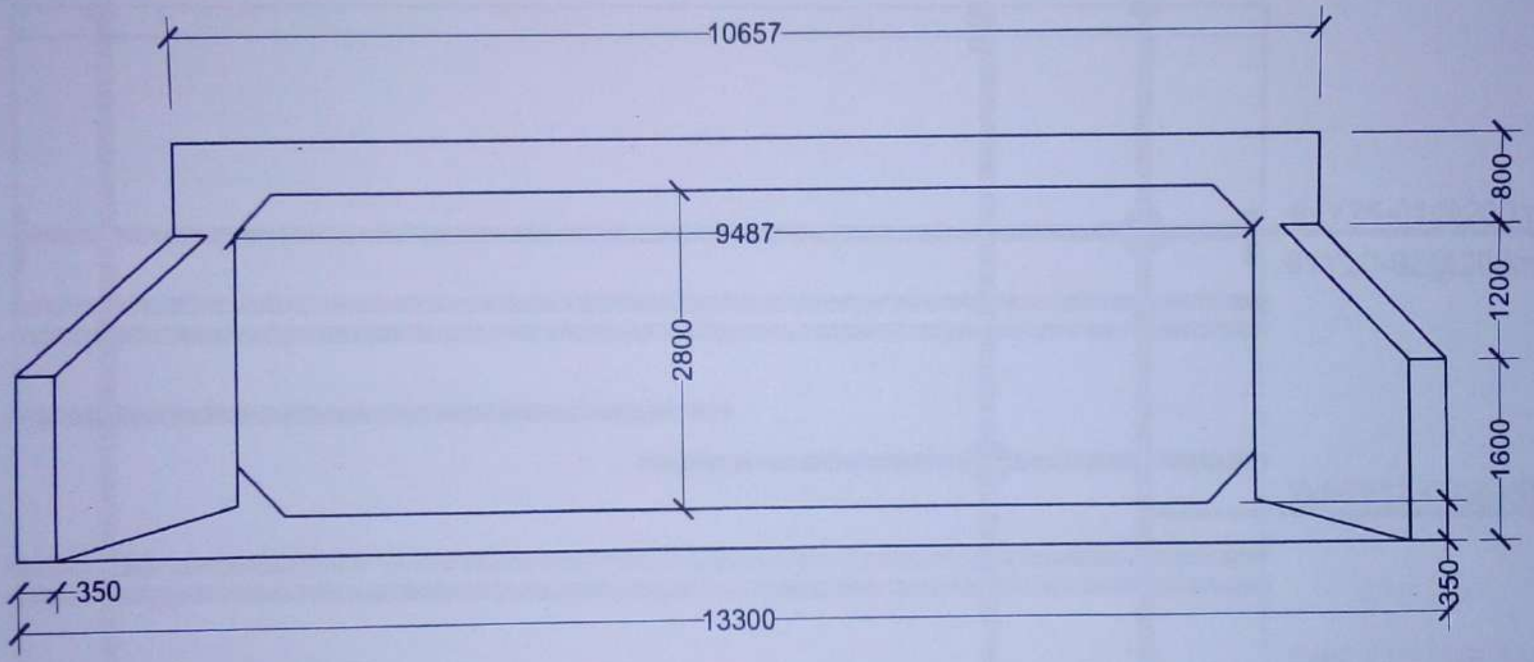


PLAN

99

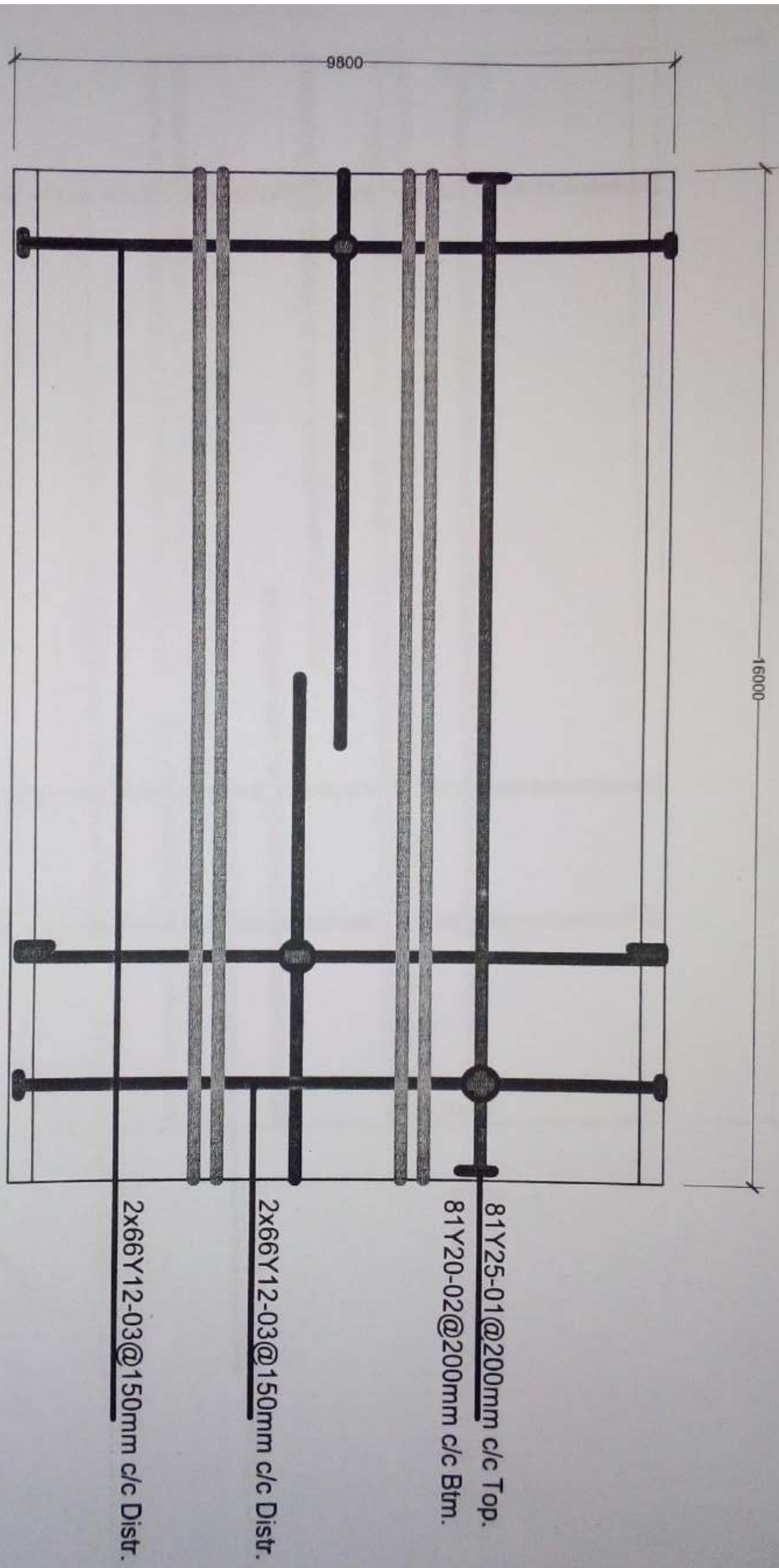


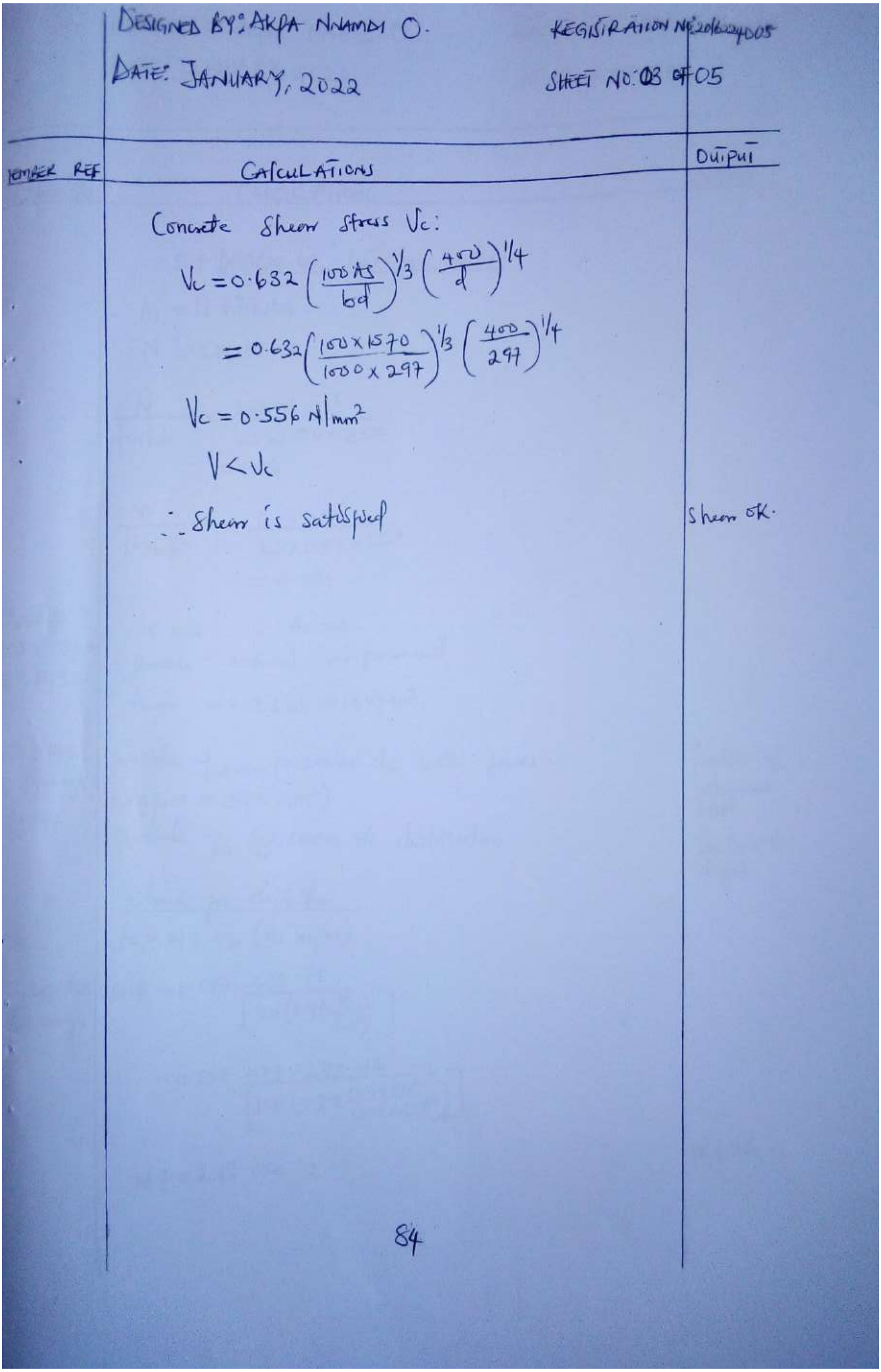
FRONT ELEVATION OF TRIPPLE CELL



FRONT ELEVATION OF SINGLE CEL

TOP SLAB DETAILS





DESIGNED BY: AKPA NNAMDI O.

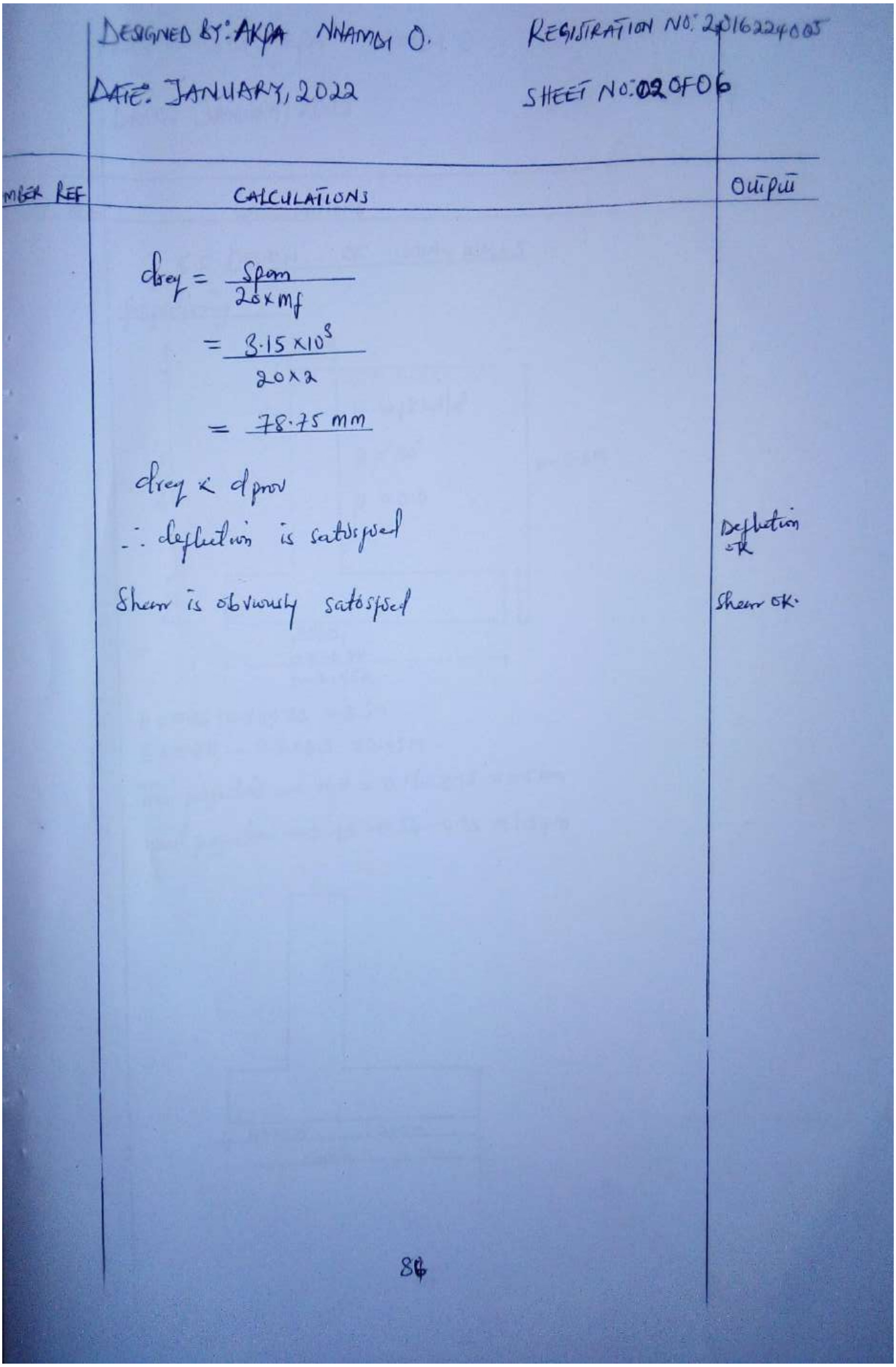
REGISTRATION NO: 2016024005

DATE: JANUARY, 2022

SHEET NO: 03 OF 05

MEMBER REF	CALCULATIONS	OUTPUT
	Concrete Shear Stress V_c:	
	$V_c = 0.632\left(\frac{100A_s}{bd}\right)^{1/3}\left(\frac{400}{d}\right)^{1/4}$	
	$= 0.632\left(\frac{100 \times 1570}{1000 \times 297}\right)^{1/3}\left(\frac{400}{297}\right)^{1/4}$	
	$V_c = 0.556\ N/mm^2$	
	$V < V_c$	
	$\therefore$ Shear is satisfied	Shear OK.

84



DESIGNED BY: AKPA NNAMDI O. REGISTRATION NO: 2016224005

DATE: JANUARY, 2022 SHEET NO: 02 OF 06

MBER REF	CALCULATIONS	OUTPUT
	$d_{req} = \frac{Span}{20 \times m_f}$	
	$= \frac{3.15 \times 10^3}{20 \times 2}$	
	$= \underline{78.75\ mm}$	
	$d_{req} < d_{prov}$	
	∴ deflection is satisfied	Deflection ok
	Shear is obviously satisfied	Shear OK.

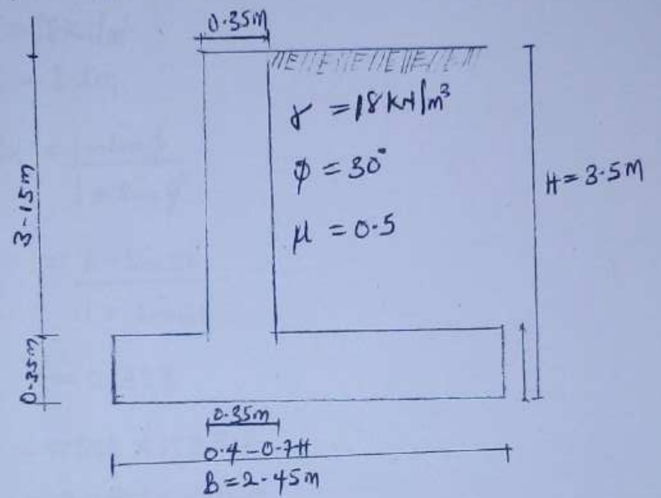
DESIGNED BY: AKPA NNAMDI O. REGISTRATION NO: 2016224005

DATE: JANURY, 2022 SHEET NO: [illegible] OF 04

EMBER REF	CALCULATIONS	OUTPUT

5.5 DESIGN OF WING WALLS

Proportioning

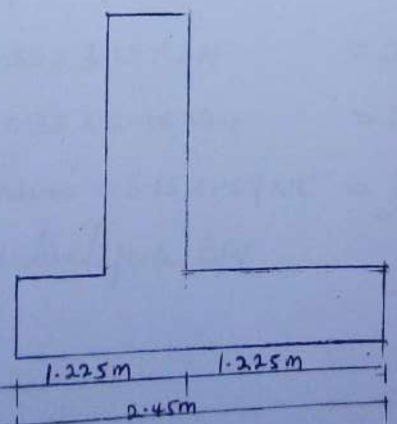


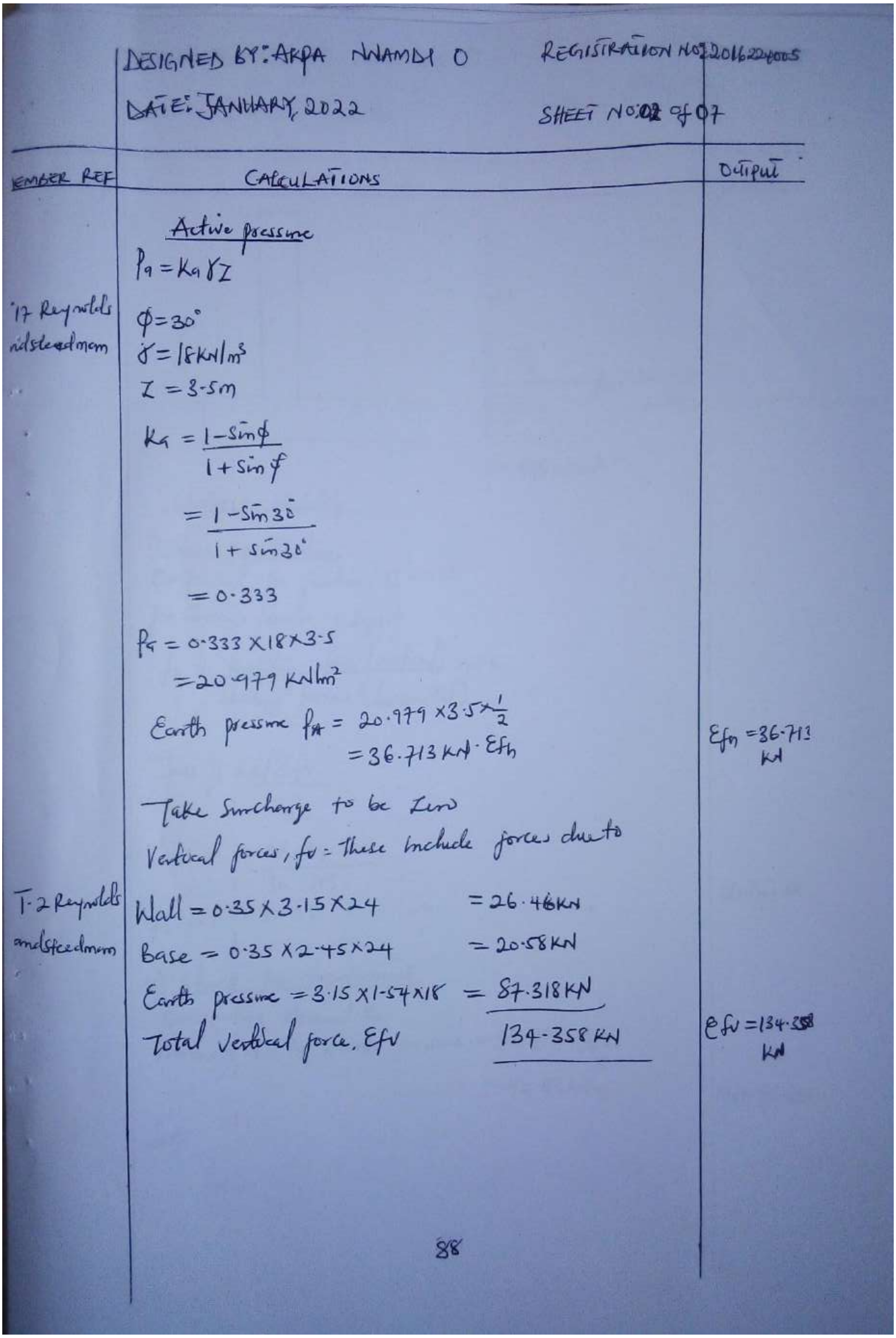
$H = 0.35 + 2.8 + 0.35 = 3.5m$

$B = 0.7H = 0.7 \times 3.5 = 2.45m$

The projection $= 0.16H = 0.16 \times 3.15 = 0.56m$

heel projection $= 2.45 - 0.56 - 0.35 = 1.54m$





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DATE: JANUARY, 2022　　SHEET NO: 02 of 07

EMBER REF	CALCULATIONS	OUTPUT
	Active pressure	
	$P_a = K_a \gamma Z$	
17 Reynolds and steedman	$\phi = 30^\circ$	
	$\gamma = 18 kN/m^3$	
	$Z = 3.5m$	
	$K_a = \frac{1-\sin\phi}{1+\sin\phi}$	
	$= \frac{1-\sin 30^\circ}{1+\sin 30^\circ}$	
	$= 0.333$	
	$P_a = 0.333 \times 18 \times 3.5$	
	$= 20.979 kN/m^2$	
	Earth pressure $P_A = 20.979 \times 3.5 \times \frac{1}{2}$	
	$= 36.713 kN \cdot Ef_h$	$Ef_h = 36.713$ kN
	Take Surcharge to be Zero	
	Vertical forces, fv = These include forces due to	
T-2 Reynolds and steedman	Wall $= 0.35 \times 3.15 \times 24 = 26.46 kN$	
	Base $= 0.35 \times 2.45 \times 24 = 20.58 kN$	
	Earth pressure $= 3.15 \times 1.54 \times 18 = 87.318 kN$	
	Total vertical force, Efv　134.358 kN	$Efv = 134.358$ kN

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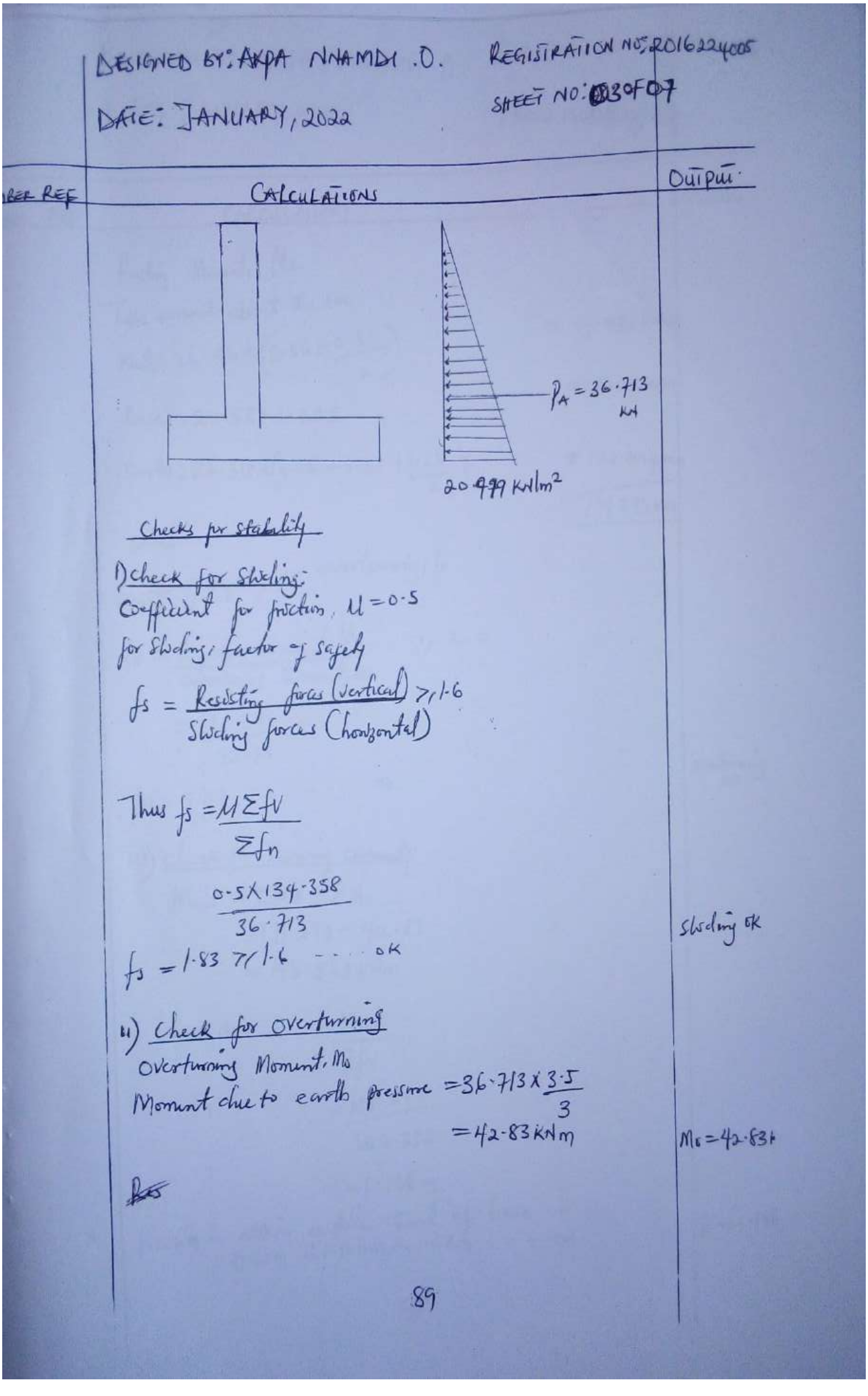

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DATE: JANUARY, 2022 SHEET NO: 03OF07

REF	CALCULATIONS	OUTPUT

Checks for stability

I) check for Sliding:

Coefficient for friction, $\mu = 0.5$

for Sliding, factor of safety

$$f_s = \frac{\text{Resisting forces (vertical)}}{\text{Sliding forces (horizontal)}} \geq 1.6$$

Thus $f_s = \dfrac{\mu \Sigma f_v}{\Sigma f_h}$

$$\frac{0.5 \times 134.358}{36.713}$$

$f_s = 1.83 \geq 1.6$ .... ok

Sliding ok

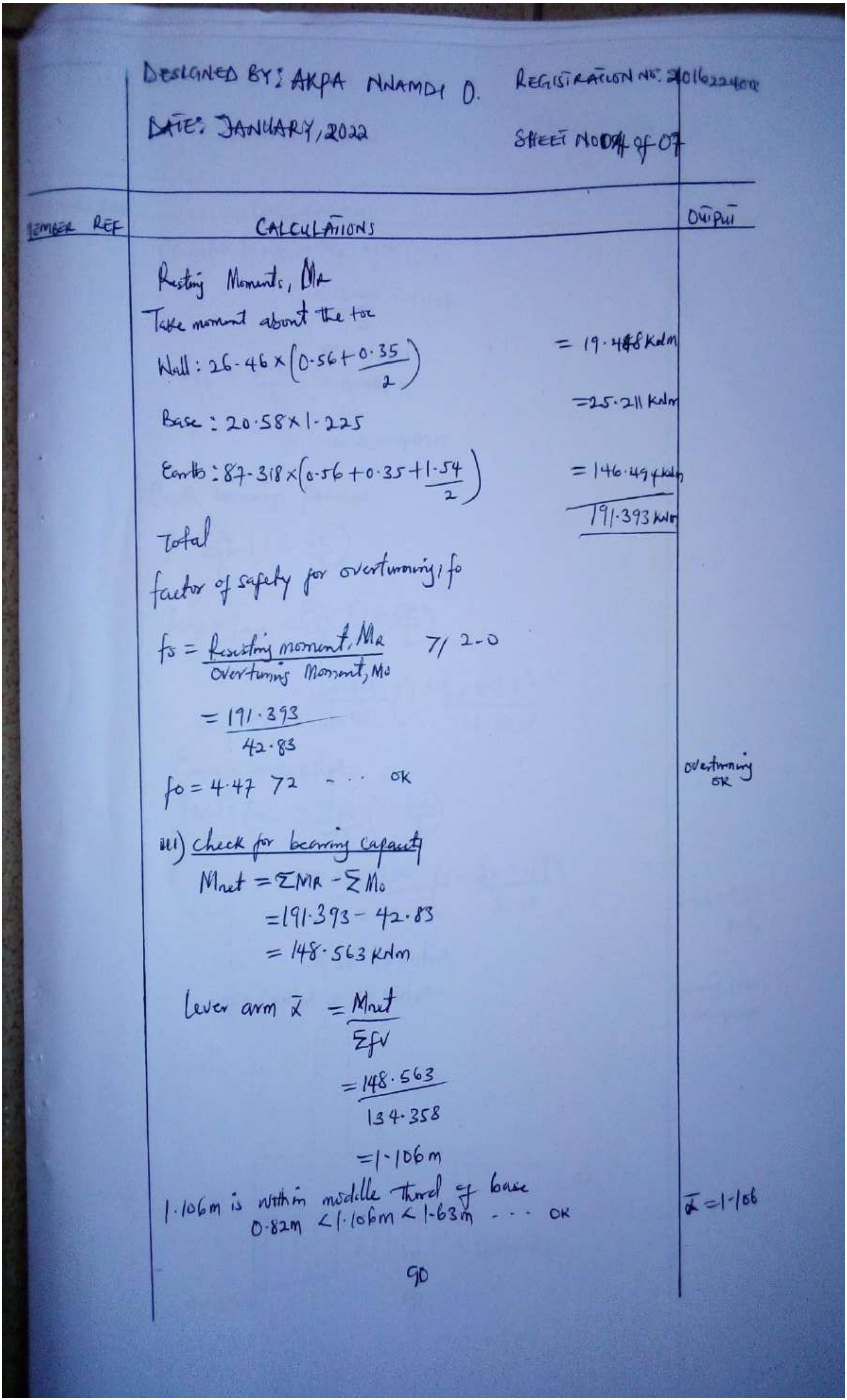
II) Check for overturning

Overturning Moment, M_o

Moment due to earth pressure $= 36.713 \times \dfrac{3.5}{3}$

$= 42.83$ kNm

$M_o = 42.83$



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DATE: JANUARY, 2022 SHEET No 04 of 07

MEMBER REF	CALCULATIONS	OUTPUT

Resting Moments, M_R

Take moment about the toe

Wall: $26.46 \times \left(0.56 + \frac{0.35}{2}\right)$ $= 19.448 \, KNm$

Base: 20.58×1.225 $= 25.211 \, KNm$

Earth: $87.318 \times \left(0.56 + 0.35 + \frac{1.54}{2}\right)$ $= 146.494 \, KNm$

Total $191.393 \, KNm$

factor of safety for overturning, fo

$$f_o = \frac{\text{Resisting moment, } M_R}{\text{Overturning Moment, } M_o} \geq 2.0$$

$$= \frac{191.393}{42.83}$$

$f_o = 4.47 \geq 2$ … OK

overturning OK

iii) check for bearing capacity

$$M_{net} = \Sigma M_R - \Sigma M_o$$

$$= 191.393 - 42.83$$

$$= 148.563 \, KNm$$

$$\text{Lever arm } \bar{x} = \frac{M_{net}}{\Sigma f_V}$$

$$= \frac{148.563}{134.358}$$

$$= 1.106 \, m$$

1.106m is within middle third of base

$0.82m < 1.106m < 1.63m$ … OK

$\bar{x} = 1.106$

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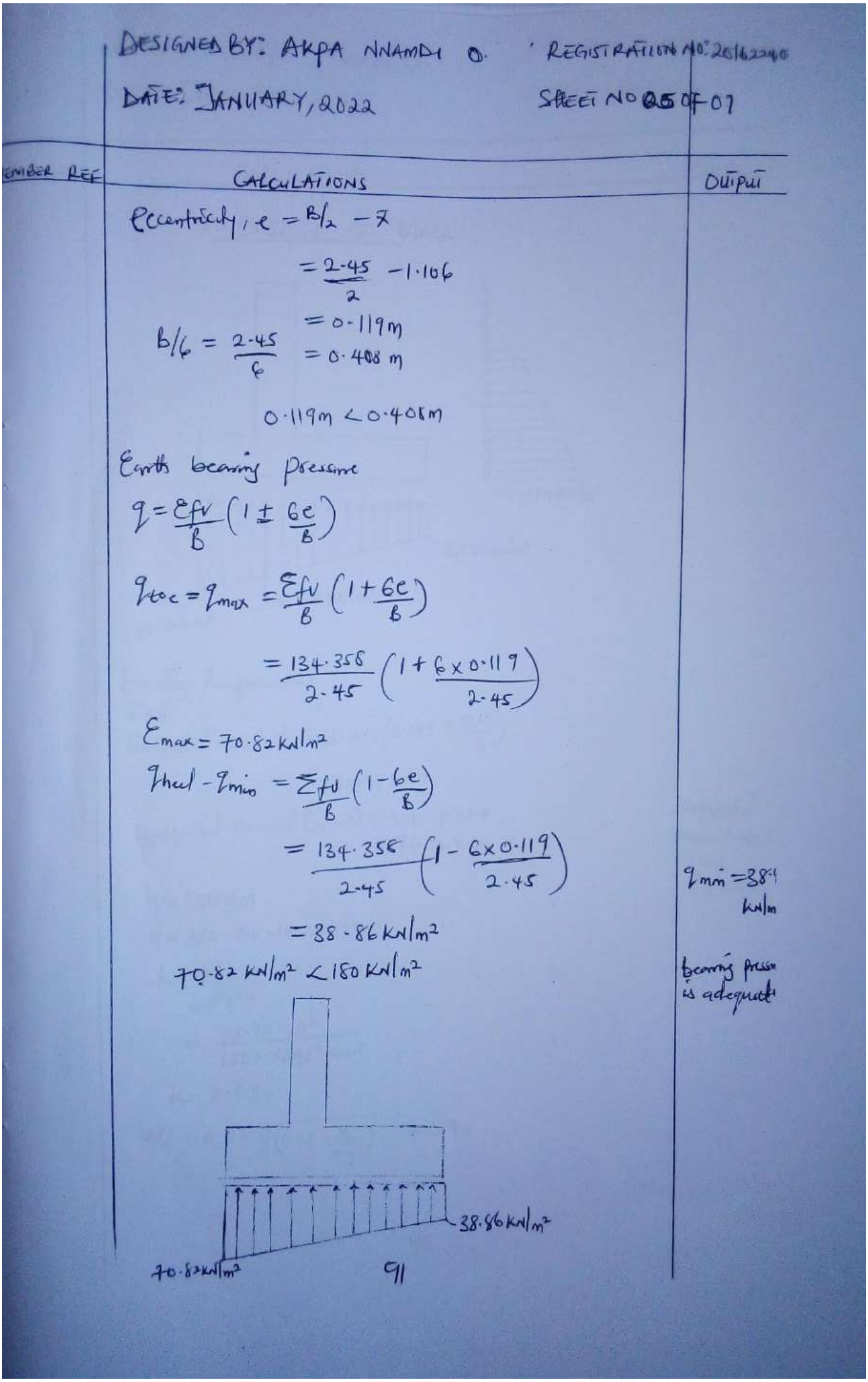

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DATE: JANUARY, 2022 SHEET NO 05 OF 07

MEMBER REF	CALCULATIONS	OUTPUT

Eccentricity, $e = B/2 - \bar{x}$

$= \frac{2.45}{2} - 1.106$

$= 0.119m$

$b/6 = \frac{2.45}{6} = 0.408\ m$

$0.119m < 0.408m$

Earth bearing pressure

$q = \frac{\Sigma fv}{B}\left(1 \pm \frac{6e}{B}\right)$

$q_{toe} = q_{max} = \frac{\Sigma fv}{B}\left(1 + \frac{6e}{B}\right)$

$= \frac{134.358}{2.45}\left(1 + \frac{6 \times 0.119}{2.45}\right)$

$\mathcal{E}_{max} = 70.82 kN/m^2$

$q_{heel} - q_{min} = \frac{\Sigma fv}{B}\left(1 - \frac{6e}{B}\right)$

$= \frac{134.358}{2.45}\left(1 - \frac{6 \times 0.119}{2.45}\right)$

$= 38.86 kN/m^2$

$70.82 kN/m^2 < 180 kN/m^2$

$q_{min} = 38.9$ kN/m

bearing pressure is adequate

38.86 kN/m²

70.82 kN/m²

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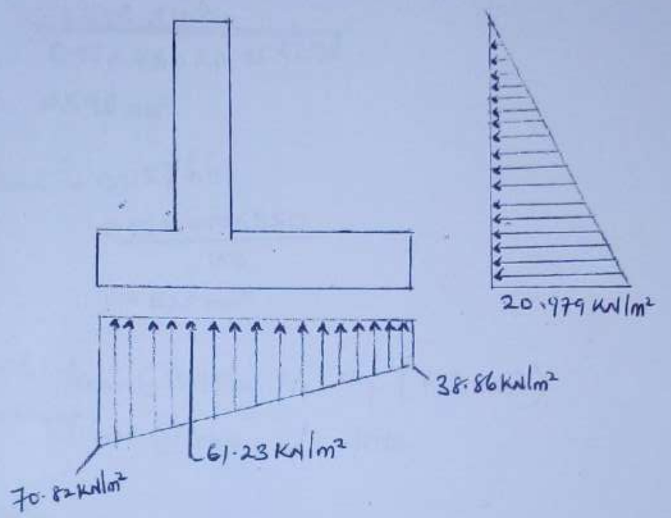
DATE: JANUARY, 2022 SHEET NO 06 of 07

EMBER REF	CALCULATIONS	OUTPUT

5.6 DESIGN OF WALL



Bending Reinforcement

Wall

$$\text{Horizontal moment} = 36.713\left(0.175 + \frac{3.15}{3}\right)$$

$$= 44.97\ \text{kNm}$$

$$\text{Horizontal moment (u.l.s)} = 44.97 \times 1.6$$

$$= 71.96\ \text{kNm}$$

Horizontal moment = 71.9 kNm (u.l.s)

$h = 350\text{mm}$

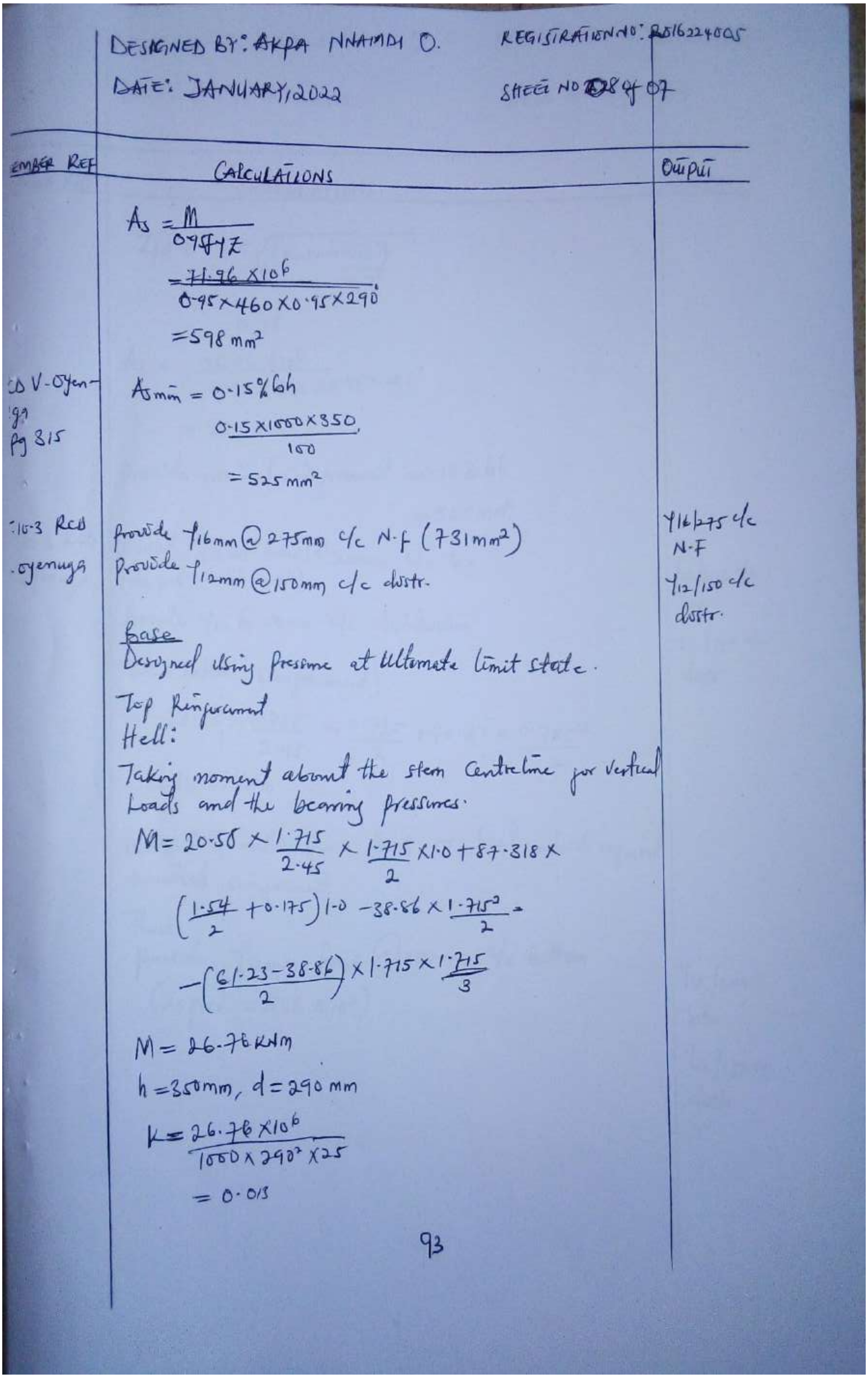
$d = 350 - 50 - 10 = 290\text{mm}$

$$K = \frac{M}{bd^2 f_{cu}}$$

$$= \frac{71.96 \times 10^6}{1000 \times 290^2 \times 25}$$

$K = 0.034$

$$Z/d = 0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)} = 0.95$$



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DATE: JANUARY, 2022 SHEET NO 28 of 07

MEMBER REF | CALCULATIONS | OUTPUT

$$A_s = \frac{M}{0.95 f_y Z}$$

$$= \frac{71.96 \times 10^6}{0.95 \times 460 \times 0.95 \times 290}$$

$$= 598\ mm^2$$

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ga
pg 315

$$A_{s\,min} = 0.15\% bh$$

$$\frac{0.15 \times 1000 \times 350}{100}$$

$$= 525\ mm^2$$

10-3 RCD
.oyenuga

provide Y16mm @ 275mm c/c N.f (731mm²)

Provide Y12mm @ 150mm c/c distr.

Y16/275 c/c N-F

Y12/150 c/c distr.

Base

Designed using pressure at Ultimate limit state.

Top Reinforcement

Hell:

Taking moment about the stem Centreline for vertical Loads and the bearing pressures.

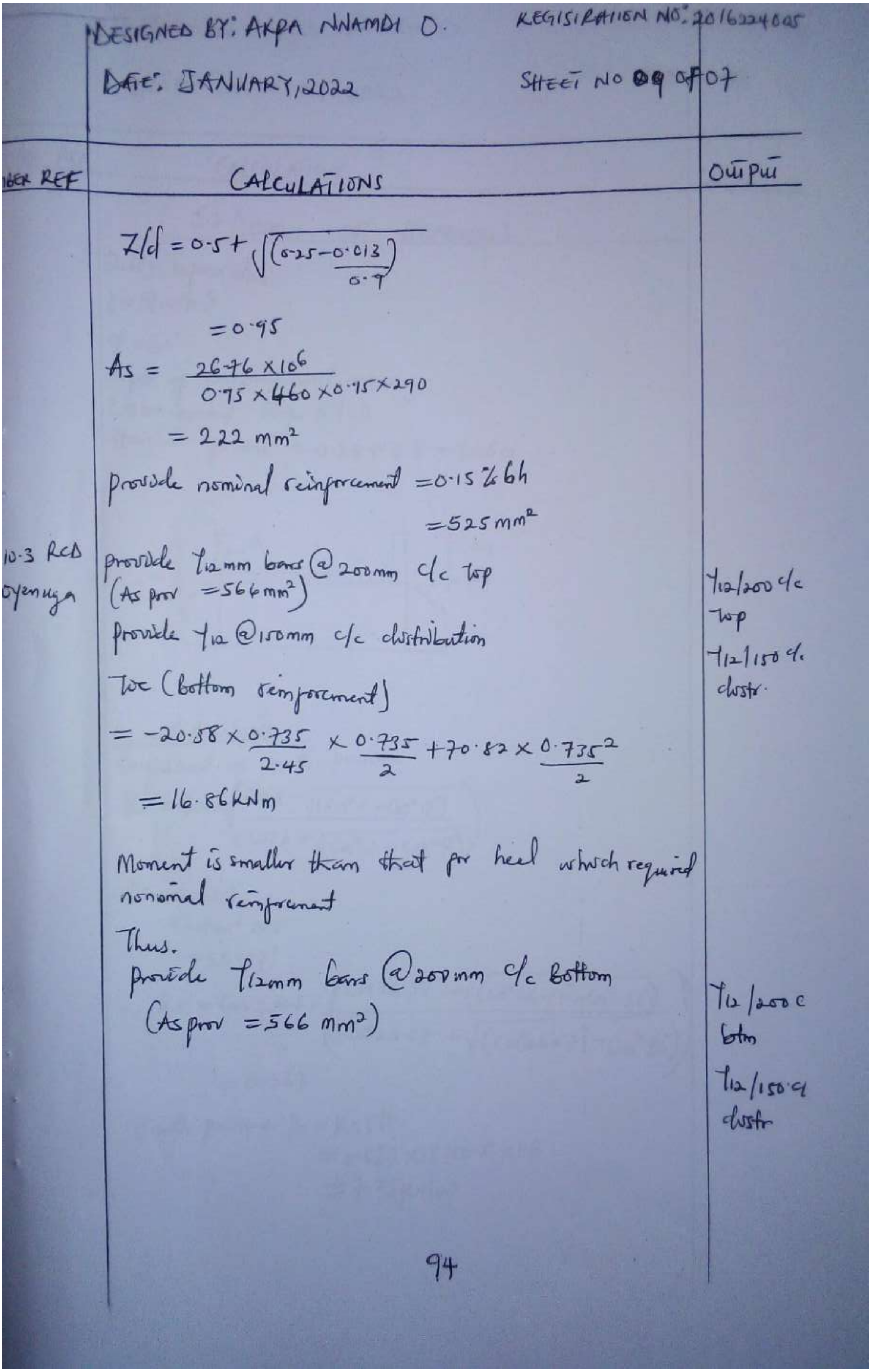
$$M = 20.58 \times \frac{1.715}{2.45} \times \frac{1.715}{2} \times 1.0 + 87.318 \times \left(\frac{1.54}{2} + 0.175\right) 1.0 - 38.86 \times \frac{1.715^2}{2} = -\left(\frac{61.23 - 38.86}{2}\right) \times 1.715 \times \frac{1.715}{3}$$

$$M = 26.76\ kNm$$

$$h = 350mm,\ d = 290\ mm$$

$$K = \frac{26.76 \times 10^6}{1000 \times 290^2 \times 25}$$

$$= 0.013$$



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DATE: JANUARY, 2022 SHEET NO 09 OF 07

REF	CALCULATIONS	OUTPUT
	$Z/d = 0.5 + \sqrt{\left(0.25 - \frac{0.013}{0.9}\right)}$ $= 0.95$ $A_s = \frac{26.76 \times 10^6}{0.75 \times 460 \times 0.95 \times 290}$ $= 222\ mm^2$ provide nominal reinforcement = 0.15 % bh = 525 mm²	
10.3 RCD Oyenuga	provide Y12mm bars @ 200mm c/c top (As prov = 564 mm²) provide Y12 @ 150mm c/c distribution	Y12/200 c/c top Y12/150 c/c distr.
	Toe (bottom reinforcement) $= -20.58 \times \frac{0.735}{2.45} \times \frac{0.735}{2} + 70.82 \times \frac{0.735^2}{2}$ $= 16.86\ KNm$ Moment is smaller than that for heel which required nonomal reinforcement Thus. provide Y12mm bars @ 200mm c/c Bottom (As prov = 566 mm²)	Y12/200 c btm Y12/150 c/c distr

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DATE: JANUARY, 2022

REGISTRATION NO: 2016224[illegible]
SHEET NO 0[illegible] OF 08

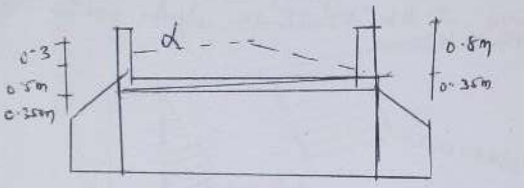
MBER REF

CALCULATIONS

OUTPUT

5.7 DESIGN OF HEADWALL

Design Information -
$\gamma = 18 KN/m^3$
$\phi = 30°$
depth of embankment = 2m
Embankment Slope = 1:2
Height of wall $= 0.35 + 0.8 = 1.15m$



Load Analysis
Coefficient of earth pressure

$$K_a = \cos\alpha \left(\frac{\cos\alpha - \sqrt{(\cos^2\alpha - \cos^2\phi)}}{\cos\alpha + \sqrt{\cos^2\alpha - \cos^2\phi)}} \right)$$

$\tan\alpha = 0.5$
$\alpha = \tan^{-1} 0.5$
$= 26.57°$

$$\therefore K_a = \cos 26.57° \left(\frac{\cos 26.57° - \sqrt{(\cos^2 26.57° - \cos^2 30°)}}{\cos 26.57° + \sqrt{(\cos^2 26.57° - \cos^2 30°)}} \right)$$

$= 0.537$

Earth pressure $f_a = K_a \gamma H$
$= 0.537 \times 18 \times 0.5 \times 1.6$
$= 7.73 KN/m^2$

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DATE: JANUARY, 2022 SHEET NO: 03 of 04

MEMBER REF | CALCULATIONS | OUTPUT

$$M.f = 0.55 + \frac{(477 - fs)}{\left[120\left(0.9 + \frac{M}{bd^2}\right)\right]}$$

$$= 0.55 + \frac{(477 - 400)}{\left[120\left(0.9 + \frac{78.47 \times 10^6}{1000 \times 292^2}\right)\right]}$$

$$= 1.48 < 2 \quad \ldots\ldots \quad ok$$

Since the slab is Continous, the span-effective depth ratio is 23

$$d_{req} = \frac{span}{23 \times m.F}$$

$$d_{req} = \frac{3.15 \times 10^3}{23 \times 1.48}$$

$$= 92.54mm$$

$d_{req} < d_{prov}$

∴ deflection is satisfied

deflection OK.

Check for shear

Max-shear $V = 271.51KN$

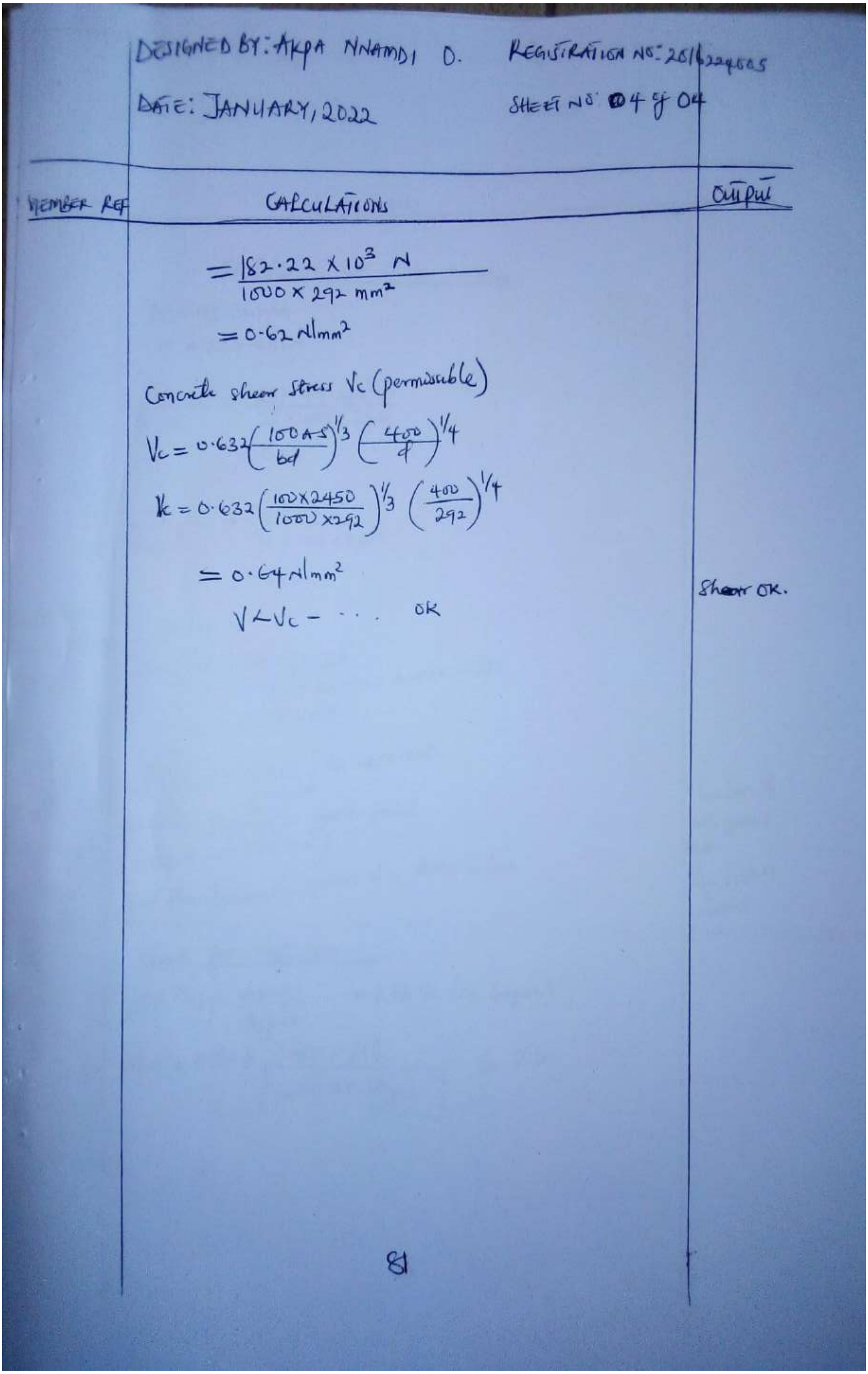
But the culvert is chamfered 550mm at the joints. Thus the maximum shear is reduced to.

$$V = 271.51 - 0.55(161.43)$$

$$= 182.22KN$$

Shear stress, $v = \frac{V}{bd}$

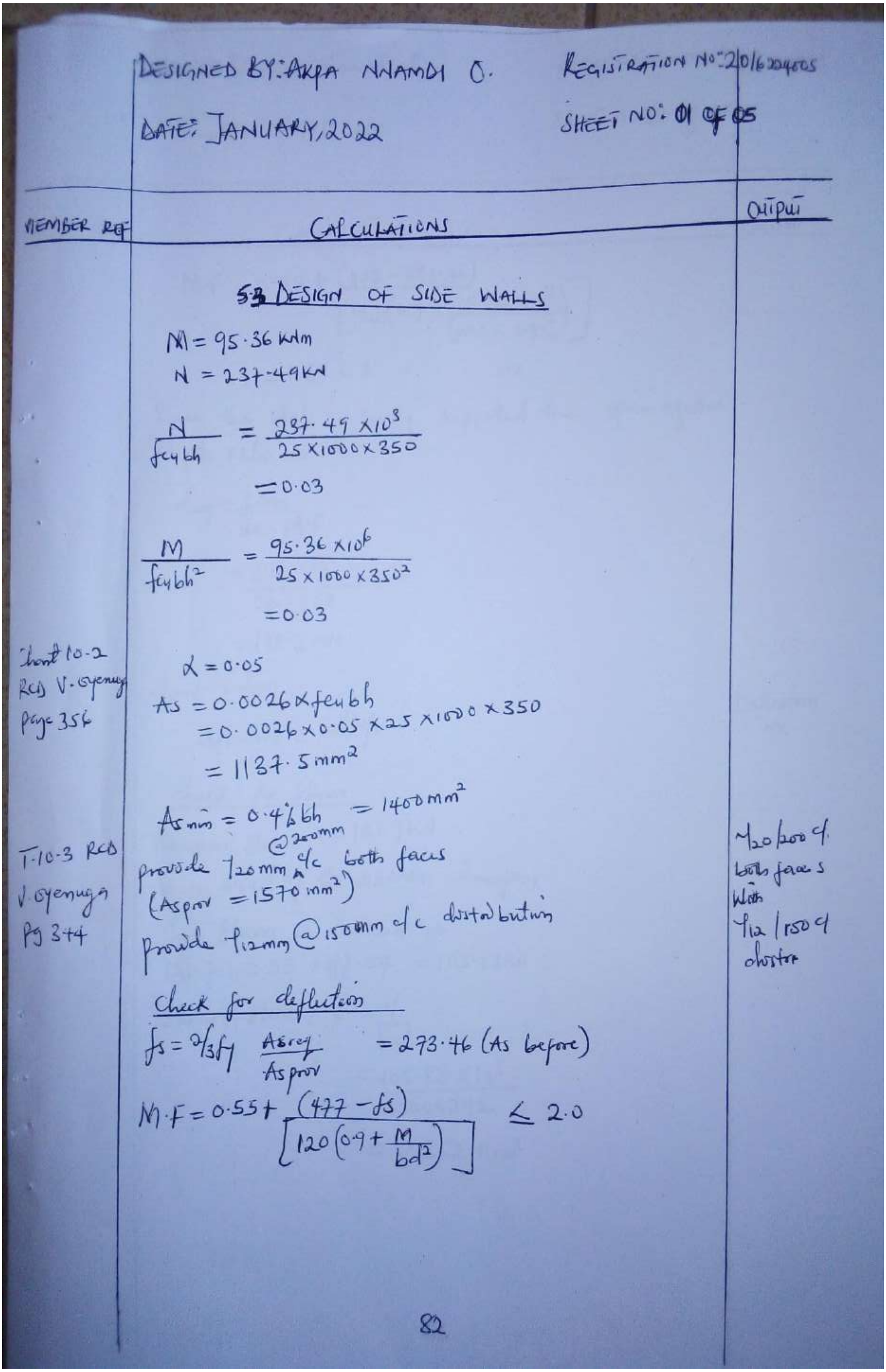
80



DESIGNED BY: AKPA NNAMDI O. REGISTRATION NO: 2016224505

DATE: JANUARY, 2022 SHEET NO: 04 of 04

MEMBER REF	CALCULATIONS	OUTPUT
	$= \frac{182.22 \times 10^3 \ N}{1000 \times 292 \ mm^2}$	
	$= 0.62 \ N/mm^2$	
	Concrete shear stress Vc (permissible)	
	$V_c = 0.632\left(\frac{100As}{bd}\right)^{1/3}\left(\frac{400}{d}\right)^{1/4}$	
	$V_c = 0.632\left(\frac{100 \times 2450}{1000 \times 292}\right)^{1/3}\left(\frac{400}{292}\right)^{1/4}$	
	$= 0.64 \ N/mm^2$	Shear OK.
	$V < V_c$ - . . . OK	



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REGISTRATION NO: 2016204005
DATE: JANUARY, 2022
SHEET NO: 01 OF 05

MEMBER REF | CALCULATIONS | OUTPUT

5.3 DESIGN OF SIDE WALLS

$M = 95.36\,kNm$

$N = 237.49\,kN$

$$\frac{N}{f_{cu}bh} = \frac{237.49 \times 10^3}{25 \times 1000 \times 350}$$

$$= 0.03$$

$$\frac{M}{f_{cu}bh^2} = \frac{95.36 \times 10^6}{25 \times 1000 \times 350^2}$$

$$= 0.03$$

Chart 10-2 RCD V. Oyenuga Page 356

$\alpha = 0.05$

$$A_s = 0.0026\alpha f_{cu}bh$$

$$= 0.0026 \times 0.05 \times 25 \times 1000 \times 350$$

$$= 1137.5\,mm^2$$

$$A_{s\,min} = 0.4\%\,bh = 1400\,mm^2$$

T-10-3 RCD V. Oyenuga Pg 344

provide Y20mm @200mm c/c both faces

$(A_{s\,prov} = 1570\,mm^2)$

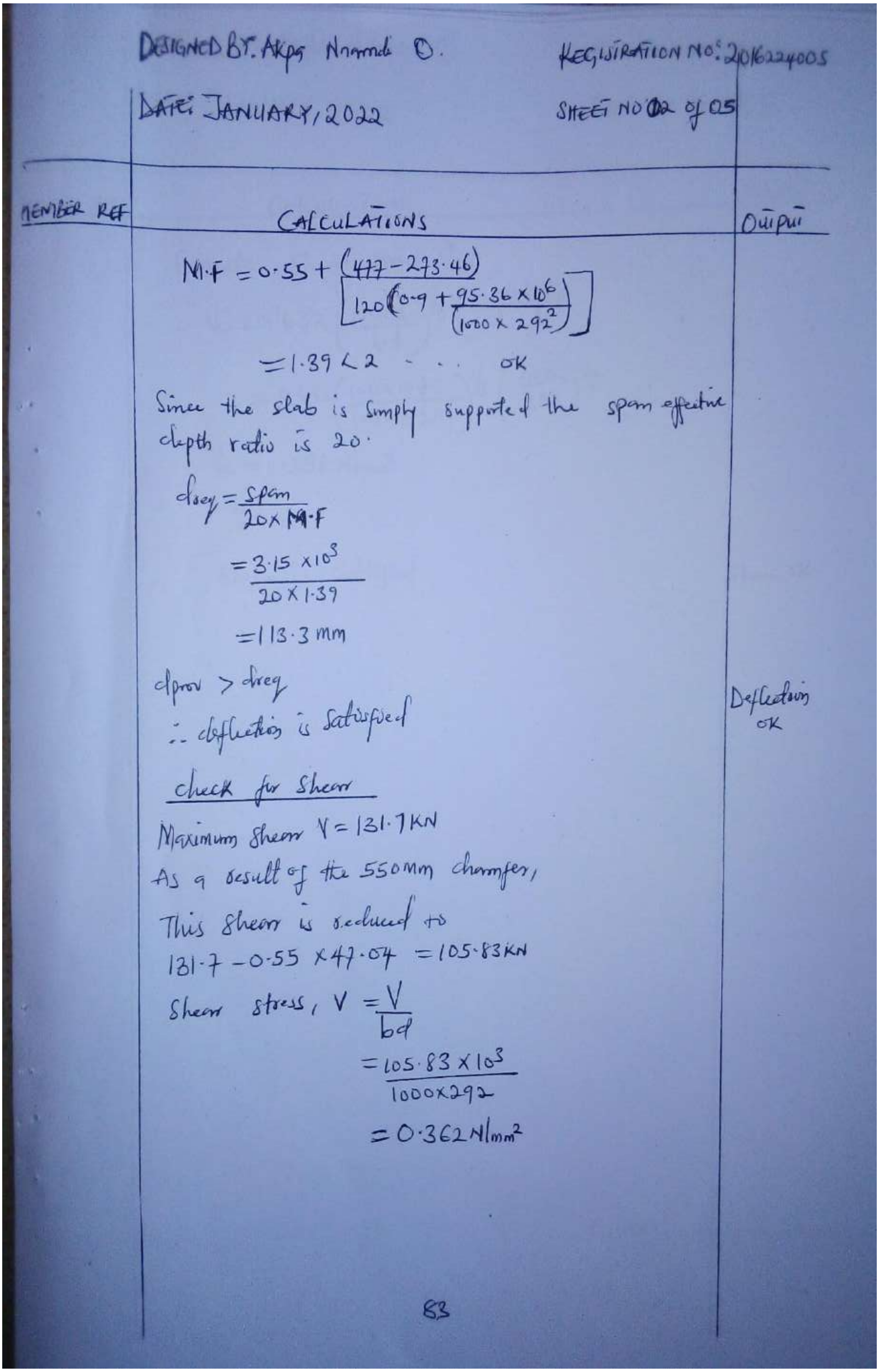
provide Y12mm @150mm c/c distribution

Y20/200 c/c both faces with Y12/150 c/c distrn

Check for deflection

$$f_s = \frac{2}{3}f_y \frac{A_{s\,req}}{A_{s\,prov}} = 273.46 \text{ (As before)}$$

$$M.F = 0.55 + \frac{(477 - f_s)}{\left[120\left(0.9 + \frac{M}{bd^2}\right)\right]} \leq 2.0$$



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DATE: JANUARY, 2022 SHEET NO 02 of 05

MEMBER REF	CALCULATIONS	OUTPUT
	$M.F = 0.55 + \frac{(477-273.46)}{\left[120\left(0.9+\frac{95.36\times10^6}{(1000\times292^2)}\right)\right]}$ $= 1.39 < 2$ . . . OK Since the slab is simply supported the span effective depth ratio is 20. $d_{req} = \frac{span}{20\times M.F}$ $= \frac{3.15\times10^3}{20\times1.39}$ $= 113.3\ mm$ $d_{prov} > d_{req}$ ∴ deflection is satisfied	Deflection OK
	<u>check for Shear</u> Maximum Shear $V = 131.7\ KN$ As a result of the 550mm chamfer, This Shear is reduced to $131.7 - 0.55 \times 47.04 = 105.83\ KN$ Shear stress, $v = \frac{V}{bd}$ $= \frac{105.83\times10^3}{1000\times292}$ $= 0.362\ N/mm^2$	

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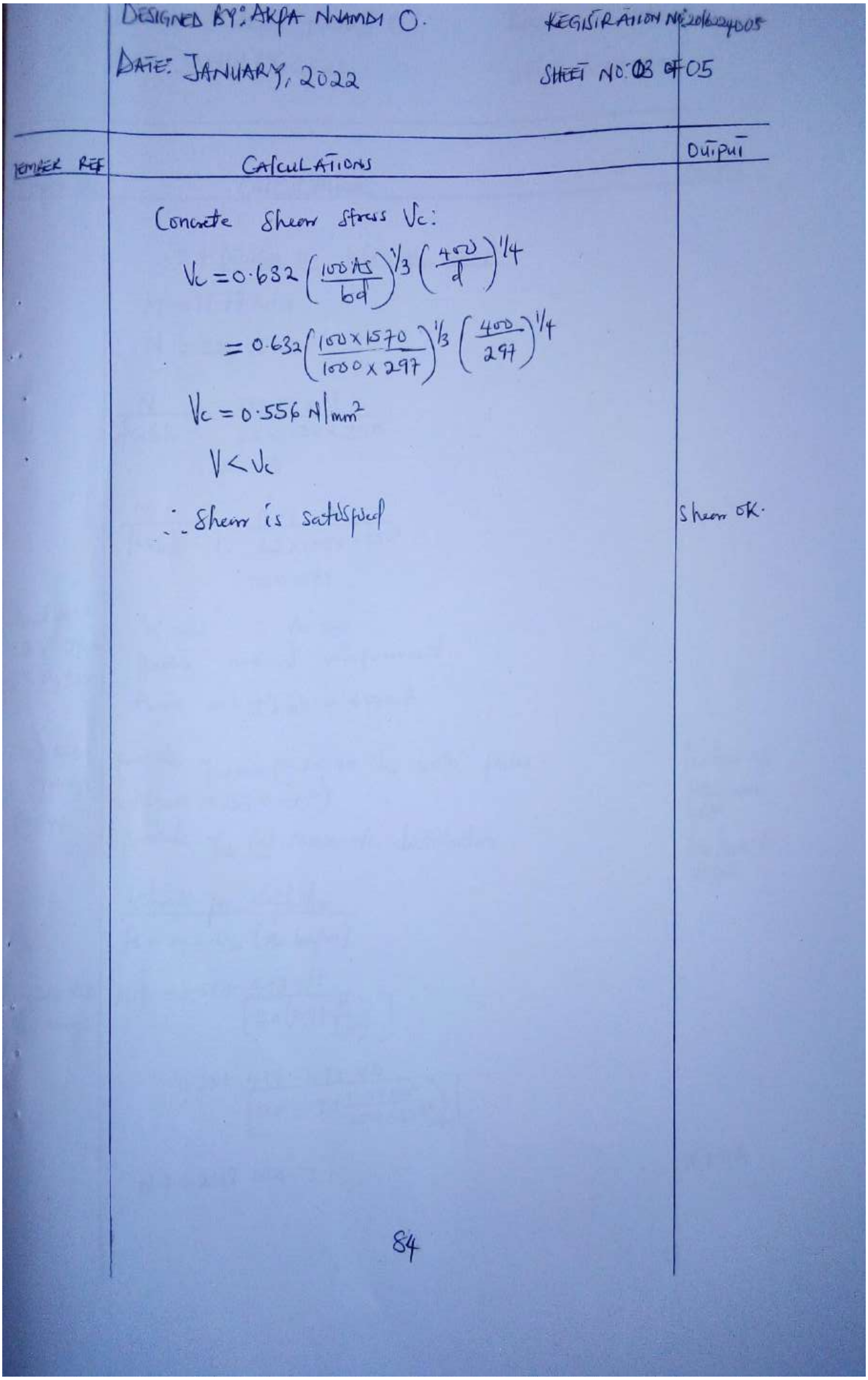

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DATE: JANUARY, 2022 SHEET NO: 03 OF 05

MEMBER REF CALCULATIONS OUTPUT

Concrete Shear stress Vc:

$$V_c = 0.632\left(\frac{100 A_s}{bd}\right)^{1/3}\left(\frac{400}{d}\right)^{1/4}$$

$$= 0.632\left(\frac{100 \times 1570}{1000 \times 297}\right)^{1/3}\left(\frac{400}{297}\right)^{1/4}$$

$$V_c = 0.556\ N/mm^2$$

$$V < V_c$$

∴ Shear is satisfied Shear OK.

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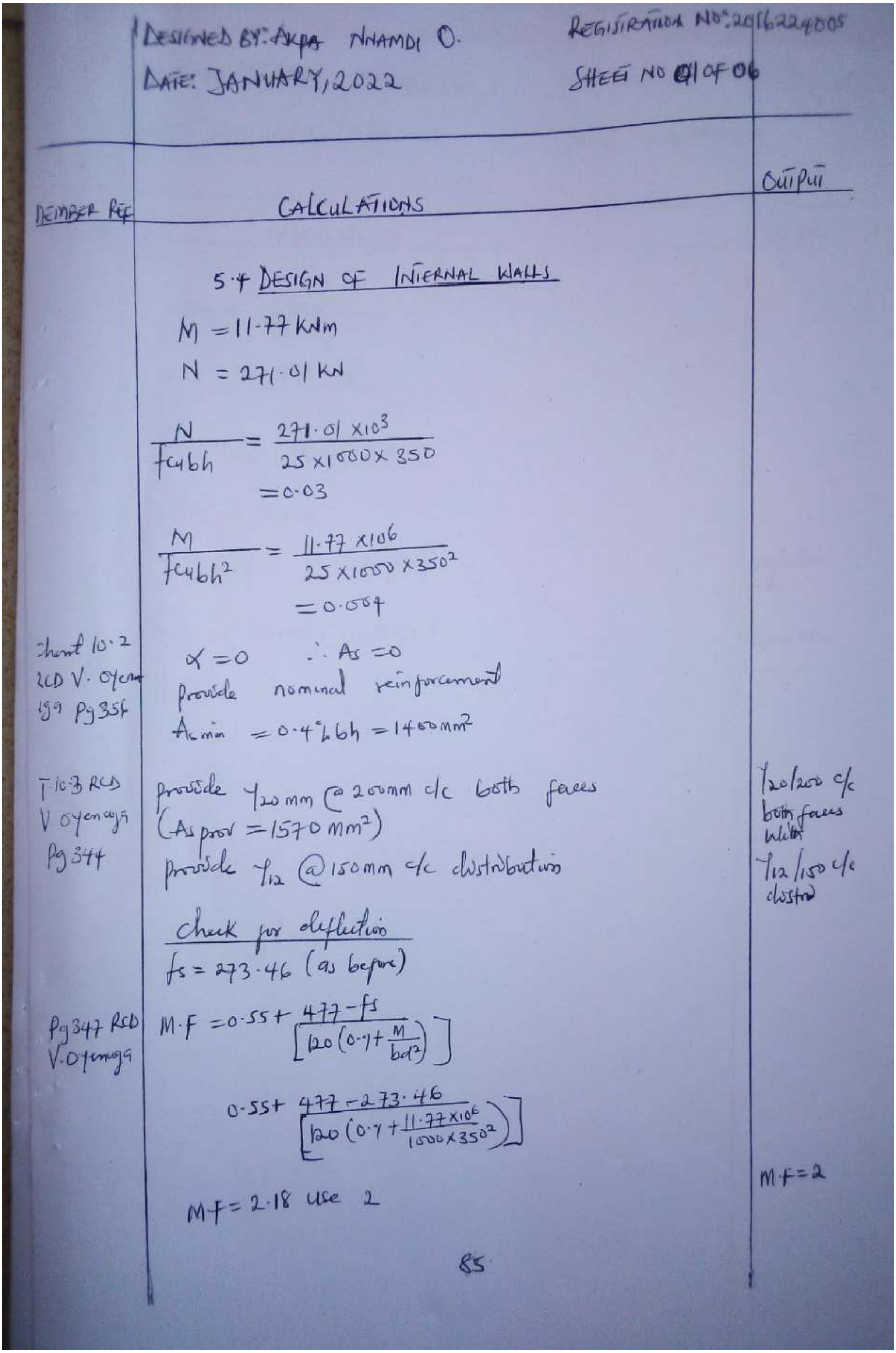

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DATE: JANUARY, 2022

REGISTRATION NO: 2016224005
SHEET NO 01 OF 06

MEMBER REF | CALCULATIONS | OUTPUT

5.4 DESIGN OF INTERNAL WALLS

$M = 11.77\text{ kNm}$

$N = 271.01\text{ kN}$

$$\frac{N}{f_{cu}bh} = \frac{271.01 \times 10^3}{25 \times 1000 \times 350} = 0.03$$

$$\frac{M}{f_{cu}bh^2} = \frac{11.77 \times 10^6}{25 \times 1000 \times 350^2} = 0.004$$

Chart 10.2 RCD V. Oyenuga Pg 354

$\alpha = 0 \quad \therefore A_s = 0$

provide nominal reinforcement

$A_{c\,min} = 0.4\% bh = 1400\text{mm}^2$

T 10.3 RCD V Oyenuga Pg 344

provide Y_{20} mm @ 200mm c/c both faces ($A_{s\,prov} = 1570\text{ mm}^2$)

provide Y_{12} @ 150mm c/c distribution

$Y_{20}/200$ c/c both faces width

$Y_{12}/150$ c/c distrn

Check for deflection

$f_s = 273.46$ (as before)

Pg 347 RCD V. Oyenuga

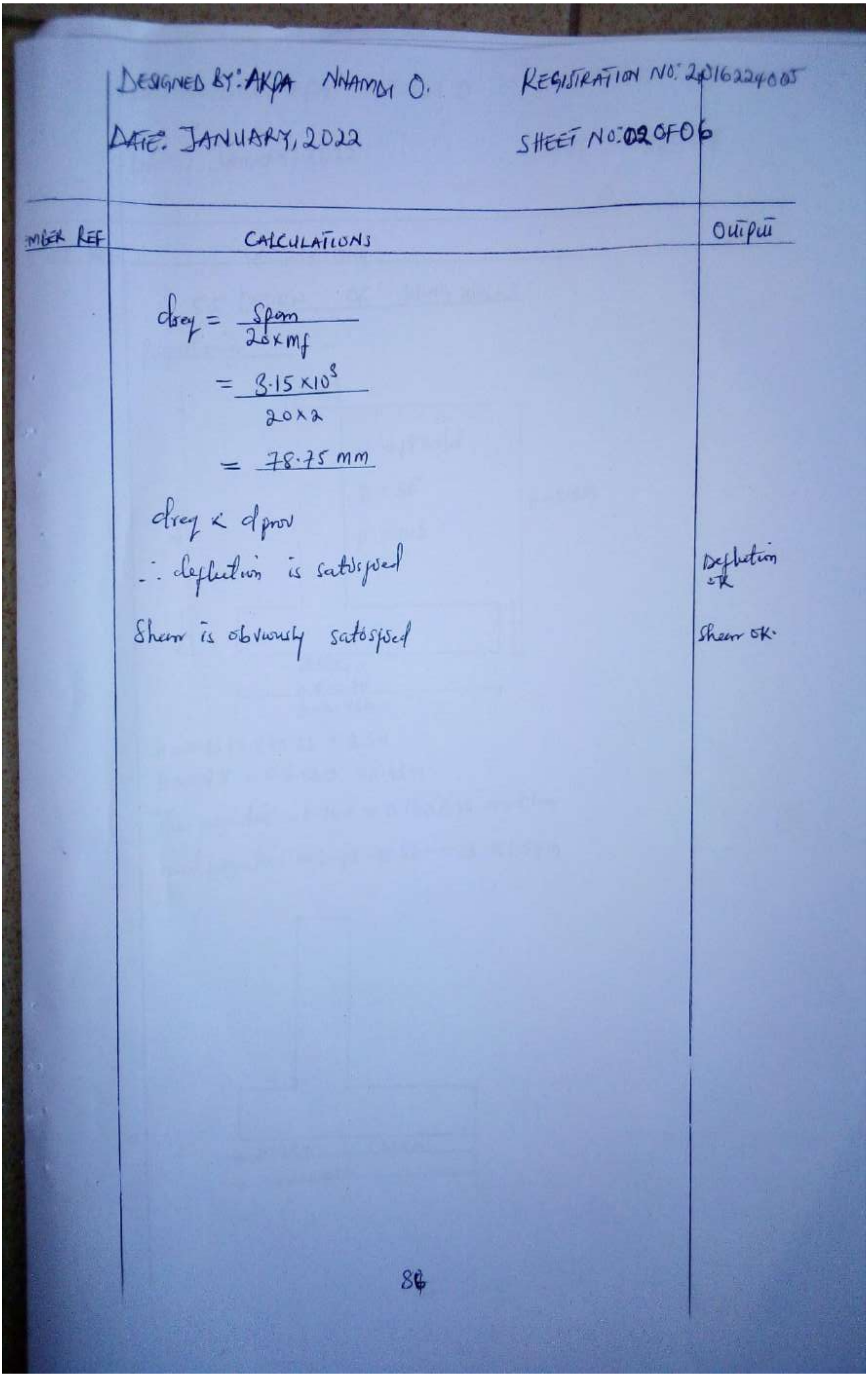
$$M.F = 0.55 + \frac{477 - f_s}{\left[120\left(0.9 + \frac{M}{bd^2}\right)\right]}$$

$$0.55 + \frac{477 - 273.46}{\left[120\left(0.9 + \frac{11.77 \times 10^6}{1000 \times 350^2}\right)\right]}$$

$M.F = 2.18$ use 2

$M.F = 2$

85



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REGISTRATION NO: 2016224005
DATE: JANUARY, 2022
SHEET NO: 02 OF 06

MBER REF	CALCULATIONS	OUTPUT
	$d_{req} = \frac{Span}{20 \times m_f}$	
	$= \frac{3.15 \times 10^3}{20 \times 2}$	
	$= 78.75\ mm$	
	$d_{req} < d_{prov}$	
	∴ deflection is satisfied	Deflection ok
	Shear is obviously satisfied	Shear ok.

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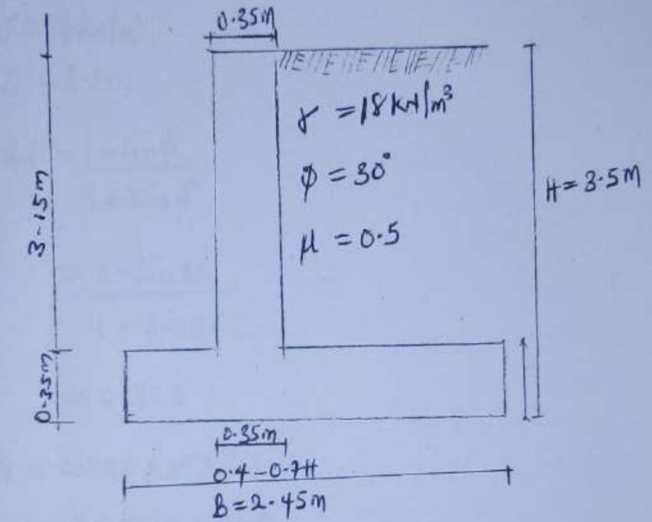
DATE: JANUARY, 2022 SHEET NO: 04 OF 04

ember Ref	CALCULATIONS	OUTPUT

5.5 DESIGN OF WING WALLS

Proportioning

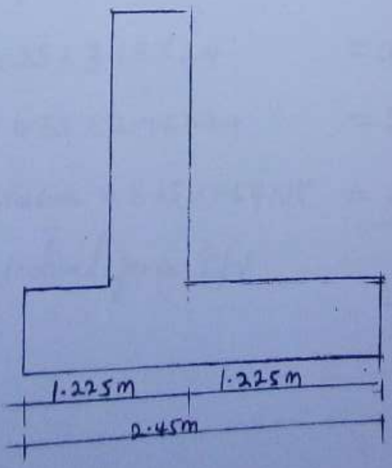


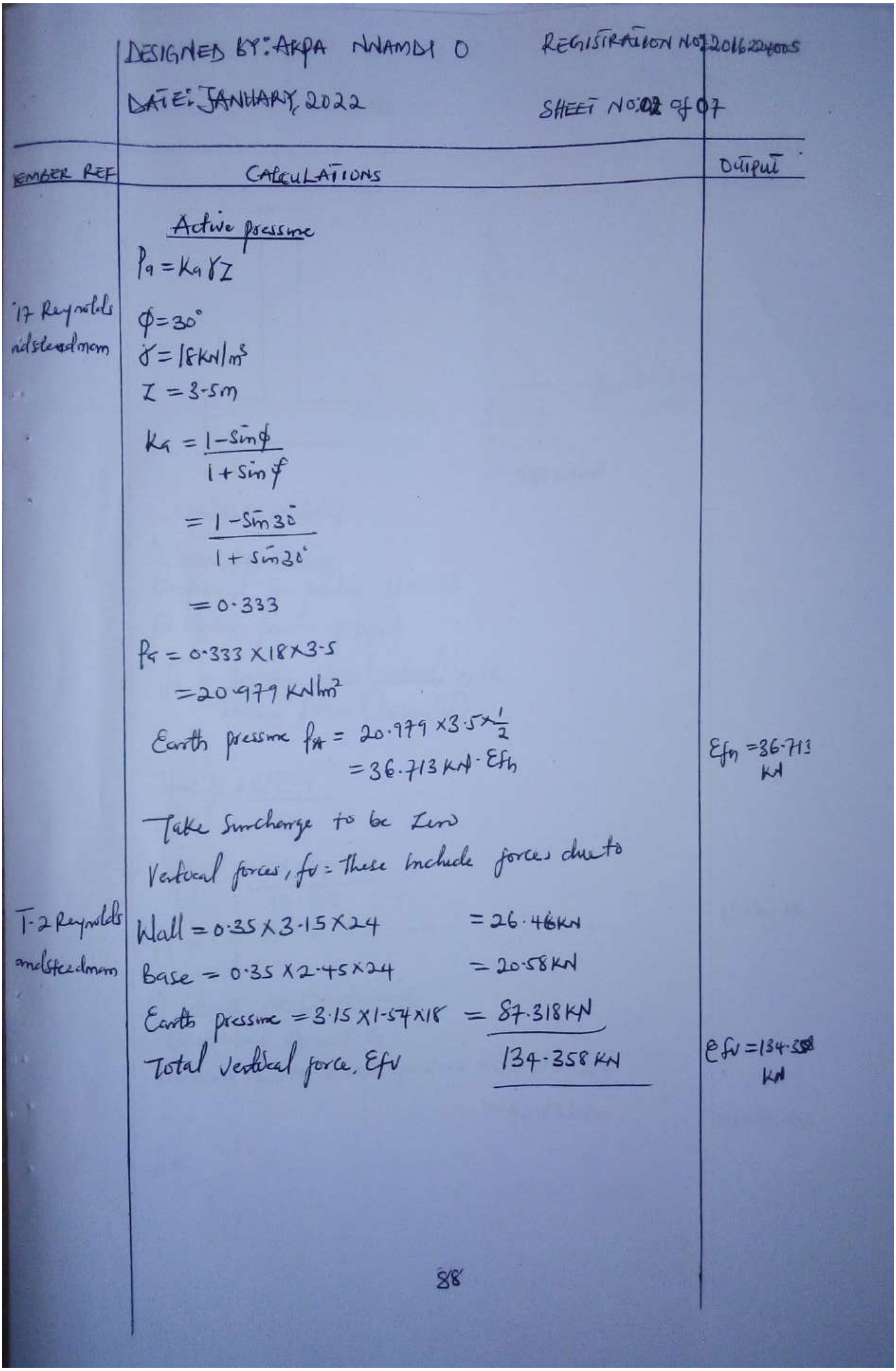
$H = 0.35 + 2.8 + 0.35 = 3.5m$

$B = 0.7H = 0.7 \times 3.5 = 2.45m$

The projection $= 0.16H = 0.16 \times 3.15 = 0.56m$

heel projection $= 2.45 - 0.56 - 0.35 = 1.54m$

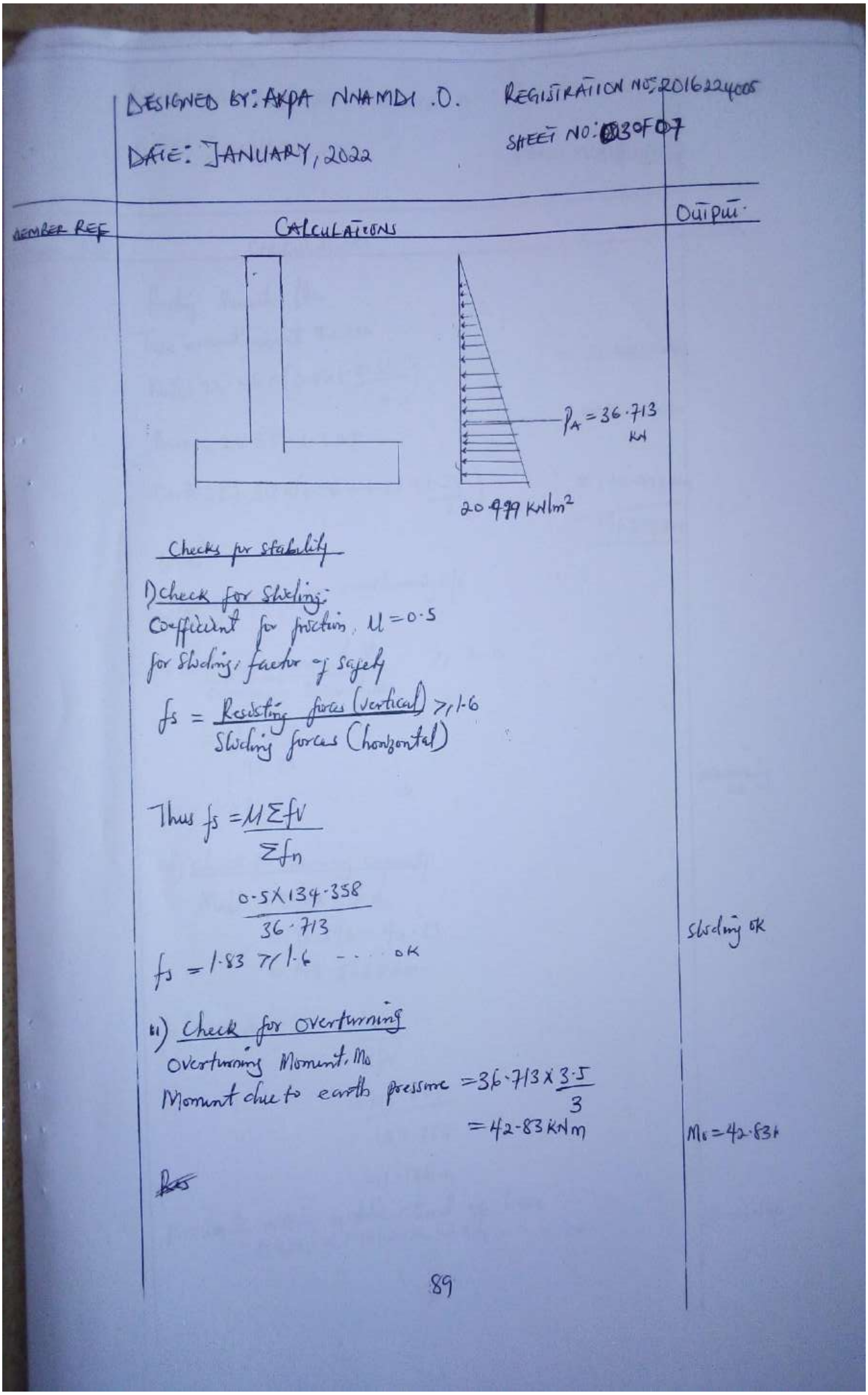




DESIGNED BY: AKPA NWAMDI O REGISTRATION NO: 2016224005

DATE: JANUARY, 2022 SHEET NO: 02 of 07

MEMBER REF	CALCULATIONS	OUTPUT
	Active pressure	
	$P_a = K_a \gamma Z$	
17 Reynolds and steadman	$\phi = 30^\circ$	
	$\gamma = 18 kN/m^3$	
	$Z = 3.5m$	
	$K_a = \frac{1-\sin\phi}{1+\sin\phi}$	
	$= \frac{1-\sin 30^\circ}{1+\sin 30^\circ}$	
	$= 0.333$	
	$P_a = 0.333 \times 18 \times 3.5$	
	$= 20.979 kN/m^2$	
	Earth pressure $P_A = 20.979 \times 3.5 \times \frac{1}{2}$	
	$= 36.713 kN \cdot \Sigma f_h$	$\Sigma f_h = 36.713 kN$
	Take Surcharge to be Zero	
	Vertical forces, f_v = These Include forces due to	
T-2 Reynolds and steedman	Wall $= 0.35 \times 3.15 \times 24 = 26.46 kN$	
	Base $= 0.35 \times 2.45 \times 24 = 20.58 kN$	
	Earth pressure $= 3.15 \times 1.54 \times 18 = 87.318 kN$	
	Total vertical force, Σf_v 134.358 kN	$\Sigma f_v = 134.358 kN$



DESIGNED BY: AKPA NNAMDI .O. REGISTRATION NO: 2016224005

DATE: JANUARY, 2022 SHEET NO: 03 OF 07

MEMBER REF | CALCULATIONS | OUTPUT

$P_A = 36.713$ kN

20.499 kN/m²

Checks for stability

i) Check for Sliding:

Coefficient for friction, $\mu = 0.5$

for Sliding, factor of safety

$$f_s = \frac{\text{Resisting forces (vertical)}}{\text{Sliding forces (horizontal)}} \geq 1.6$$

Thus $f_s = \dfrac{\mu \Sigma f_v}{\Sigma f_h}$

$$\frac{0.5 \times 134.358}{36.713}$$

$f_s = 1.83 \geq 1.6$ ... ok

Sliding ok

ii) Check for overturning

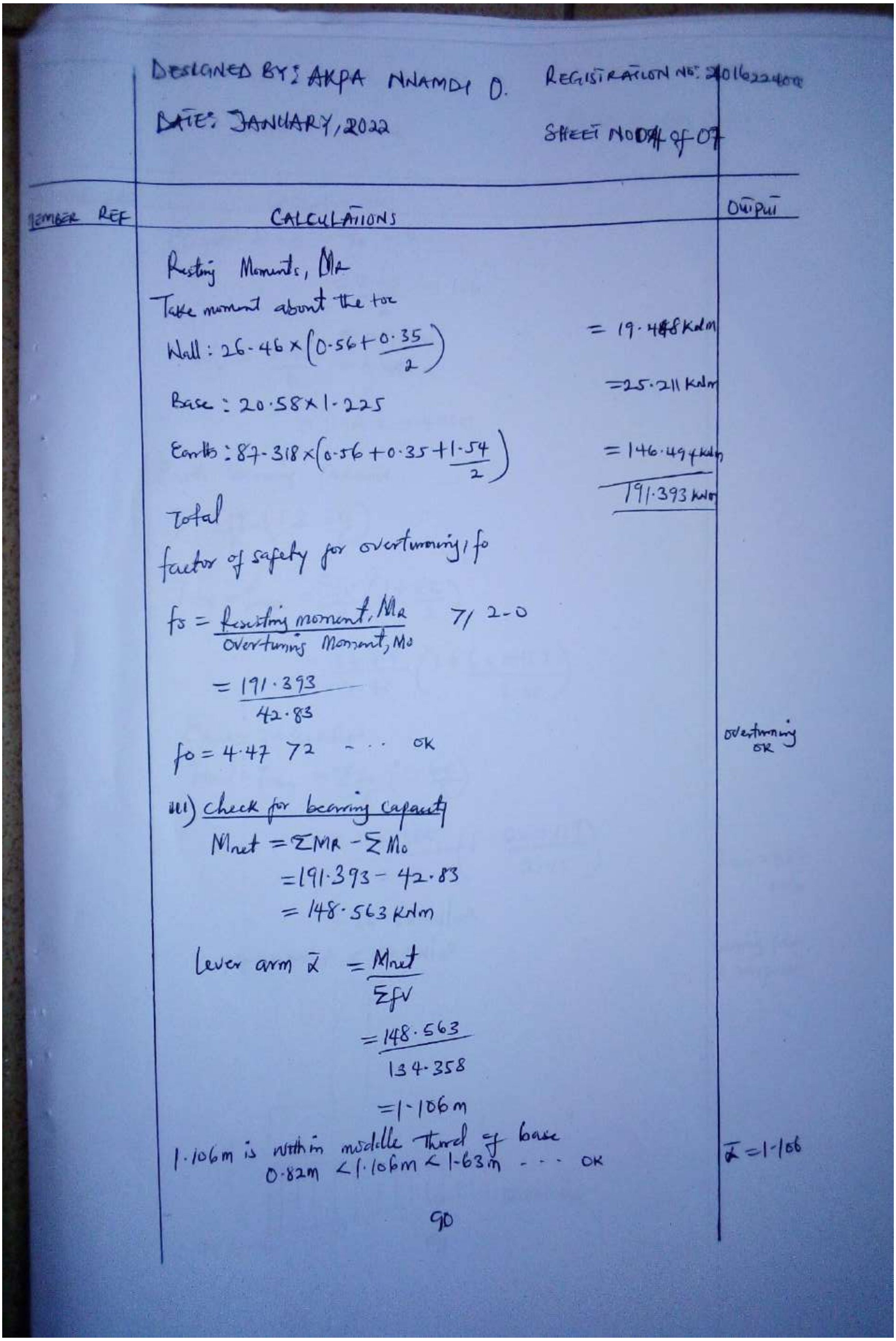
Overturning Moment, M_o

Moment due to earth pressure $= 36.713 \times \dfrac{3.5}{3}$

$= 42.83$ kNm

$M_o = 42.83$k

~~Res~~



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DATE: JANUARY, 2022 SHEET NO 04 of 07

MEMBER REF	CALCULATIONS	OUTPUT
	Resting Moments, M_R	
	Take moment about the toe	
	Wall : $26.46 \times \left(0.56 + \frac{0.35}{2}\right)$	= 19.448 KNm
	Base : 20.58×1.225	= 25.211 KNm
	Earth : $87.318 \times \left(0.56 + 0.35 + \frac{1.54}{2}\right)$	= 146.494 KNm
	Total	191.393 KNm
	factor of safety for overturning, fo	
	$fo = \frac{\text{Resisting moment}, M_R}{\text{Overturning Moment}, M_o} \geq 2.0$	
	$= \frac{191.393}{42.83}$	
	$fo = 4.47 \geq 2$ ... OK	overturning OK
	iii) <u>check for bearing capacity</u>	
	$M_{net} = \Sigma M_R - \Sigma M_o$	
	$= 191.393 - 42.83$	
	$= 148.563$ KNm	
	Lever arm $\bar{x} = \frac{M_{net}}{\Sigma F_V}$	
	$= \frac{148.563}{134.358}$	
	$= 1.106$ m	
	1.106m is within middle third of base $0.82m < 1.106m < 1.63m$ ... OK	$\bar{x} = 1.106$

90

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DATE: JANUARY, 2022 SHEET NO 05 OF 07

MEMBER REF	CALCULATIONS	OUTPUT

Eccentricity, $e = B/2 - \bar{x}$

$$= \frac{2.45}{2} - 1.106$$

$$= 0.119m$$

$$b/6 = \frac{2.45}{6} = 0.408\ m$$

$$0.119m < 0.408m$$

Earth bearing pressure

$$q = \frac{\Sigma fv}{B}\left(1 \pm \frac{6e}{B}\right)$$

$$q_{toe} = q_{max} = \frac{\Sigma fv}{B}\left(1 + \frac{6e}{B}\right)$$

$$= \frac{134.358}{2.45}\left(1 + \frac{6 \times 0.119}{2.45}\right)$$

$$\varepsilon_{max} = 70.82kN/m^2$$

$$q_{heel} - q_{min} = \frac{\Sigma fv}{B}\left(1 - \frac{6e}{B}\right)$$

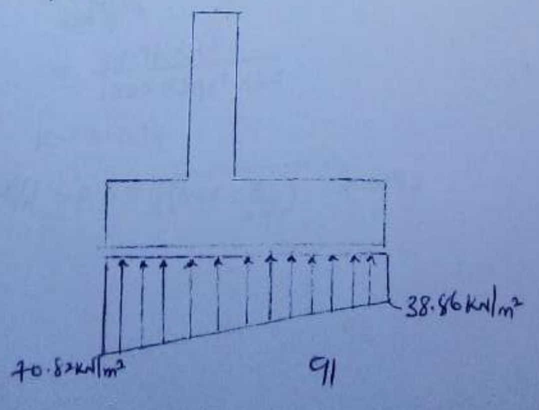
$$= \frac{134.358}{2.45}\left(1 - \frac{6 \times 0.119}{2.45}\right)$$

$$= 38.86kN/m^2$$

$$70.82\ kN/m^2 < 180\ kN/m^2$$

$q_{min} = 38$
kN/m

bearing press
is adequat



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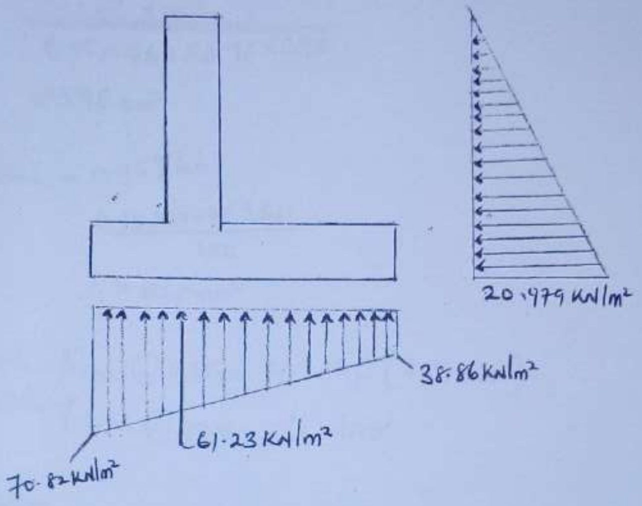
DATE: JANUARY, 2022 SHEET NO 06 of 07

MEMBER REF | CALCULATIONS | OUTPUT

5.6 DESIGN OF WALL



Bending Reinforcement
Wall

Horizontal moment $= 36.713\left(0.175 + \frac{3.15}{3}\right)$
$= 44.97$ KNm

Horizontal moment (U.L.S) $= 44.97 \times 1.6$
$= 71.96$ KNm

Horizontal moment = 71.9 KNm (U.L.S)

$h = 350$ mm
$d = 350 - 50 - 10 = 290$ mm

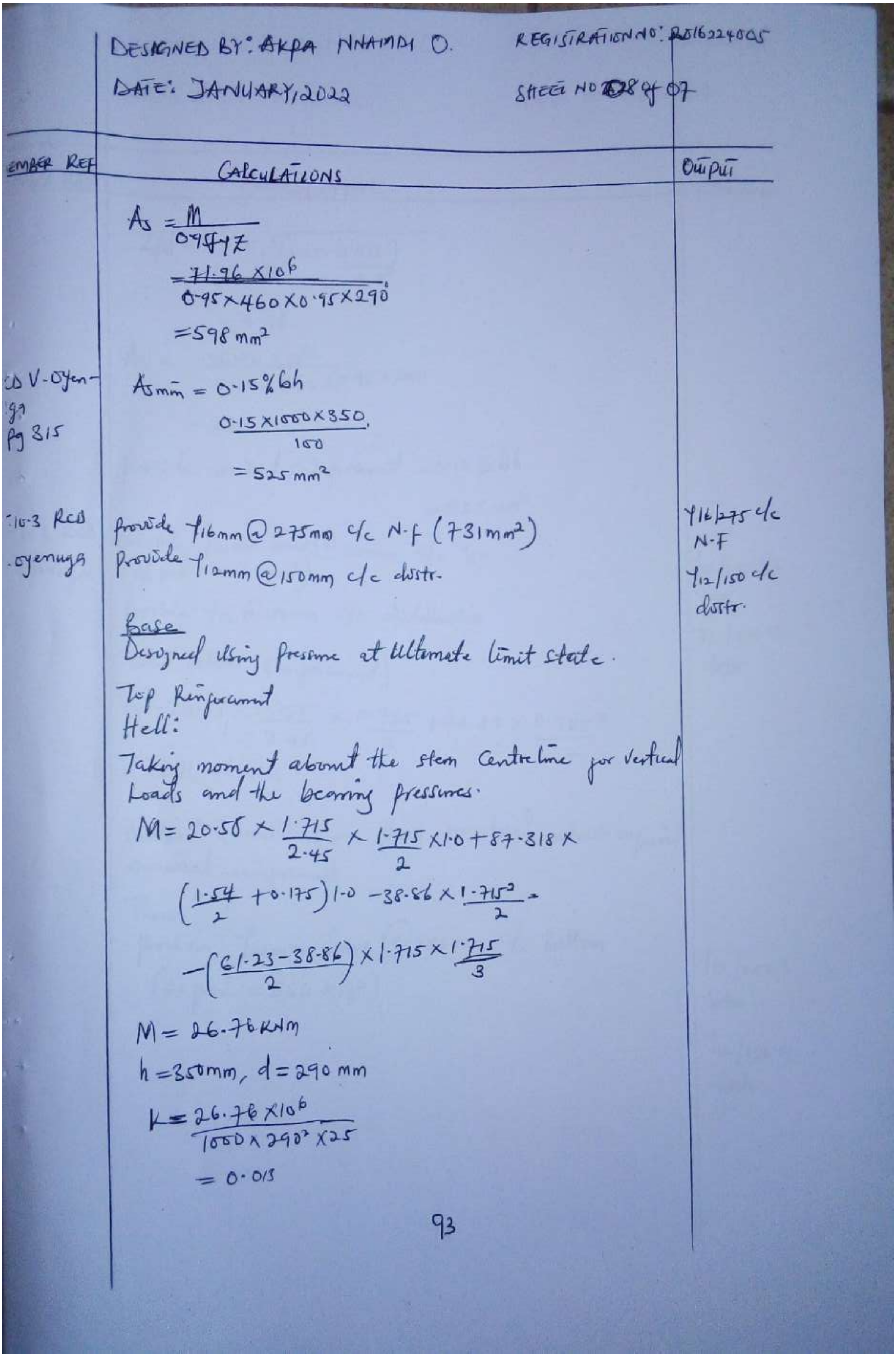
$K = \frac{M}{bd^2 f_{cu}}$

$= \frac{71.96 \times 10^6}{1000 \times 290^2 \times 25}$

$K = 0.034$

$Z/d = 0.5 + \sqrt{\left(0.25 - \frac{K}{0.9}\right)} = 0.95$

92



DESIGNED BY: AKPA NNAMDI O. REGISTRATION NO: 2016224005

DATE: JANUARY, 2022 SHEET NO 08 of 07

MEMBER REF	CALCULATIONS	OUTPUT
	$A_s = \frac{M}{0.95 f_y Z}$	
	$= \frac{71.96 \times 10^6}{0.95 \times 460 \times 0.95 \times 290}$	
	$= 598\ mm^2$	
RCD V-Oyenuga pg 315	$A_{s\,min} = 0.15\%\,bh$	
	$\frac{0.15 \times 1000 \times 350}{100}$	
	$= 525\ mm^2$	
10.3 RCD Oyenuga	provide Y16mm @ 275mm c/c N.F ($731 mm^2$)	Y16/275 c/c N.F
	Provide Y12mm @ 150mm c/c distr.	Y12/150 c/c distr.

Base

Designed using pressure at Ultimate limit state.

Top Reinforcement

Heel:

Taking moment about the stem Centreline for Vertical Loads and the bearing pressures.

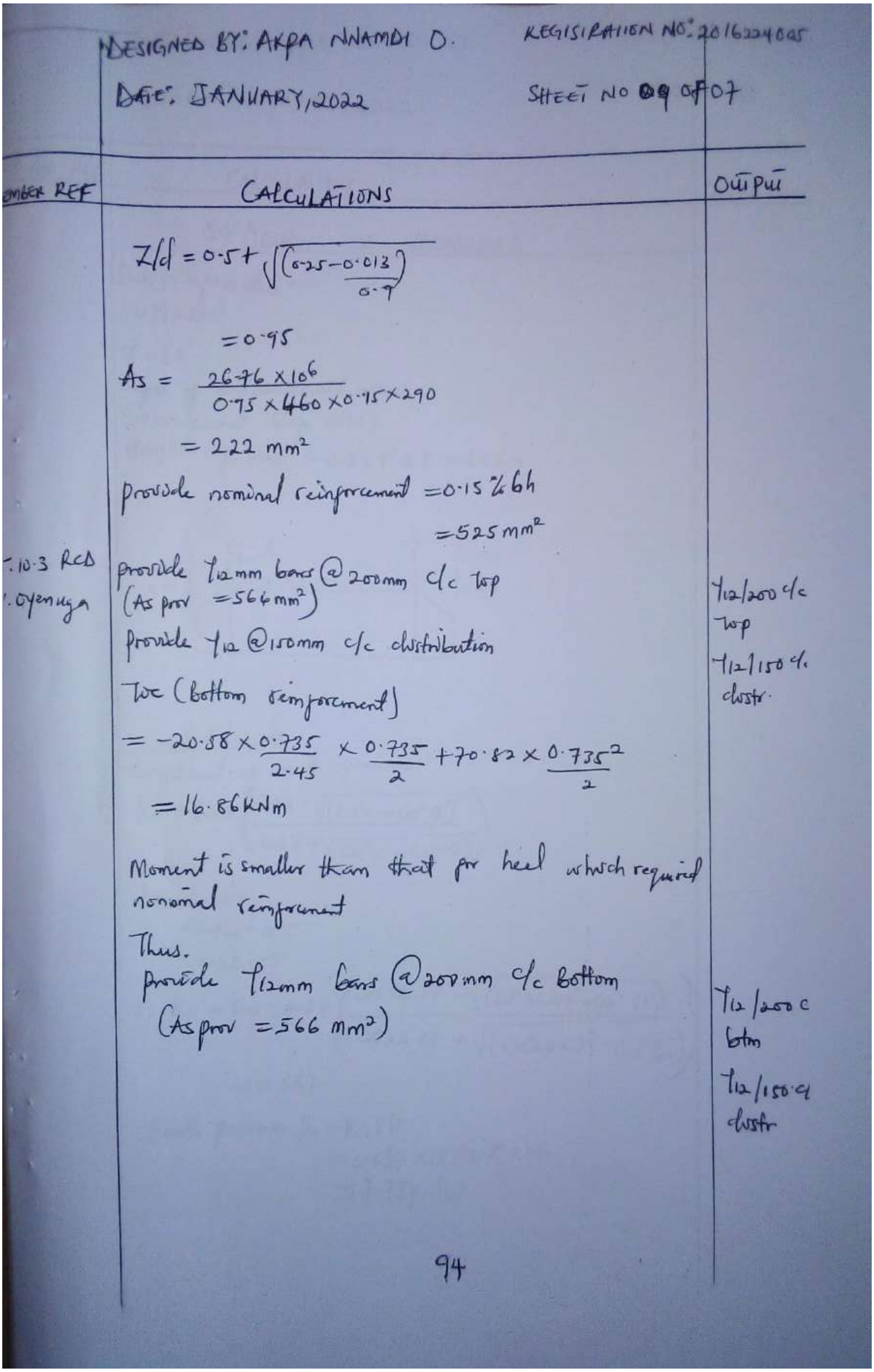
$$M = 20.58 \times \frac{1.715}{2.45} \times \frac{1.715}{2} \times 1.0 + 87.318 \times \left(\frac{1.54}{2} + 0.175\right) 1.0 - 38.86 \times \frac{1.715^2}{2} - \left(\frac{61.23 - 38.86}{2}\right) \times 1.715 \times \frac{1.715}{3}$$

$M = 26.76\ KNm$

$h = 350mm,\ d = 290\ mm$

$$K = \frac{26.76 \times 10^6}{1000 \times 290^2 \times 25}$$

$= 0.013$



DESIGNED BY: AKPA NNAMDI O. REGISTRATION NO: 2016224005

DATE: JANUARY, 2022 SHEET NO 09 OF 07

MBER REF | CALCULATIONS | OUTPUT

$Z/d = 0.5 + \sqrt{\left(0.25 - \frac{0.013}{0.9}\right)}$

$= 0.95$

$A_s = \frac{26.76 \times 10^6}{0.95 \times 460 \times 0.95 \times 290}$

$= 222\ mm^2$

provide nominal reinforcement $= 0.15\%bh$

$= 525\ mm^2$

.10.3 RCD
.Oyenuga

provide Y12mm bars @ 200mm c/c top
(A_s prov $= 564\ mm^2$)

provide Y12 @150mm c/c distribution

Y12/200 c/c top

Y12/150 c/c distr.

Toe (bottom reinforcement)

$= -20.58 \times \frac{0.735}{2.45} \times \frac{0.735}{2} + 70.82 \times \frac{0.735^2}{2}$

$= 16.86\ KNm$

Moment is smaller than that for heel which required nominal reinforcement

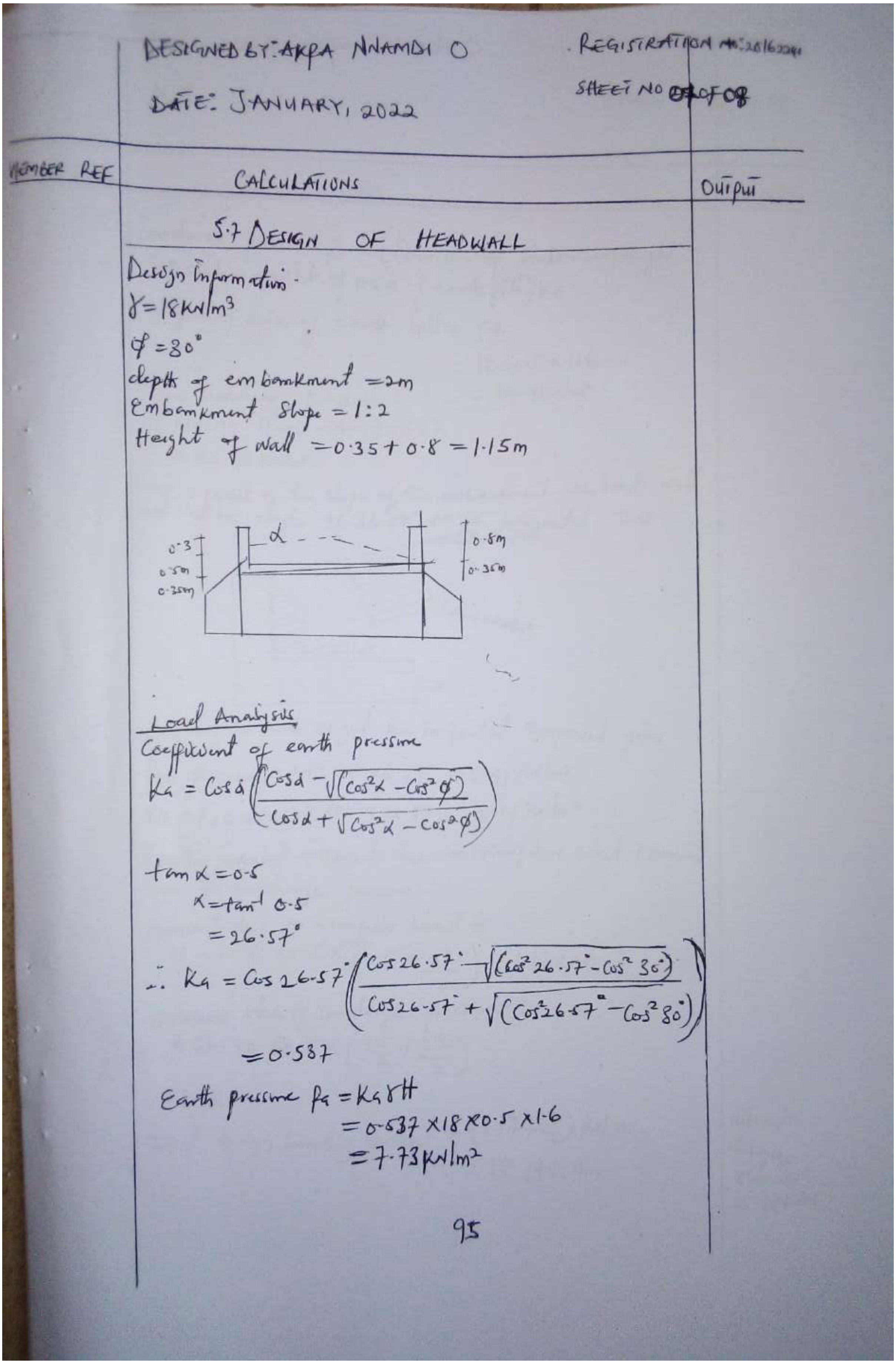
Thus.

provide Y12mm bars @200mm c/c Bottom
(A_s prov $= 566\ mm^2$)

Y12/200 c btm

Y12/150 c/c distr

94



DESIGNED BY: AKPA NNAMDI O

REGISTRATION No: 20162241

DATE: JANUARY, 2022

SHEET NO 01 OF 08

MEMBER REF	CALCULATIONS	OUTPUT

5.7 DESIGN OF HEADWALL

Design information -

$\gamma = 18 kN/m^3$

$\phi = 30°$

depth of embankment = 2m

Embankment Slope = 1:2

Height of wall = 0.35 + 0.8 = 1.15m

Load Analysis

Coefficient of earth pressure

$$K_a = \cos\alpha \left(\frac{\cos\alpha - \sqrt{(\cos^2\alpha - \cos^2\phi)}}{\cos\alpha + \sqrt{\cos^2\alpha - \cos^2\phi}} \right)$$

$\tan\alpha = 0.5$

$\alpha = \tan^{-1} 0.5$

$= 26.57°$

$$\therefore K_a = \cos 26.57° \left(\frac{\cos 26.57° - \sqrt{(\cos^2 26.57° - \cos^2 30°)}}{\cos 26.57° + \sqrt{(\cos^2 26.57° - \cos^2 30°)}} \right)$$

$= 0.537$

Earth pressure $p_a = K_a \gamma H$

$= 0.537 \times 18 \times 0.5 \times 1.6$

$= 7.73 kN/m^2$

95

DESIGNED BY: ARPA NNAMDI O REGISTRATION NO: 20162246

DATE: JANUARY, 2022 SHEET NO 02 OF 08

MEMBER REF	CALCULATIONS	OUTPUT

Surcharge pressure, p_s = (Load on top slab – selfweight of Top slab – weight of 0.5m of earth fill) K_a

Weight of 0.5m of earth fill = γz

$= 18 \times 0.5 \times 1.6$

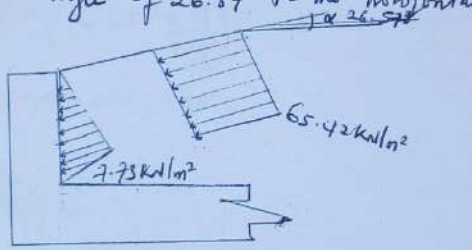
$= 14.4 KN/m^2$

Thus surcharge pressure

$(149.99 - 11.76 - 14.4) 0.537$

$= 65.42 KN/m^2$

As a result of the slope of the embankment. The loads wall act at an angle of 26.57° to the horizontal. Thus



Resolving the forces to get the horizontal component gives

$P_{ah} - P_a \cos\alpha = 7.73 \cos 26.57° = 6.91 KN/m^2$

$P_{sh} = P_s \cos\alpha = 65.42 \cos 26.57 = 58.14 KN/m^2$

Bending moment = Moment due to triangular load + moment due to surcharge pressure.

Moment due to triangular load =

$\frac{1}{2} \times 6.91 \times 0.5 \times \left(0.5 + \frac{0.35}{2}\right) = 1.17 KNm$

Moment due to surcharge pressure

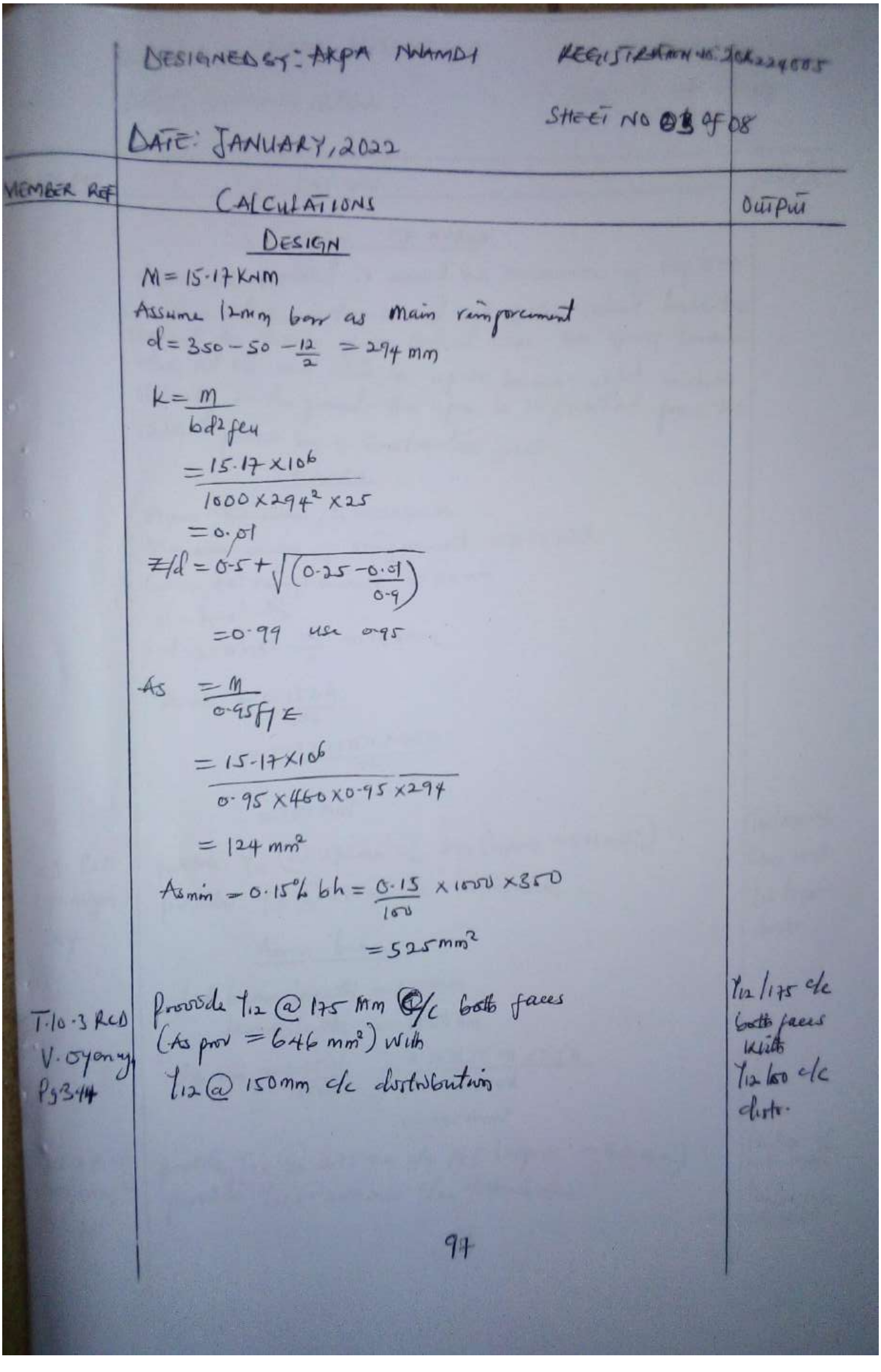
$= 65.42 \times 0.5 \times \left(\frac{0.5}{2} + \frac{0.35}{2}\right)$

$= 14 KNm$

Total design bending moment $= (1.17 + 14) KNm$

$= 15.17 KNm$

ultimate design moment 15.17KNm



DESIGNED BY: AKPA NNAMDI REGISTRATION NO: 20K224005

SHEET NO 03 OF 08

DATE: JANUARY, 2022

MEMBER REF	CALCULATIONS	OUTPUT

DESIGN

$M = 15.17\,KNm$

Assume 12mm bar as main reinforcement

$d = 350 - 50 - \frac{12}{2} = 294\,mm$

$K = \frac{M}{bd^2 f_{cu}}$

$= \frac{15.17 \times 10^6}{1000 \times 294^2 \times 25}$

$= 0.01$

$Z/d = 0.5 + \sqrt{\left(0.25 - \frac{0.01}{0.9}\right)}$

$= 0.99$ use 0.95

$A_s = \frac{M}{0.95 f_y Z}$

$= \frac{15.17 \times 10^6}{0.95 \times 460 \times 0.95 \times 294}$

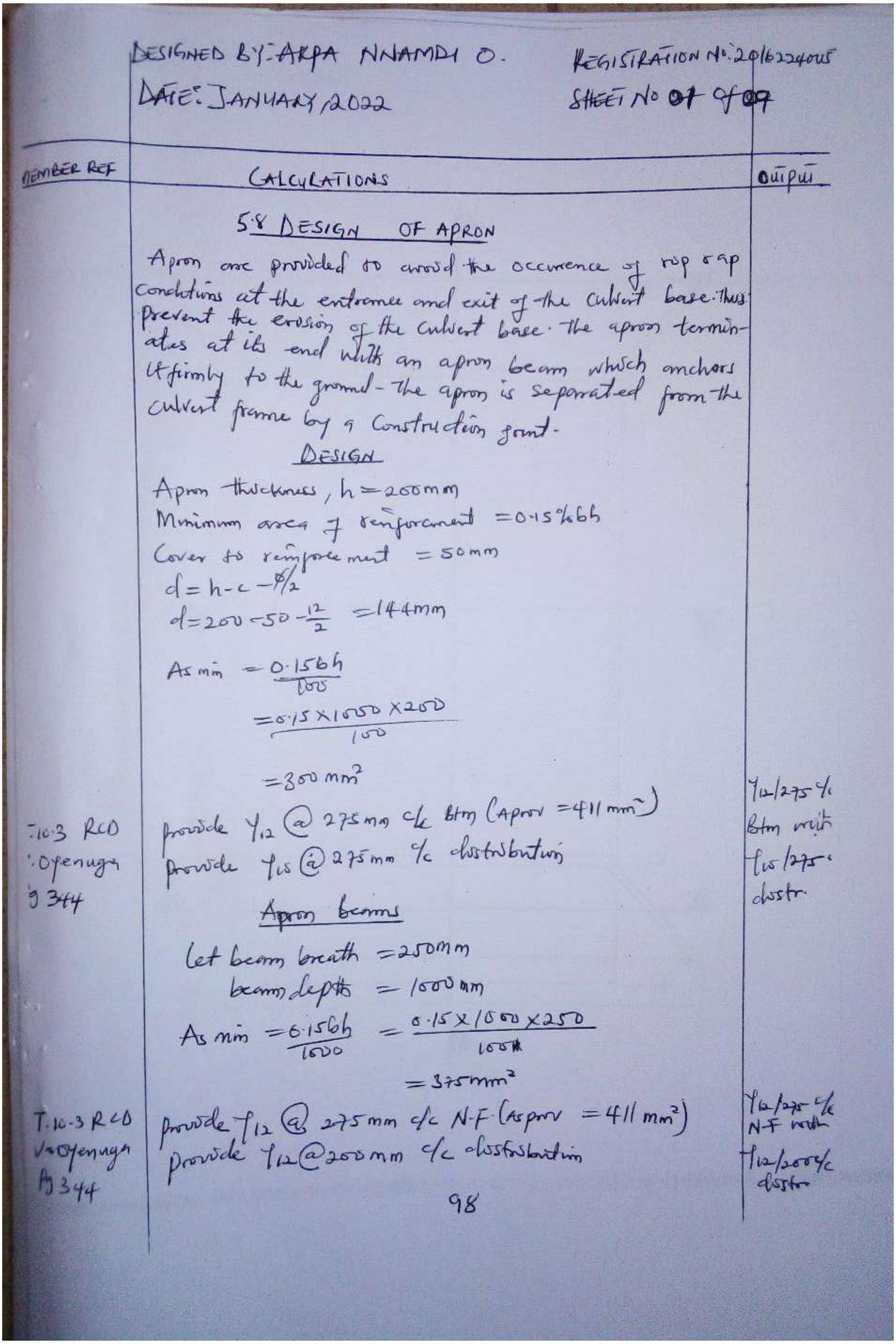
$= 124\,mm^2$

$A_{s\,min} = 0.15\%\,bh = \frac{0.15}{100} \times 1000 \times 350$

$= 525\,mm^2$

MEMBER REF	CALCULATIONS	OUTPUT
T.10.3 RCD V. Oyenuga Pg 3.44	Provide Y_{12} @ 175 mm c/c both faces (A_s prov $= 646\,mm^2$) with Y_{12} @ 150mm c/c distribution	Y_{12}/175 c/c both faces with Y_{12}/150 c/c distr.

97



DESIGNED BY:- AKPA NNAMDI O.　　REGISTRATION No: 2016224005

DATE: JANUARY, 2022　　SHEET No 01 of 09

MEMBER REF | CALCULATIONS | OUTPUT

5.8 DESIGN OF APRON

Apron are provided to avoid the occurrence of rip rap conditions at the entrance and exit of the culvert base. thus prevent the erosion of the culvert base. The apron terminates at its end with an apron beam which anchors it firmly to the ground. The apron is separated from the culvert frame by a Construction joint.

DESIGN

Apron thickness, $h = 200mm$

Minimum area of reinforcement $= 0.15\% bh$

Cover to reinforcement $= 50mm$

$d = h - c - \phi/2$

$d = 200 - 50 - \frac{12}{2} = 144mm$

$As_{min} = \frac{0.15bh}{100}$

$= \frac{0.15 \times 1000 \times 200}{100}$

$= 300 mm^2$

T.10.3 RCD
V.Oyenuga
Pg 344

provide Y_{12} @ 275mm c/c Btm ($A_{prov} = 411 mm^2$)

provide Y_{10} @ 275mm c/c distribution

$Y_{12}/275$ c/c Btm with $Y_{10}/275$ c/c distr.

Apron beams

Let beam breath $= 250mm$

beam depth $= 1000mm$

$As_{min} = \frac{0.15bh}{1000} = \frac{0.15 \times 1000 \times 250}{100}$

$= 375mm^2$

T.10.3 RCD
V.Oyenuga
Pg 344

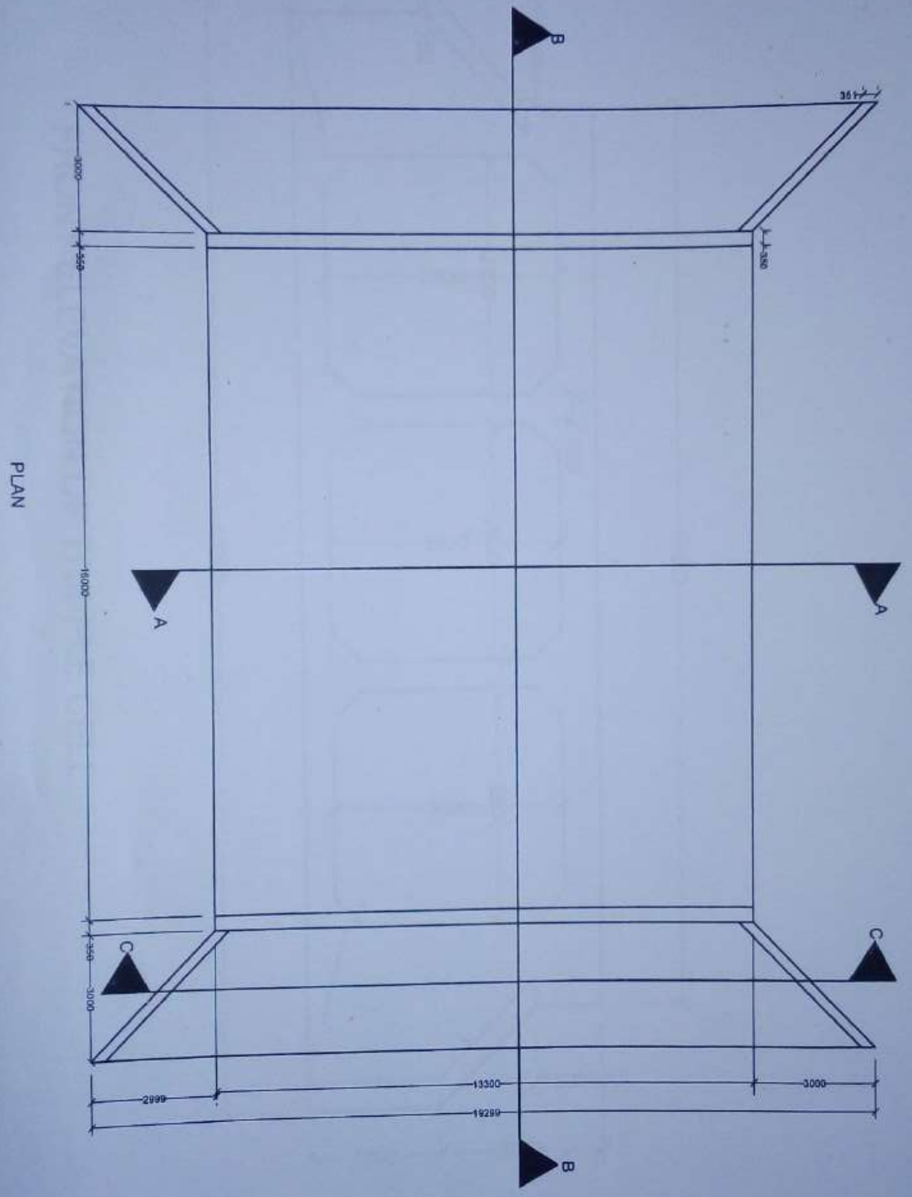
provide Y_{12} @ 275mm c/c N.F ($As_{prov} = 411 mm^2$)

provide Y_{12} @ 200mm c/c distribution

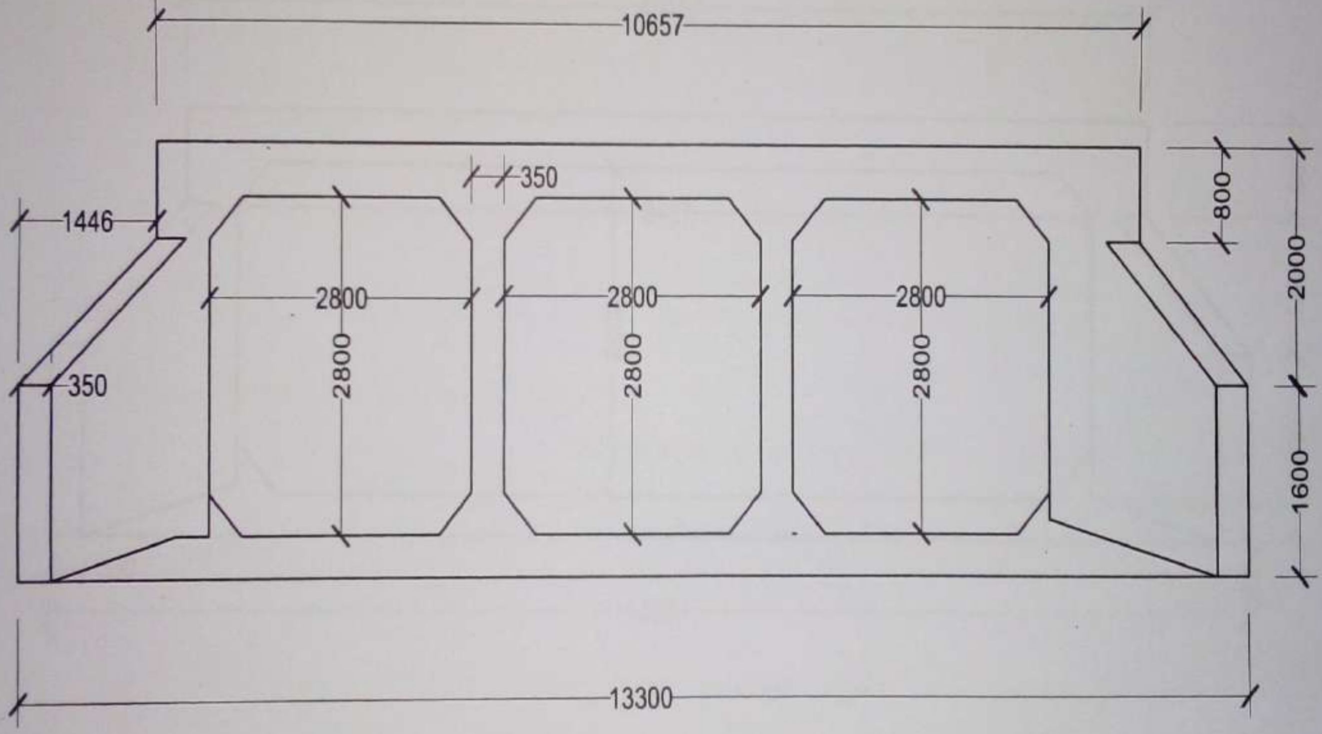
$Y_{12}/275$ c/c N-F with $Y_{12}/200$ c/c distr.

98

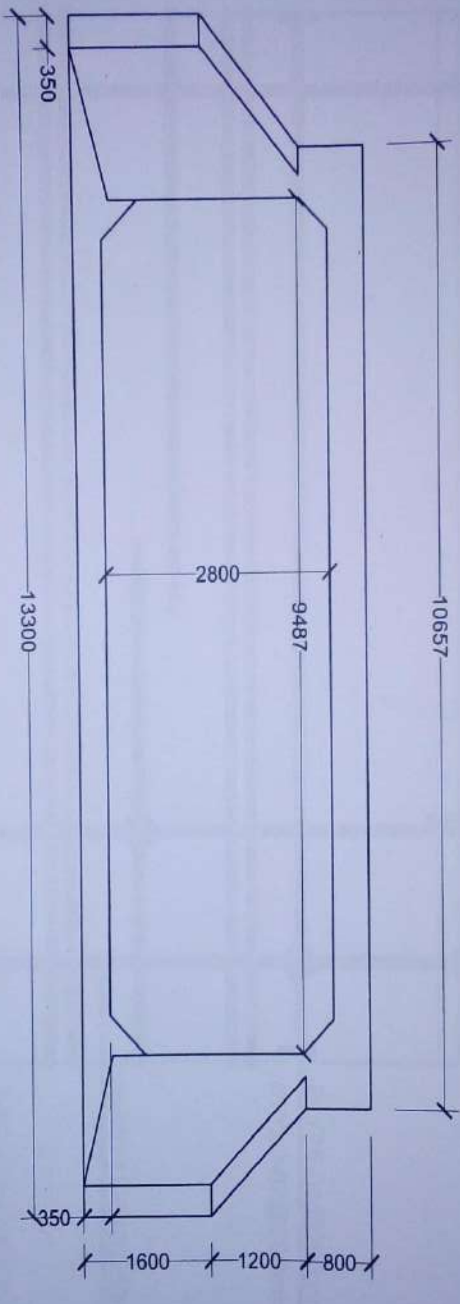
DETAILING



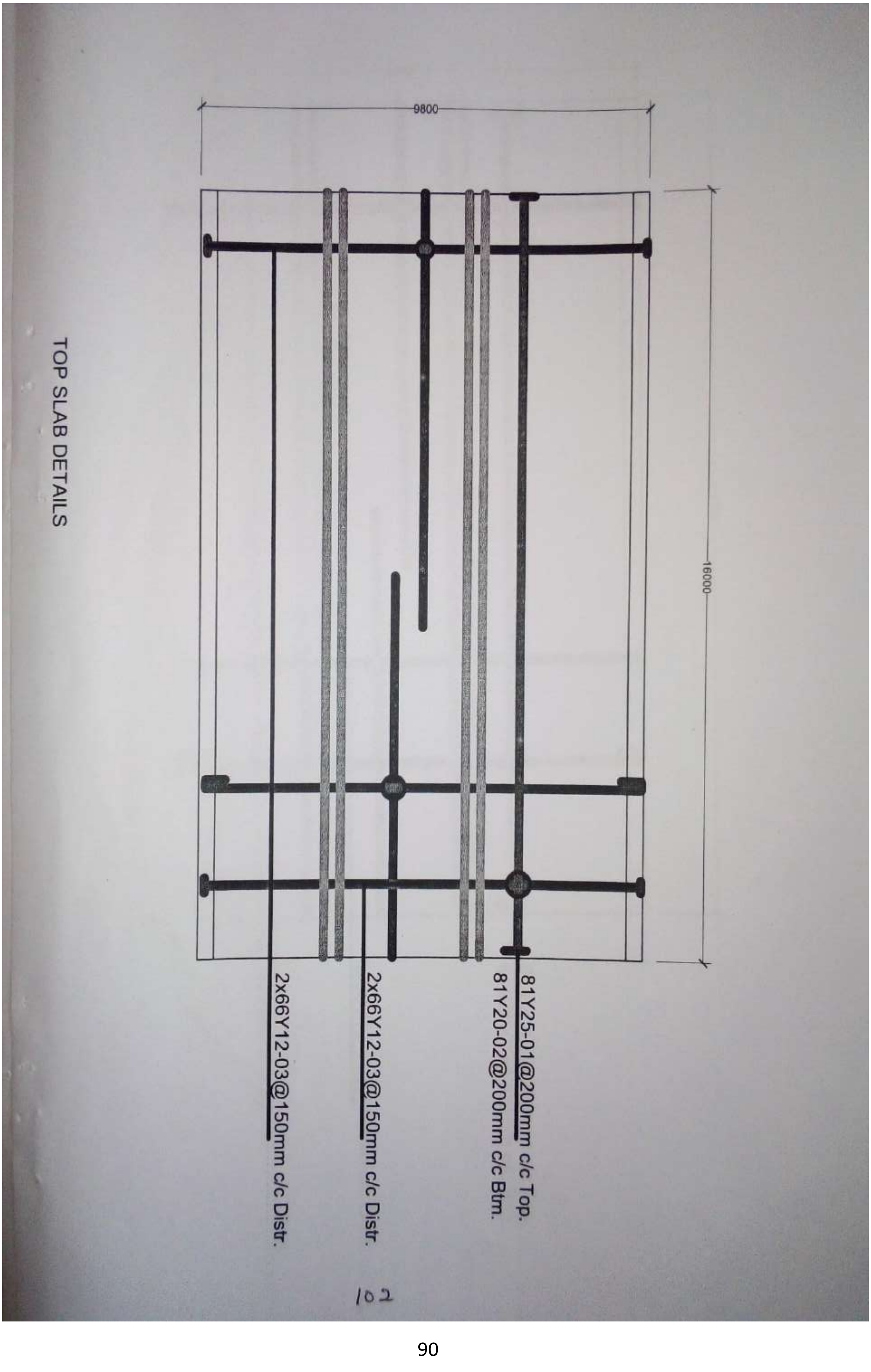
99

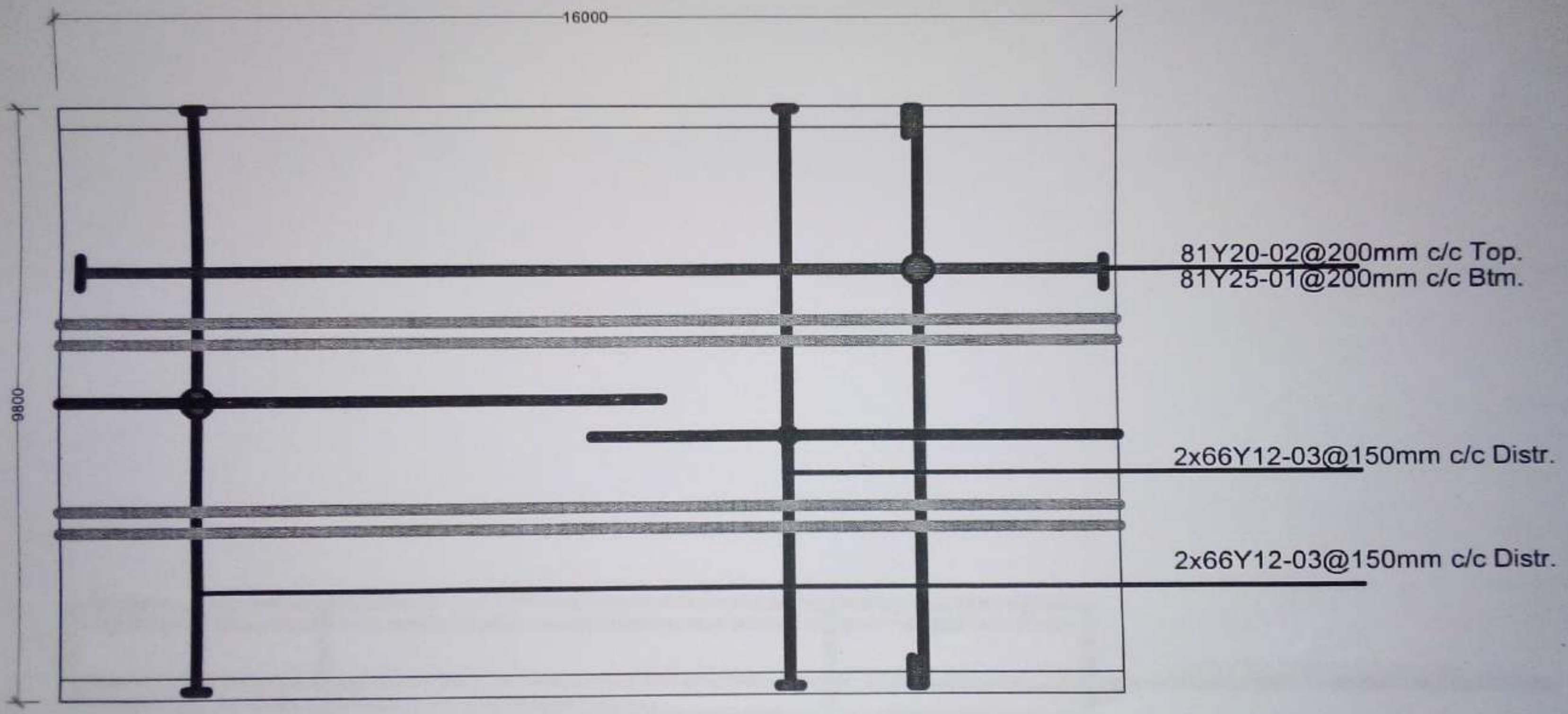


FRONT ELEVATION OF TRIPPLE CELL

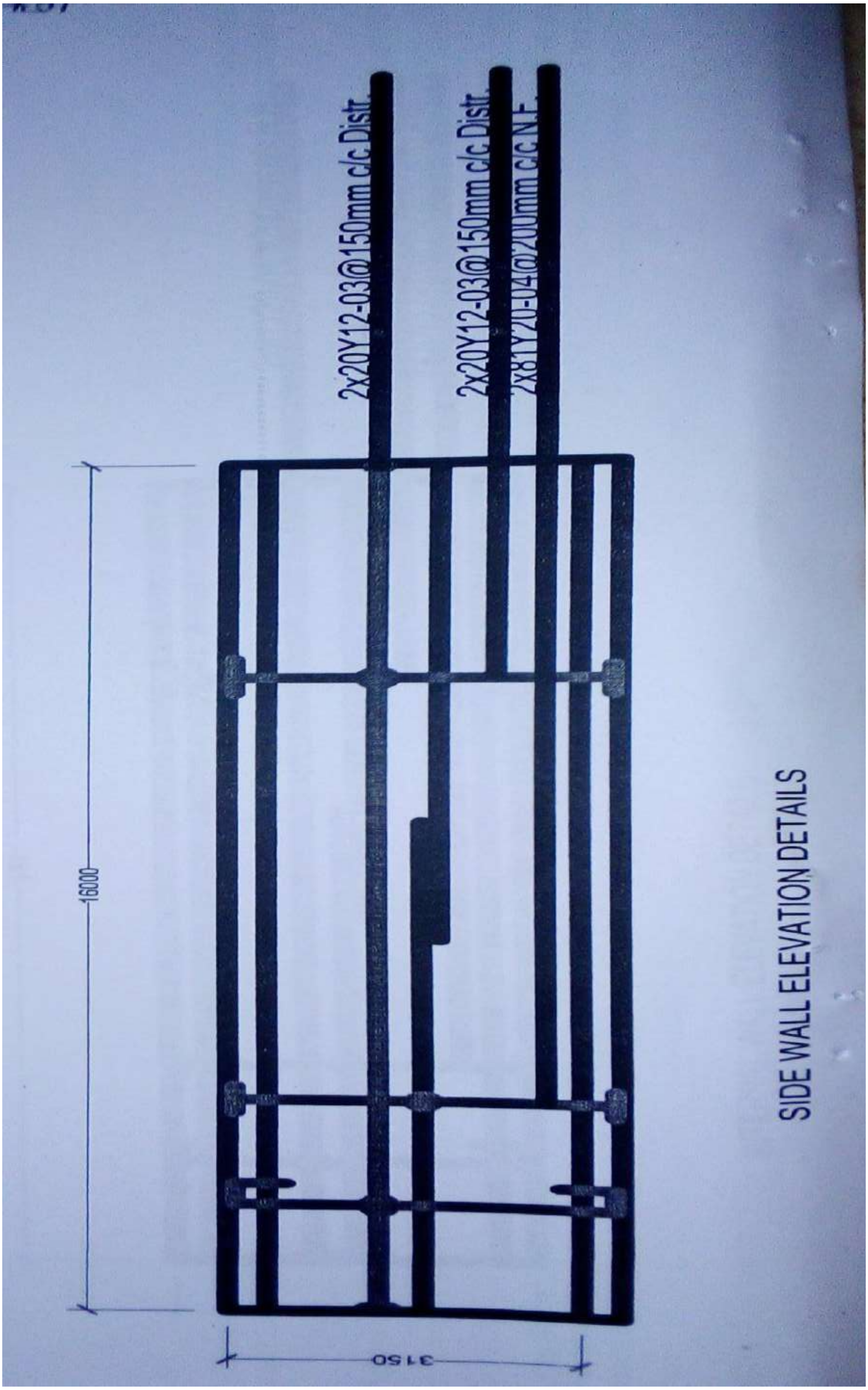


FRONT ELEVATION OF SINGLE CEL

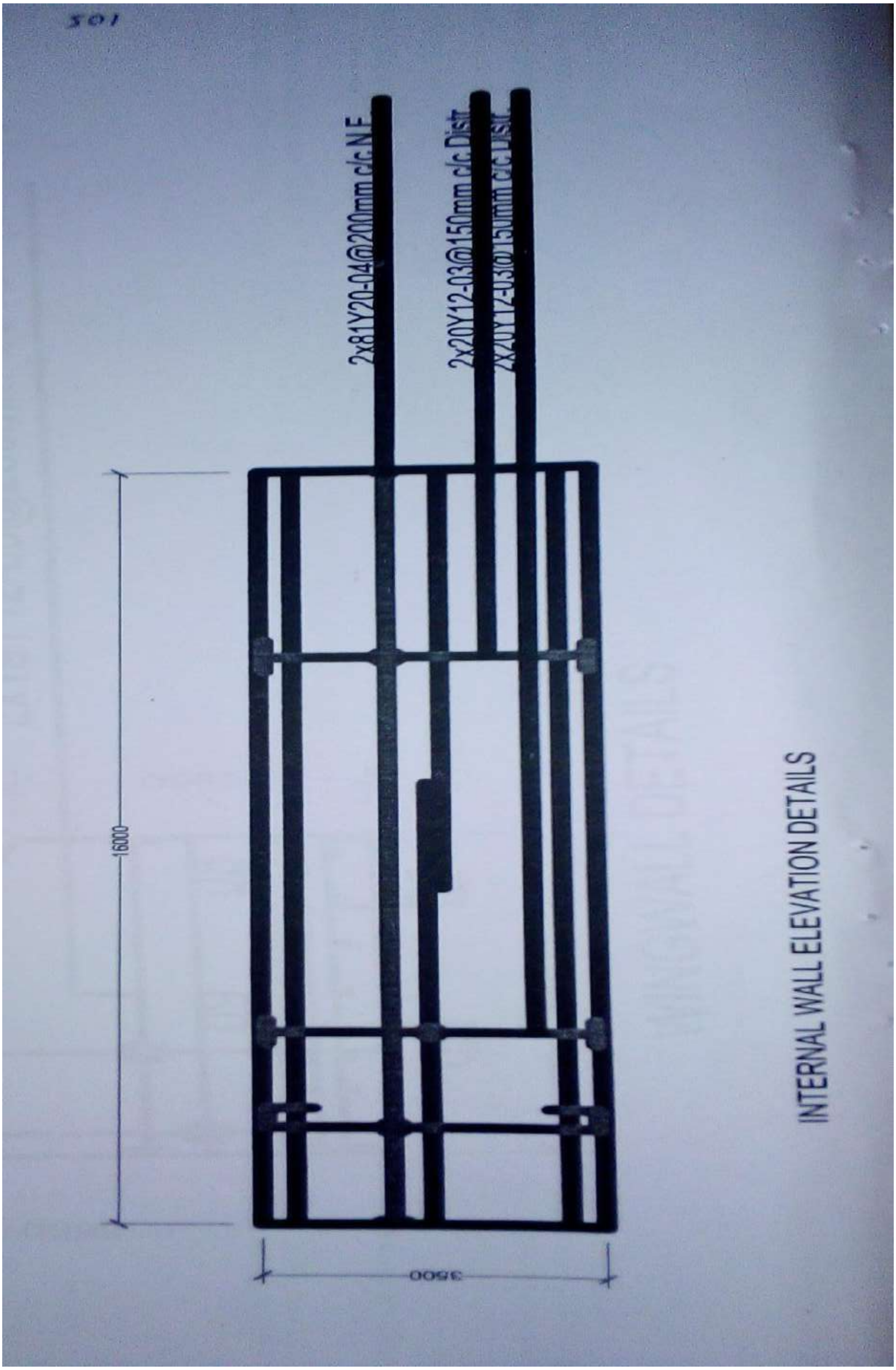

TOP SLAB DETAILS
9800
16000
81Y25-01@200mm c/c Top.
81Y20-02@200mm c/c Btm.
2x66Y12-03@150mm c/c Distr.
2x66Y12-03@150mm c/c Distr.
102



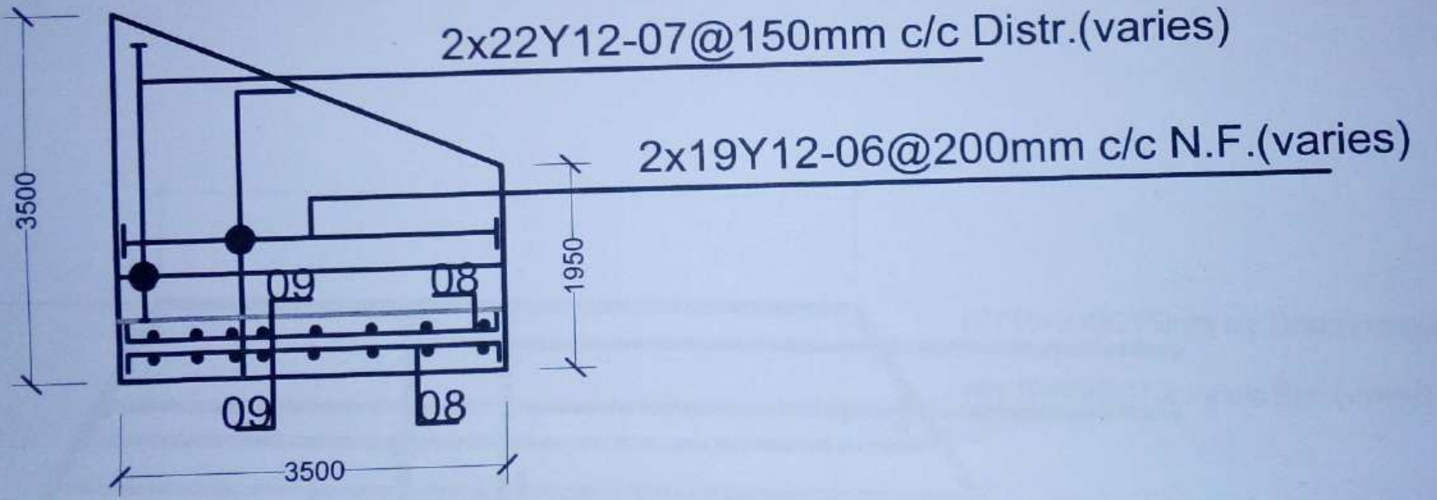
BOTTOM SLAB DETAIL



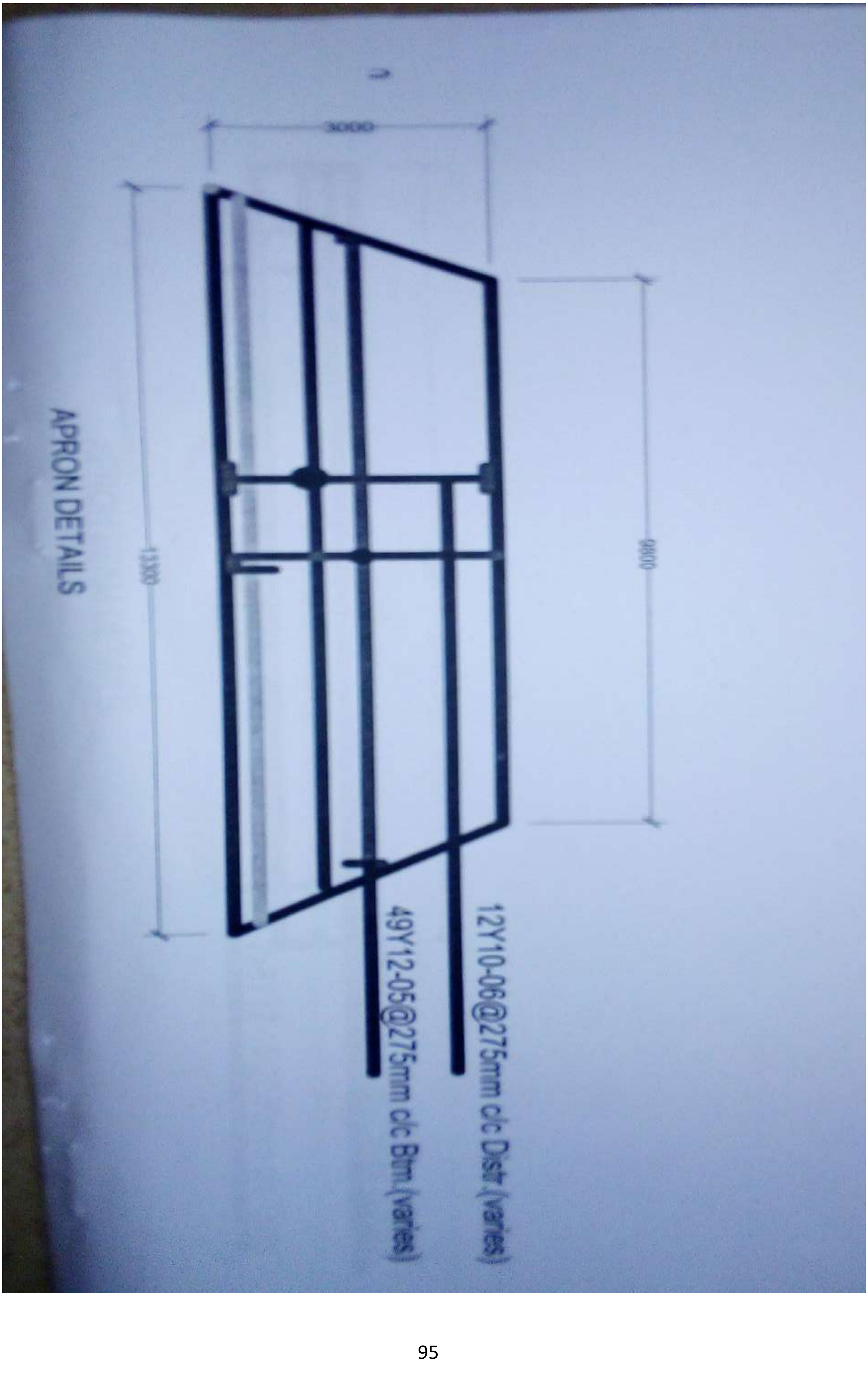
SIDE WALL ELEVATION DETAILS

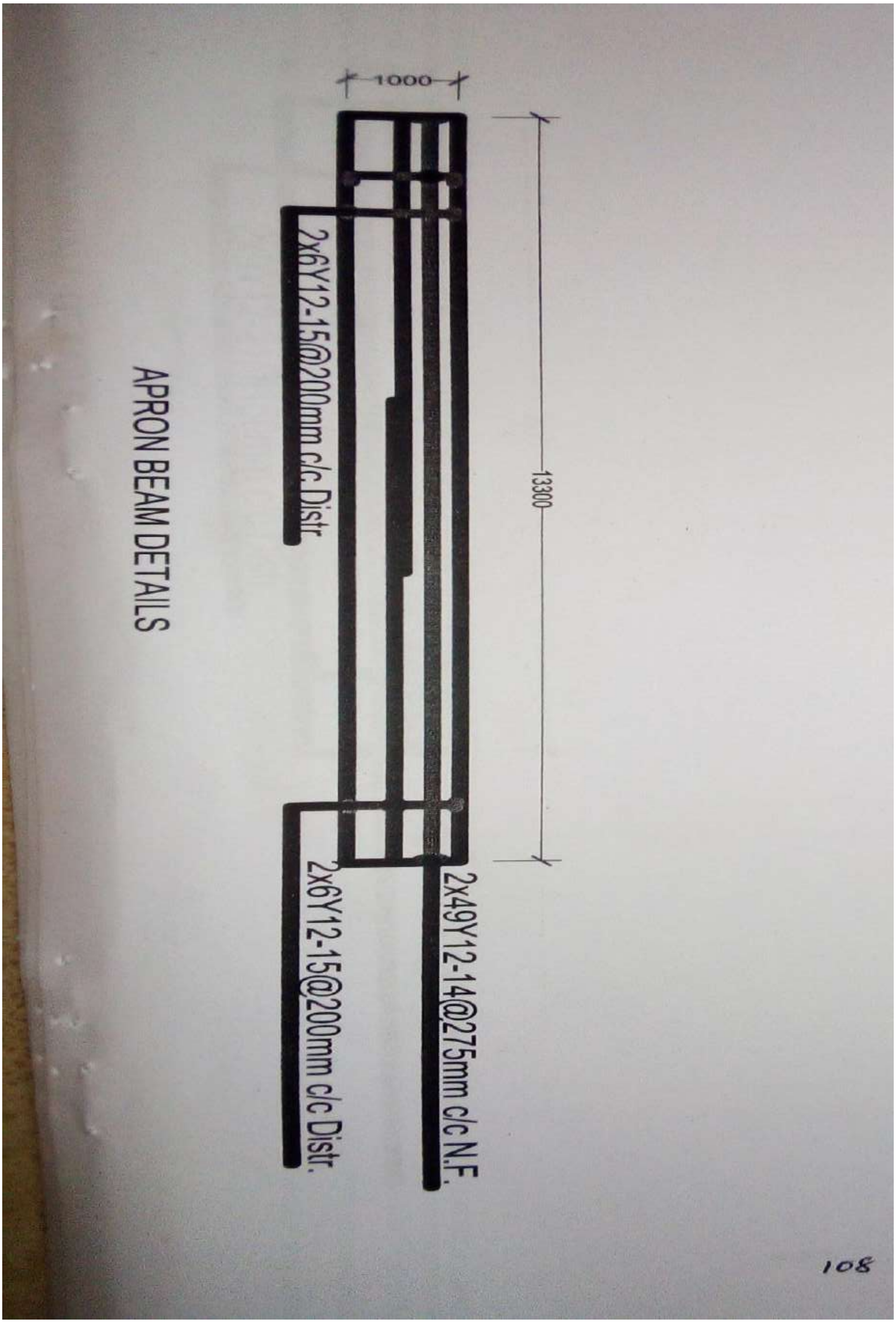


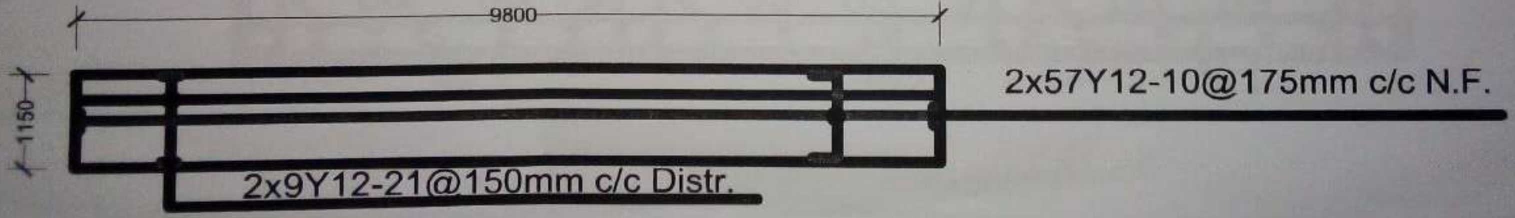
INTERNAL WALL ELEVATION DETAILS



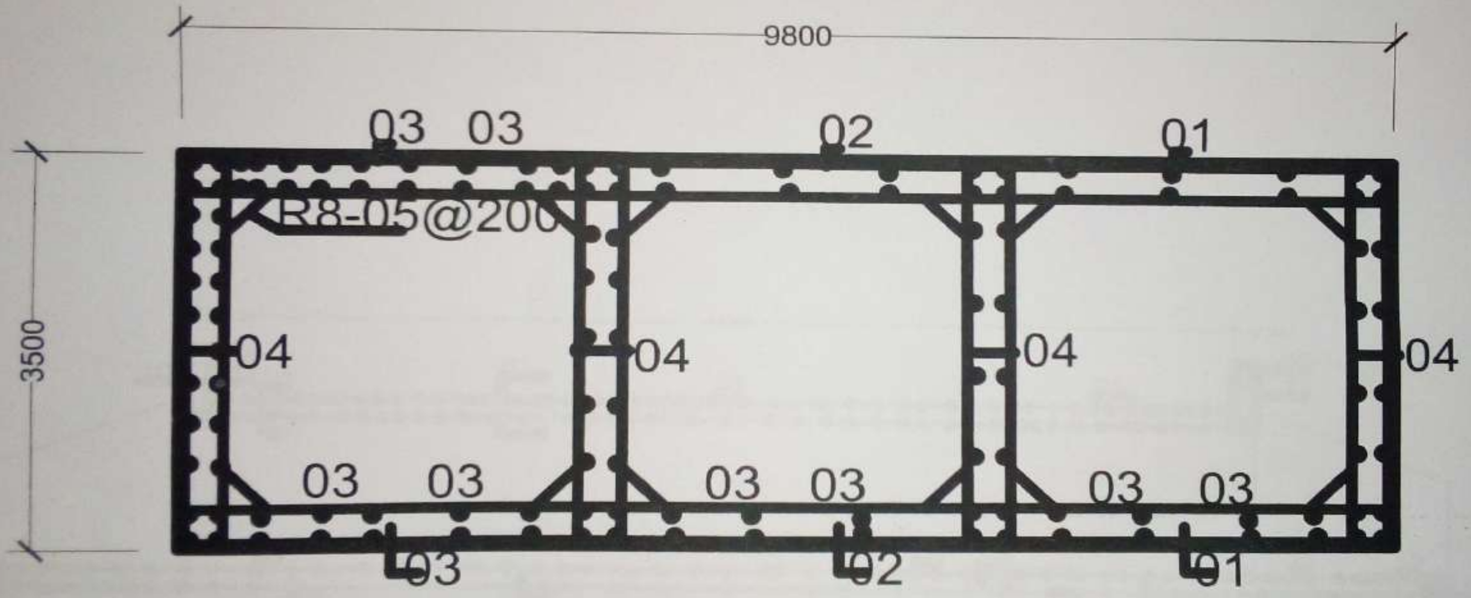
WINGWALL DETAILS


3000
9800
1300
12Y10-06@275mm c/c Distr.(varies)
49Y12-05@275mm c/c Btm.(varies)
APRON DETAILS

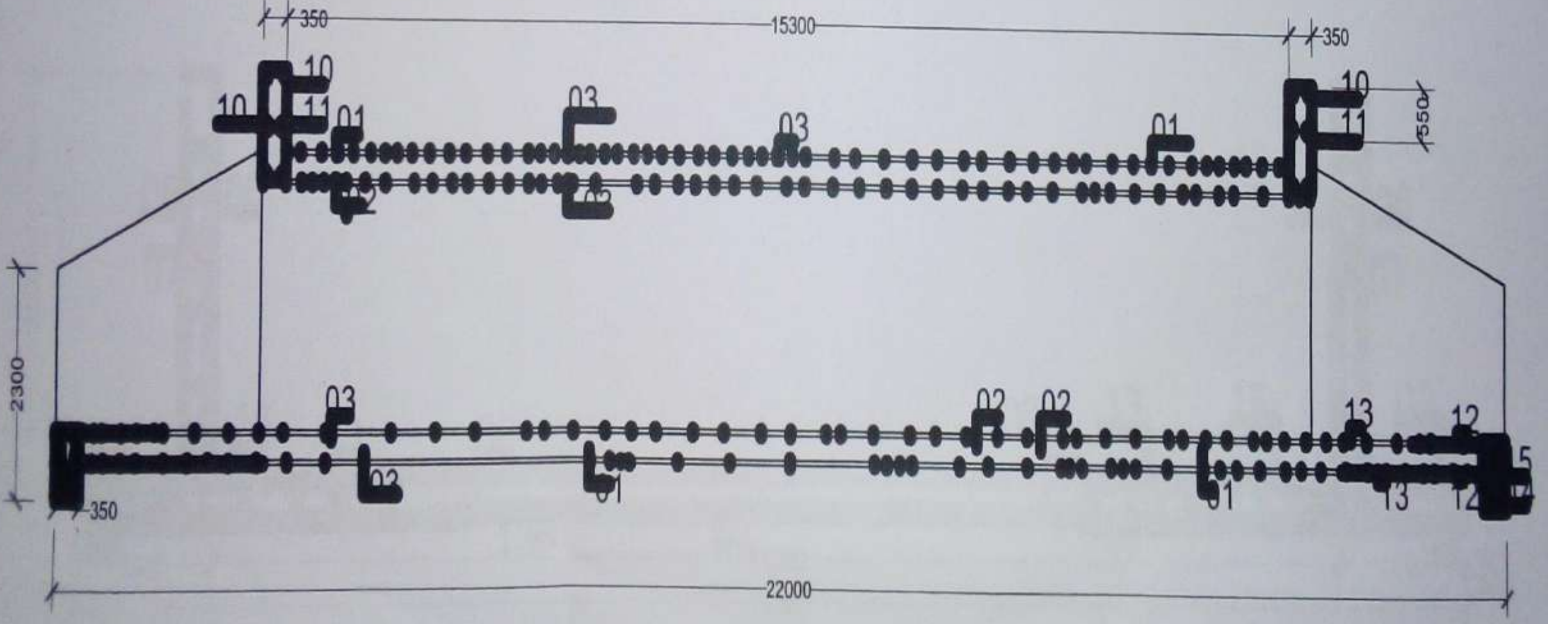

1000
1300
2x6Y12-15@200mm c/c Distr.
2x49Y12-14@275mm c/c N.F.
2x6Y12-15@200mm c/c Distr.
APRON BEAM DETAILS
108



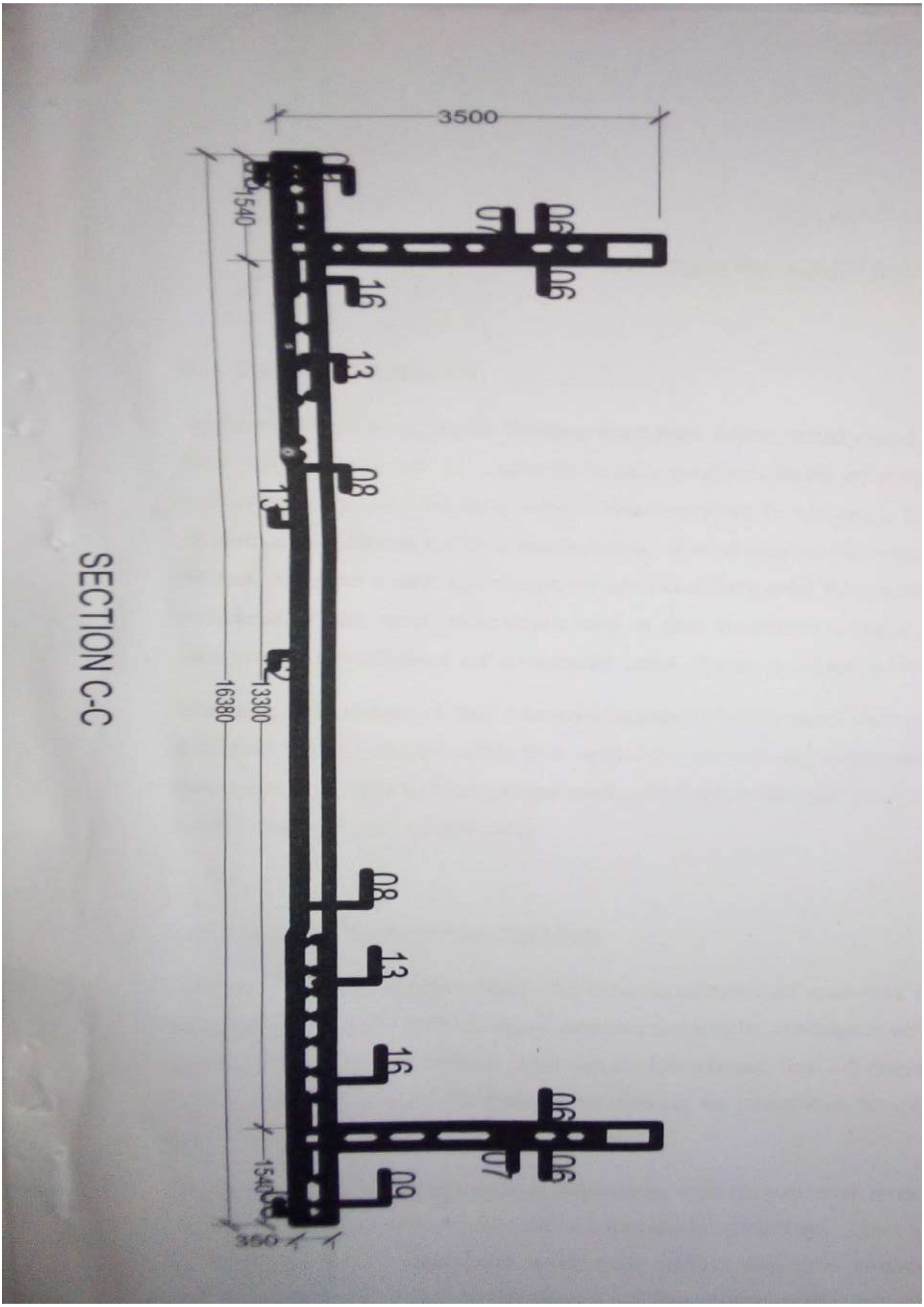
HEADWALL DETAILS



SECTION A-A


350
15300
350
10
10
11
01
03
03
01
10
11
550
02
2300
03
02
02
13
12
5
350
03
01
01
13
12
22000

SECTION B-B



SECTION C-C

3500
1540
16380
13300
1540
350
06
07
06
16
13
08
13
12
08
13
16
06
07
06
09

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCULSION

Box culvert is a rigid frame and has been analyzed as such using method of force. It can be seen from the analysis of culvert loads under cases of culvert empty and culvert flowing full that the worst condition occurs when the culvert is empty. It has also been observed that due to the interconnections of the members, the shear in the walls introduce axial forces in the slab and vice versa. Hence each element must be designed for moment and axial pull just like columns. The mildest shear and moments are at the internal walls of the triple and single cell box culvert and the worst condition of moment and shear occurs at the bottom slab.

The schedule of reinforcement suggest that 113 length of Y_{25} is required for main bars and 98 length of Y_{20} is to be required as distribution bars for the triple cell and also 98 length of Y_{20} is required for main bars and 34 length of Y_{12} is required for distribution bars for the single cell

Having considered the factors stated above and more, the culvert has been designed for the ultimate limit state with the application of appropriate factors of safety. And having satisfied all necessary checks, the proposed culvert is fit for construction and is sure to perform optimally under the worst condition.

6.2 RECOMMENDATIONS

I hereby recommend that the construction of culvert be supervised by a qualified engineer. In accordance with the design concrete grade strength of 20N/mm^2, a concrete mix of 1:2:4 should be used for construction and must be cured for 28 days to allow the concrete attain its maximum strength. Care must be taken as much as possible to ensure that the slope of the culvert aligns with that of the natural stream bed.

For proper interconnection between the structural members of the culvert, the reinforcements of the various members should adequately overlap. There should be at least a 600mm lap of the reinforcement of the wall with that of the top and bottom slab. The reinforcement of the side walls should also lap with those of the wing walls by at least 600mm. there should be at least a 1m lap of the head wall reinforcement and that of the top slab. At the edge, at least a 1m should occur between the headwall reinforcement and the wall reinforcement.

Proper maintenance of the culvert should be carried out by inspecting the culvert regularly to identify potential problems and prevent them, removing accumulated debris from the culvert, resurfacing of spalled areas and so on.

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APPENDICES

BAR BENDING SCHEDULE FOR TRIPLE CELL BOX CULVERT

Bar Mark	Size/Type	Number of each	Number of member	Shape code	Length (mm)	Total length of each (mm)
01	**Y_{25}**	**81**	**1**	**U- Shape**	**16000**	**1296000**
02	**Y_{20}**	**81**	**1**	———	**9800**	**793800**
03	**Y_{12}**	**20**	**2**	———	**9800**	**392000**
04	**Y_{10}**	**81**	**2**	**U-shape**	**3150**	**510300**
05	**Y_{20}**	**49**	**2**	**-----------**	**3500**	**343000**
06	**R_8**	**12**	**1**			

Total length of Y25 = 1296000 mm

Total length of Y20 = 793800+343000 = 1136800 mm

Total length of Y12 = 392000 mm

Total length of Y10 = 510300 mm

Conversion

Y25

1 length =11500

$= \frac{1296000}{11500}$ = 113 lengths

Y20

1 length = 11500

$= \frac{1136800}{11500}$ = 98 length

Y12

1lenght = 11500

$= \frac{392000}{11500}$ =34 length

Y10

1 length = 11500

$= \frac{510300}{11500}$ = 44 length

THE EFFECTS OF PARTIAL REPLACEMENT OF CEMENT WITH RICE HUSK ASH FROM DIFFERENT LOCATIONS ON CONCRETE PROPERTIES

BY

OKPALAEZE CHINEDU FRANCIS
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CERTIFICATION

This is to certify that the research project on "THE EFFECTS OF PARTIAL REPLACEMENT OF CEMENT WITH RICE HUSK ASH FROM DIFFERENT LOCATIONS ON CONCRETE PROPERTIES" was carried out by Okpalaeze Chinedu Francis with registration number (NAU/2015244012) of the department of civil engineering in partial fulfilment of the requirement for the award of Bachelor's Degree in Civil Engineering, Nnamdi Azikiwe University Awka under the close supervision of Engr Ifeanyi Kenneth Omaliko of Department of Civil Engineering, Nnamdi Azikiwe University, Awka. This work has never been submitted either in part or in full for any degree in any university.

Okpalaeze Chinedu Francis (Student)	Date

APPROVAL PAGE

This research thesis on “The effects of partial replacement of cement with rice husk ash from different location on concrete properties” was carried out by Okpalaeze Chinedu Francis with registration number (NAU/2015244012) has satisfied all the requirements of this university for the award of Bachelor’s degree (B.Eng) in Civil Engineering, Nnamdi Azikiwe University, Awka.

Engr Ifeanyi Kenneth Omaliko (Project Supervisor)	Date
Engr. Dr. A.C. Ezeagu (Head of Department)	Date
Engr. Prof. D.O. Onwuka (External Examiner)	Date

DEDICATION

This research project is solely dedicated to God Almighty, the giver of knowledge, wisdom and protection and also my parents, siblings, lecturers and well wishers that have contributed immensely to the successful completion of this project.

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ABSTRACT

This research addresses a comparative study on effects of partial replacement of cement with rice husk ash from Anaku and Omor town on concrete properties. Cement is widely noted to be one of the most expensive constituents of concrete. The entire construction industry is in search of a suitable and effective the waste product that would considerably minimize the use of cements and ultimately reduces the construction cost. This research will go a long way in reducing these agricultural waste (rice husk) which may pose great threat to the environment and also brings about reduction in weight of concrete. Rice husk ash of both locations were prepared by open control burning, grinded and replaced with cement at 0%, 2.5%, 5% and 7.5% respectively, with a mix ratio of 1:2:4 at a constant water- cement ratio of 0.55. The compressive strength, particle size distribution and workability test of these concrete specimens were extensively studied. The compressive strength of the concrete is dependent on the curing period. The compressive strength is directly proportional to the curing period. This was observed from 7 days, 14 days, 21 days and 28 days specimens from both locations. The compressive strength of the concrete specimens decreases with an increase in the proportion of rice husk ash content for specimens from both locations; therefore the control mix (0% RHA) gave the highest strength gain. It was concluded that at 7th day of curing Anaku concrete specimen gave early strength gain while at 28th day of curing Omor concrete specimen gave higher late strength gain. Concrete workability is inversely proportional to the percentage of rice husk ash content for all the specimens from both locations. It was concluded that Anaku concrete specimen gave higher workability compared to Omor concrete specimen.

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CHAPTER ONE

1.0 INTRODUCTION

Concrete is made up of three basic components: water, aggregate (rock, sand, or gravel) and Portland cement(Wang, 2002). Cement usually in powder form, acts as a binding agent when mixed with water and aggregates(Vollpracht, 2016). This combination, or concrete mix, will be poured and harden into the durable material with which we are all familiar. This process of hardening is known as setting of concrete(Hooton, 2001).These above materials (cement, aggregates, sand and water) are the normal and basic components of concrete. But, studies have proven that high compressive strength of concrete cannot be achieved, especially on high grade of concrete(example, M40) without addition of admixture(Pazderka, 2016). Some of the limitations of concrete includes; relatively low tensile strength when compared to other building materials, low ductability, low strength-to-water ratio, it is susceptible to cracking etc(Hornbostel, 2017).

Following a natural growth in population, the amount and type of waste materials have increased accordingly creating thus environmental problems. Historically agricultural and industrial wastes have created waste management and pollution problems. Different alternative waste materials and industrial by-products such as rice husk ash fly ash, bottom ash, recycled aggregates, crumb rubber, saw dust, brick bats etc. were replaced with cement or natural aggregates(Morsy, 2015)..

Although these materials are traditionally considered as primitive and therefore inferior to more highly processes in terms of safety, durability, performance, occupant's health and comfort with respect to environmental issue, consumption of environmental products and energy within the construction industry has created a significant demand for raw materials and for production thereby contributing to the many environmental problems associated with diverse ecosystem(Marieta, 2021).

The wastes have generally no commercial value and are locally available at a minimal transportation cost. The use of these wastes has complemented other traditional materials in construction and hence provides practical and economic advantages(Aydin, 2016). Also proper utilization of these wastes conserves the natural resources and protects the environment. Consequently, due to high demand of building and infrastructure, there is a need to fast-track construction process thereby reducing construction time in other to improve the time for project execution, therefore precast construction method are usually adopted. But one of the major disadvantage of precast item is difficulty in lifting and transportation by hand due to its very dense weight.

Rice husk ash is a light weight aggregate(Azhar, 2020). So, in response to the problem, this study is carried out to discover the alternative ways of reducing weight of concrete through the use of agricultural waste products (RHA) and at the same time maintain the mechanical properties of concrete.

A need for more research on other mechanical properties (compressive and flexural strength) is necessary to better understand the overall mechanical behavior of concrete incorporating RHA as a replacement for OPC.

1.1 BACKGROUND OF STUDY

The construction industry relies heavily on conventional materials such as cement, sand and granite for production of concrete. Concrete is the basic civil engineering composite, it is the mixture of cement, aggregates, water. The quality of concrete is determined by the quality of paste/mix. It is the world's most consumed man made material (Naik, 2008).

Concrete's versatility and relative economy in filling wide range of needs has made it a competitive building material. The demand for concrete in today's infrastructural development is rising day-by-day. In light of this, the non-availability of natural resources to future generation has also been realized. Concrete production is not only a valuable source of societal development but also a significant source of employment(Ahmad, 2010).

Rice husk Ash is an agricultural by-product on which rice husk is burnt into ashes. RHA is found to be good material which fulfils the physical characteristics and chemical composition of mineral admixtures(Ghosal and Moulik, 2015). It is the hard protective coverings of rice grains which are separated from the grains during milling process. Rice husk is an abundantly available waste material in all rice producing countries, and it contains about 30%-50% of organic carbon. It can be used for partial replacement of cement or sand in light weight concrete.

Usage of the fine rice husk ash reduces the temperature as compared to the normal ordinary Portland cement temperature. RHA depends mainly on silica content, silica crystallization phase, and size and surface area of ash particles(Chirsty, 2021).

1.2 STATEMENT OF THE PROBLEM

Concrete is a very common material used in everyday construction of various structures. This concrete is usually reinforced with steel due to its weakness in tension. This reinforcing steel is expensive and its amount is dependent upon the load being carried by the concrete structure. This load is a combination of dead loads and live loads. The self-weight of the concrete is a major contributor to the dead load on the concrete structure. A reduction in the self-weight of the concrete will give rise to a reduction in the dead load resulting in a much more economical construction as the amount of reinforcing steel required for resisting this load will be lessened. Rice milling generates a by-product known as husk. The Rice Husk Ash (RHA) had no useful application and had usually been dumped into water streams and caused pollution until it was known to be usefulness in concrete. Partial replacement of Rice husk ash with cement will bring about reduction these agricultural waste (rice husk) which causes environmental pollution in the society.

The use of Rice husk ash(RHA) in concrete creates an avenue to manage RHA in a sustainable and effective way. A reduction in the use and cost of cement can be achieved through the use of RHA as a replacement for cement.A need for more research on other mechanical properties (compressive and flexural strength) is necessary to better understand the overall mechanical behavior of concrete incorporating RHA as a replacement for OPC.

1.3 AIMS AND OBJECTIVES

To study the effects of partial replacement of cement with rice husk ash from different locations on concrete properties.

The objectives of this research are as follows:

1 To gather an abundance of pertinent information through an in-depth review of previous studies and pinpoint the areas that need to be addressed.

2 To carry out a sieve analysis of the RHA, fine and coarse aggregate.

3 To design the mix proportions.

4 To determine the workability of the fresh concrete.

5 Curing of all the concrete specimens for 7, 14, 21 and 28 (days).

6 To determine the compressive strength of the hardened concrete.

1.4 SIGNIFICANCE OF THE STUDY

This research tends to benefit both the public and private client. A reduction in the use of cement as partial replacement with rice husks ash in concrete production will go a long way in reducing these agricultural waste (rice husk) which may pose great threat to the environment, bring about reduction in quantity of cement and also brings about reduction in weight of concrete.

The cost of cement has made concrete production expensive such that the housing deficit in developing countries is on the rise despite all the efforts by governments and other stakeholders to produce affordable housing units for the populace. The information gotten from this study will be beneficial in the area of economical construction as there would be reduction in quantity of cement and also (RHA) material are easily sourced and less costly in Anambra state.

The study will provide information on the partial replacement of cement with rice husk ash in concrete production.

1.5 SCOPE OF STUDY

This study would lead to the determination of the compressive strength of concrete test, concrete workability (slump test), sieve analysis, moisture content of the rice husk ash. The concrete mix proportion to be used is 1:2:4, with 0.5 water-cement ratio. The freshly mixed concrete would be cast in a concrete cube of 150mm x 150mm x 150mm. The concrete cubes would be cured for 7 days, 14 days, 21 days, and 28days.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The most widely used construction material is reinforced concrete which is heavy, has high embedded carbon, use a lot of non-renewable resources and exhibit rather poor building physical properties(Kromoser, 2018). The construction industry consumes more natural resources than any other industry. With increasing public awareness of the need and demands of sustainable development and environmental conservation, no other industry is called on as much as the construction industry to evolve their practices and to satisfy the need of our current generation without curtailing the resources of future generations to meet theirs(Memon,2016).

Sustainable development is a very important agenda in this country. This is where the world needs balance in maintaining resources, energy and resolving environmental problems(Suliman et al., 2019). The increasing demand for high performance sustainable materials in the construction industry, which represents shift towards sustainable eco-friendly and green practices, poses a huge challenge to structural engineers, environmental engineers and architects (D'Alessandro et al., 2014; Mahmoud et al., 2013; Sojobi et al. 2016; Yet et al., 2012). Sieffert et al.(2014) posit that for sustainability to be achieved there must be effective collaboration among these professions that are also stakeholders in the construction industry.

Large demand has been placed on building materials industry especially in the last decade owing to the increased population which caused a chronic shortage to building materials. The civil engineer has been challenged to the industrial waste to useful buildings and construction materials. According to some previous researchers, the construction materials expending is about one third of the whole society expense (Zhao, 2013). According to Narayanan et al. (2017) the utilization of concrete is increasing at a higher rate due to development in infrastructure and construction activity all around the world. As a result of increase in the cost of construction materials especially the use of alternative building materials which are locally available (Usman et al., 2012).

Engineering consideration on the use of waste, cheaper and locally available materials is highly attractive successful utilization of waste materials depends on its economically competitive with alternative natural materials (Nazar, 2013).The selection and combination of supplementary cementious and recycled materials must take into consideration the properties relevant to their usage, performance, durability as well as the exposure conditions (Elahi 2010).

Unfortunately, there is low usage of these local materials in construction which is attributed to several factors such as lack of reliable data on the engineering properties of these materials in concrete and block production (Ukpata and Ephraim, 2012). Low level of awareness about the potential of these materials and their potential to improve properties of concrete, low research and development on these materials, poor development and support of the industries which would utilize the materials in production of concrete and concrete products, widening gap between engineering researchers in the universities and the industry, apathy towards local materials linking it with poverty and the insatiable craving for imported concrete products are among the many factors limiting the usage of these local materials in our society (Sojobi, 2016).

2.2 CONCRETE

2.2.1 Limitations of Concrete

The limitations of concrete include:

1. Relatively low tensile strength when compared to other building materials.
2. Low ductability.

3. Low strength-to-weight ratio.
4. It is susceptible to cracking.

2.2.2 Classification of Concrete

Classification of concrete by weight

Ultra-light concrete

Ultra-light Weight Concrete is created with the addition of either polystyrene beads (non-structural) or a lightweight aggregate (structural) to the formula. Although both formulations are lightweight products, they have several important differences that make each one suitable to specific projects. Ultra-light weight concrete has a density less than 1,200kg/m^3.The present study presents a methodology to design ultra-lightweight concrete that could be potentially applied in monolithic concrete structures, performing as both load bearing element and thermal insulator.

Light weight concrete

Lightweight concrete is a mixture made with lightweight coarse aggregates such as shale, clay, or slate, which give it its characteristic low density. Structural lightweight concrete has an in-place density of 90 to 115 lb/ft^3, whereas the density of regular weight concrete ranges from 140 to 150 lb/ft^3. This makes lightweight concrete ideal for building modern structures that require minimal cross sections in the foundation. It is being increasingly used to build sleek foundations, and has emerged as a viable alternative to regular concrete.

The lightweight is due to the cellular or high internal porous microstructure, which gives this type of aggregate a low bulk specific gravity. The most important aspect of lightweight aggregate is the porosity. They have high absorption values, which requires a modified approach to concrete proportioning. For instance, slump loss in lightweight concrete due to absorption can be an acute problem, which can be alleviated by pre-wetting (but not saturating) the aggregate before batching. Lightweight concrete is a cost effective alternative to normal concrete, especially since it does not compromise on the structure's strength. The higher porosity of LWC also influences its thermal conductivity, making it suitable for projects that require insulation from heat damage.

Normal weight concrete

The nominal weight of normal concrete is 144 lb / ft^3 for non-air-entrained concrete, but is less the air-entrained concrete. (The weight of concrete plus steel reinforcement is often assumed as 150 lb / ft^3).Strength for normal-weight concrete ranges from 2000 to 20,000 psi. It may be used for concrete paving mixes. It can be produced with many variable characteristics including strength, fluidity, colour and weight.

Heavy weight concrete

Concretes made with heavyweight aggregates are used for shielding and structural purposes in construction of nuclear reactors and other structures exposed to high intensity radiation. Heavyweight aggregates are used where heavyweight is needed, such as ship's ballast and encasement of underwater pipes, and for making shielding concretes because absorption of such radiation is proportional to density, and consequently, these aggregates have greater capacity for absorption than those ordinarily used for normal concrete. With such aggregates, concrete weighing up to about 385 lb/ft^3 can be produced.

Concrete made with limonite or magnetite can develop densities of 210 to 224 lb/ft^3 and compressive strengths of 3200 to 5700 psi. With barite, concrete may weigh 230 lb/ft^3 and have a strength of 6000 psi. With steel punching and sheared bars as coarse aggregate and steel shot as fine aggregate, densities of 250 to 288 lb/ft^3 and strengths of about 5600 psi can be attained. Generally, grading of aggregates and mix proportions are similar to those used for normal concrete. The properties of heavyweight concrete are similar to those of normal-weight concrete. Mixing and placing operations, however, are more difficult than those for normal-weight concrete, because of segregation.

Good grading, high cement content, low W/C, and air entrainment should be employed to prevent segregation. Sometimes, heavyweight aggregates are grouted in place to avoid segregation. Heavyweight concretes usually do not have good resistance to weathering or abrasion.

Classification of concrete by strength

Low strength concrete

A weak concrete is considered generally anything with a characteristic compressive strength of below 20 MPa or N/mm2.

Moderate strength concrete

A moderate strength concrete is defined as concrete with compressive a strength between 20 MPa to 50MPa.

High strength concrete

A moderate strength concrete is defined as concrete with a compressive strength between 50 to 200MPa.

Ultra high strength concrete

Ultra high strength concrete is defined as concrete with a compressive strength above 220MPa.

2.2.3 Benefits of Concrete

There are numerous positive aspects of concrete:

1. It is a relatively cheap material and has a relatively long life with few maintenance requirements.
2. It is strong in compression.
3. Before it hardens it is a very pliable substance that can easily be shaped.
4. It is non-combustible.

2.2.4 Properties of Concrete

Concrete, as a structural member has to pass through two stages, plastic or fresh stage and the hardened stage. The properties of both fresh and the hardened concrete are of utmost importance to the concrete user.

Fresh Concrete

Fresh concrete or plastic concrete is a freshly mixed material which can be moulded into any shape. The relative quantity of cement, aggregates and water mixed together, control the properties of concrete in wet state as well as in hardened state. To obtain quality concrete, its properties in plastic as well as hardened stage play important roles. The properties in plastic stage include:

1. Bleeding
2. Harshness
3. Segregation
4. Workability

Bleeding

Bleeding can be referred to as water gain. It is a particular form of segregation in which some of the water from concrete comes out to the surface of the concrete, being of the lowest specific gravity among all the ingredients of concrete. This also refers to the appearance of water along with cement particles on the surface of freshly laid concrete on compaction and finishing. Bleeding is predominantly observed in a highly wet mix, badly proportioned and insufficiently mixed concrete.

Due to bleeding, water comes and accumulates at the surface. Sometimes, along with this water, certain quantity of cement also comes to the surface. Bleeding causes the formation of pores in the concrete making it porous and weak. The surface layer (consisting of water and some cement particles) dries and cracks making the concrete surface weak. This bleeding can be controlled by controlling the quantity of water, providing finer grading of fine aggregates, using finely ground cement and performing suitable optimum compaction.

Harshness

This is the resistance offered by concrete to its surface finishing, that is, the concrete which cannot be easily finished with a smooth surface. This happens as a result of the presence of lesser fine aggregates, lesser cement mortar and the use of poorly graded crushed or angular aggregates and insufficient water content required for workability. The surface of harsh concrete remains rough and porous.

Segregation

This is the separation of the coarse particles from the mix which results in non-homogeneity of the concrete mix. To keep the concrete mass cohesive, sufficient fine aggregates must be present in the concrete mass. Apart from suitable grading and enough proportion of lines, the concrete should not be thrown from a height to avoid segregation. Segregation results in honeycomb decrease in the density and ultimate loss of strength of hardened concrete.

Workability

This can be defined as the ease with which concrete can be compacted hundred percent having regards to mode of compaction and place of deposition. It can also be defined as the property of concrete which determines the amount of useful internal work necessary to produce full compaction. The workability of concrete depends on the quantity of water, grading of aggregates, and the percentage of fine materials in the mix. It is measured in terms of slump test, compacting factor and Vee-Bee degrees. In the test, four results can be expected; zero slump, true slump, shear slump and collapse slump. The desired one is the true slump.

Workability is the amount of useful internal work necessary to produce full compaction. The useful work refers to physical property of concrete and the energy requires overcoming the internal friction between individual particles in the concrete. A concrete is workable if it is consistence. A consistency in this context refers to the firmness and the case with which the concrete flows.

Factors that affect workability of concrete

There are many factors that affect the workability of concretes. Some of the interacting factors are

1. Water content which is paramount
2. Type of grading of aggregates
3. Cement\aggregate ratio

4. Presence of admixtures
5. Fineness of cement
6. Temperature
7. Time.

Workability test

Workability of a concrete is tested with the following methods;

1. Slump test
2. Compacting factor test
3. Vebe test
4. Flow table test
5. Ball penetration test

Slump test

This test is not only to determine the workability of green concrete but also to find out how consistent the concrete produced is. The consistency in this context refers to how wet or dry the concrete is. Changes in slump might be as a result in unusual quantity of water use for the same mix ratio or use of different grading proportion of aggregates.

Workability of concrete is the ease and homogeneity with/at which a freshly mixed concrete can be transported, placed without any segregation. A workable concrete is defined as a concrete suitable for placing and compacting under the site's conditions. Workability refers to the case with/in which concrete can be placed and compacted (Neville, 1973). In study, slump test is the method used to assess the above. Since workability of a given concrete increases with the amount of water added, the slump test provided a means of controlling the water content of successive batched of the same mix. The mould for the slump test was a frustum of a cone, 300mm high.

Types of Slump Test

1 True slump
2 Collapse slump
3 Shear slump
4 Zero slump

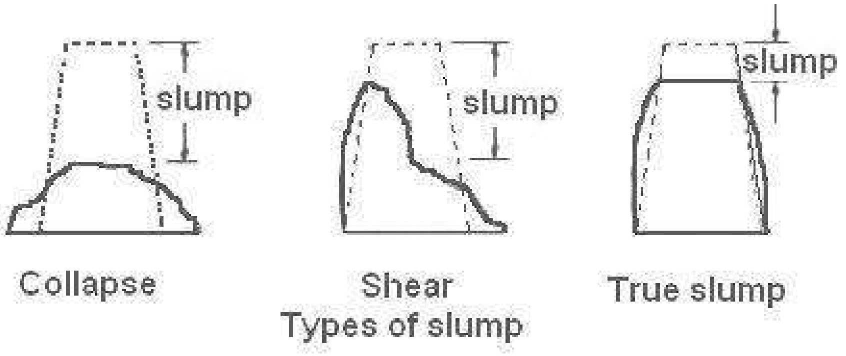

Plate 2.1: Types of slumps

The procedure for the experiment includes:

1. The internal surface of the mould was thoroughly cleaned and applied with a light coat of oil.
2. The mould was placed under a smooth, horizontal and non-absorbed surface. With the smaller opening at the top.
3. The mould was filled in three layers with freshly mixed concrete each approximately to one-third of the height of the mould.
4. Each layer was then tampered 25 times with a steel rounded end and tamping rod (strokes are distributed evenly over the cross-section).
5. After the top layer was tamped, the concrete was struck off the level with a trowel.

6. The mould was removed from the concrete immediately by raising it slowly in the vertical direction.
7. The difference in level between the heights if the mould and that of the highest point of the subsided concrete was measured.
8. The difference in height is the slump of the concrete.

Hardened State

The properties in the hardened stage include;

1. Dimensional changes
2. Durability
3. Impermeability
4. Strength

Dimensional changes

Dimensional changes in concrete are caused due to shrinkage (reduction of volume during hardening) of concrete, thermal changes, elasticity and creep (permanent deformation under sustained loading) in concrete. Dimensional changes may induce certain stresses in concrete which may lead to its cracking. From research and practical experience, it is observed that the sender the concrete, the greater the strength. Therefore, to obtain the optimum density, it is necessary to compact concrete fully to drive away all entrapped air. For good compaction if fresh concrete, it should be of such plasticity that all particles can easily move with the available external effort to the remotest corner of the mould.

Durability

Durability of concrete refers to its resistance to deterioration under the forces of environment such as weathering, chemical attack abrasion, fire and corrosion of steel, etc. Freezing and thawing in cold weather results in disintegration of concrete due to water in its capillary pores. Generally, strong and dense concrete have better durability in extreme weather conditions. To achieve durable concrete in an environment surcharge, special type of cements such as sulphate resisting Portland cement, super sulphate cements, blast furnace slag cements are to be used. Porous concrete brings about corrosion of steel and this can be avoided by reducing soluble chlorides alkalinity of the protective cover.

Impermeability

This is the resistance of the concrete to the flow of water through the pore spaces in it. Excess water during concrete manufacture leaves a large number of continuous pored leading to permeability in concrete. To achieve impermeable concrete, a low water cement ratio is used, use of dense and we'll graded aggregate and also ensure full compaction and cure continuously under moist and low temperature conditions, etc. This is very important especially in exposed and water retaining structures such as dams, etc.

Strength

Strength of concrete is its resistance to bear the load imposed on it. The strength of concrete plays a very important role in its structural behaviour and design of cement concrete structural members. Its strength can be measured by determining its compressive strength which indicates resistance of concrete to crushing. The compressive strength of concrete is an important property of hardened concrete and can easily be produced for various compressive strengths generally ranging from 5N/mm² to 45N/mm².

Compressive Strength

Compressive strength is determined by the force required to crush it and is measured in pounds per square inch or kilograms per square centimetre. Strength can be affected by many variables including moisture and temperature. The tensile strength of concrete can be improved with the addition of metal rods, wires, cables or mesh. Where very high tensile stresses are expected (such as in wide unsupported spans in roofs or bridges) concrete can include pretension steel wires. This creates compressive forces in the concrete that help offset the tensile forces that the structure is subject to. Sacrificial probes can be integrated within concrete to provide strength determination and this is likely to help improve construction methodologies.

Characteristics of concrete

The characteristics of concrete are determined by the aggregate or cement used, or by the method that is used to produce it. The water-to-cement ratio is the determining factor in ordinary structural concrete with a lower water content resulting in a stronger concrete. This, however, reduces the workability of the concrete, which can be measured using the slump test. The grading, shape, texture and proportion of aggregate can also have a similar affect. If a particularly strong concrete is required, the amount of aggregate can be reduced in relation to the cement. However, cement is a significant cost factor, and increasing its proportion in the mix will increase the overall price.

Factors affecting strength of concrete

The strength of concrete is usually affected by many factors, in this project work, such factors are discussed with particular reference to compressive strength. The factors include:

Water-cement ratio

The water-cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix. A lower ratio leads to higher strength and durability, but may make the mix difficult to work with and form. Workability can be resolved with the use of plasticizers or super-plasticizers. Often, the ratio refers to the ratio of water to cementitious materials, w/cm. Cementitious materials include cement and supplementary cementitious materials such as fly ash, ground granulated blast-furnace slag, silica fume, rice husk ash and natural pozzolan. Supplementary cementitious materials are added to strengthen concrete.

The notion of water–cement ratio was first developed by Duff A. Abrams and published in 1918. Refer to concrete slump test. The 1997 Uniform Building Code specifies a maximum of 0.5 ratio when concrete is exposed to freezing and thawing in a moist condition or to de-icing chemicals, and a maximum of 0.45 ratio for concrete in a severe or very severe sulphate condition. Concrete hardens as a result of the chemical reaction between cement and water (known as hydration, this produces heat and is called the heat of hydration). For every pound (or kilogram or any unit of weight) of cement, about 0.35 pounds (or 0.35 kg or corresponding unit) of water is needed to fully complete hydration reactions.

However, a mix with a ratio of 0.35 may not mix thoroughly, and may not flow well enough to be placed. More water is therefore used than is technically necessary to react with cement. Water–cement ratios of 0.40 to 0.60 are more typically used. For higher-strength concrete, lower ratios are used, along with a plasticizer to increase flowability. Too much water will result in segregation of the sand and aggregate components from the cement paste. Also, water that is not consumed by the hydration reaction may leave concrete as it hardens, resulting in microscopic pores (bleeding) that will reduce final strength of concrete.

A mix with too much water will experience more shrinkage as excess water leaves, resulting in internal cracks and visible fractures (particularly around inside corners), which again will reduce the final strength. Water is required in the production of concrete to hydrate the cementing materials of the concrete so as to allow for the chemical combination. Functions of water in concrete includes:

1. To wet the surface of aggregates to develop adhesion because the cement paste adheres quickly and satisfactory to the wet surface of the aggregate than the dry surface.
2. To prepare a plastic mixture of the various ingredients and to impact workability to concrete to facilitate placing in the desired position.
3. Water is also needed for the hydration of the cementing materials to set and harden during the period of curing.

Sustainability

Concrete has a relatively high embodied energy, resulting from its extraction, manufacture and transportation. Waste materials can be included within the concrete mix such as Recycled Crushed Aggregate (RCA), Ground Granulated Blast-Furnace Slag (GGBS) and Pulverized Fuel Ash (PFA). In addition, moves are being made to assess the potential of using recycled concrete, however, issues such as moisture content and material variability may make this unviable. Concrete is a very durable, low maintenance material and can provide thermal mass, helping reduce the energy consumption of buildings in operation.

2.2.5 Components of Concrete

Concrete is a composite material which consists of a binder (which is typically cement), coarse aggregates (which is usually stone), fine aggregates (which is usually sand) and water. These comprises the constituent materials of concrete.

In a layman’s term;

1. Cement + water = cement paste
2. Cement paste + sand = mortar; and finally
3. Mortar + stone = concrete.

Admixtures may be included in the mix to control certain properties.

The chemical reactions that take place when different constituent materials are combined can vary depending on the properties of the individual materials. The materials can vary in their chemical makeup and performance characteristics, depending on where they were mined or quarried and according to the manufacturing methods used and conditions in the manufacturing plant.

Cement

There are different types of cement but Portland cement is the binder used most widely. Although Portland cement is named after an area in n England where it's use was originated, today it is manufactured all over the world. Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and non-specialty grout. It was developed from other types of hydraulic lime in England in the early 19th century by Joseph Aspdin, and usually originates from limestone.

It is a fine powder, produced by heating limestone and clay minerals in a kiln to form clinker, grinding the clinker, and adding 2 to 3 percent of gypsum. Several types of Portland cement are available. The most common, called ordinary Portland cement (OPC), is grey, but white Portland cement is also available. Its name is derived from its resemblance to Portland stone which was quarried on the Isle of Portland in Dorset, England. It was named by Joseph Aspdin who obtained a patent for it in 1824. However, his son William Aspdin is regarded as the inventor of "modern" Portland cement due to his developments in the 1840s.

ASTM International defines Portland cement as "hydraulic cement (cement that forms a water-resistant product) produced by pulverizing clinkers consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulphate as an inter-ground addition." Portland cement is made by fusing calcium-bearing materials with aluminum-bearing materials. The calcium may come from limestone, shells, chalk or marl which is a soft stone or hard mud, sometimes called mudstone that is rich in lime. Portland cement is caustic, so it can cause chemical burns. The powder can cause irritation or, with severe exposure, lung cancer, and can contain a number of hazardous components, including crystalline silica and hexavalent chromium. Environmental concerns are the high energy consumption required to mine, manufacture, and transport the cement, and the related air pollution, including the release of greenhouse gases (e.g., carbon dioxide), dioxin, NOx, SO2, and particulates.

The production of Portland cement contributes to about 10% of world carbon dioxide emission. The International Energy Agency has estimated that cement production will increase by between 12 and 23% by 2050 to meet the needs of the world's growing population. There are several ongoing researches targeting a suitable replacement of Portland cement by supplementary cementitious materials. The low cost and widespread availability of the limestone, shales, and other naturally-occurring materials used in Portland cement make it one of the lowest-cost materials widely used over the last century. Concrete produced from Portland cement is one of the world's most versatile construction materials.

Plate 2.2: Bags of Portland cement

Manufacturing of cement

Portland cement clinker is made by heating, in a cement kiln, a mixture of raw materials to a calcining temperature of above 600 °C (1,112 °F) and then a fusion temperature, which is about 1,450 °C (2,640 °F) for modern cements, to sinter the materials into clinker. The materials in cement clinker are alite, belite, tri-calcium aluminate, and tetra-calcium alumino ferrite. The aluminium, iron, and magnesium oxides are present as a flux allowing the calcium silicates to form at a lower temperature, and contribute little to the strength. For special cements, such as low heat (LH) and sulphate resistant (SR) types, it is necessary to limit the amount of tricalcium aluminate ($3\ CaO{\cdot}Al2O3$) formed.

The major raw material for the clinker-making is usually limestone (CaCO3) mixed with a second material containing clay as source of alumino-silicate. Normally, an impure limestone which contains clay or SiO2 is used. The CaCO3 content of these limestones can be as low as 80%. Secondary raw materials (materials in the raw mix other than limestone) depend on the purity of the limestone. Some of the materials used are clay, shale, sand, iron ore, bauxite, fly ash, and slag. When a cement kiln is fired by coal, the ash of the coal acts as a secondary raw material.

Cement grinding

To achieve the desired setting qualities in the finished product, a quantity (2–8%, but typically 5%) of calcium sulfate (usually gypsum or anhydrite) is added to the clinker, and the mixture is finely ground to form the finished cement powder. This is achieved in a cement mill. The grinding process is controlled to obtain a powder with a broad particle size range, in which typically 15% by mass consists of particles below 5µm diameter, and 5% of particles above 45µm. The measure of fineness usually used is the 'specific surface area', which is the total particle surface area of a unit mass of cement.

The rate of initial reaction (up to 24 hours) of the cement on addition of water is directly proportional to the specific surface area. Typical values are 320–380 m2·kg−1 for general purpose cements, and 450–650 m2·kg−1 for 'rapid hardening' cements. The cement is conveyed by belt or powder pump to a silo for storage. Cement plants normally have sufficient silo space for one to 20 weeks of production, depending upon local demand cycles. The cement is delivered to end users either in bags, or as bulk powder blown from a pressure vehicle into the customer's silo. In industrial countries, 80% or more of cement is delivered in bulk.

Setting and Hardening

Cement sets when mixed with water by way of a complex series of chemical reactions still only partly understood. The different constituents slowly crystallize, and the interlocking of their crystals gives cement its strength. Carbon dioxide is slowly absorbed to convert the portlandite ($Ca(OH)^2$) into insoluble calcium carbonate. After the initial setting, immersion in warm water will speed up setting. Gypsum is added as an inhibitor to prevent flash (or quick) setting.

The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element. Concrete can be used in the construction of structural elements like panels, beams, and street furniture, or may be cast-in situ for superstructures like roads and dams. These may be supplied with concrete mixed on site, or may be provided with 'ready-mixed' concrete made at permanent mixing sites. Portland cement is also used in mortars (with sand and water only), for plasters and screeds, and in grouts (cement/water mixes squeezed into gaps to consolidate foundations, road-beds, etc.).

When water is mixed with Portland cement, the product sets in a few hours, and hardens over a period of weeks. These processes can vary widely, depending upon the mix used and the conditions of curing of the product, but a typical concrete sets in about 6 hours and develops a compressive strength of 8 MPa in 24 hours. The strength rises to 15 MPa at 3 days, 23 MPa at 1 week, 35 MPa at 4 weeks, and 41 MPa at 3 months. In principle, the strength continues to rise slowly as long as water is available for continued hydration, but concrete is usually allowed to dry out after a few weeks and this causes strength growth to stop.

Types of Portland Cements

Five types of Portland cements exist, with variations of the first three according to ASTM C150. Type I Portland cement is known as common or general-purpose cement. It is generally assumed unless another type is specified. It is commonly used for general construction, especially when making precast, and precast-prestressed concrete that is not to be in contact with soils or ground water. The typical compound compositions of this type are:55% (C3S), 19% (C2S), 10% (C3A), 7% (C4AF), 2.8% MgO, 2.9% (SO3), 1.0% ignition loss, and 1.0% free CaO (utilizing Cement chemist notation).A limitation on the composition is that the (C3A) shall not exceed 15%.

Type II provides moderate sulphate resistance, and gives off less heat during hydration. This type of cement costs about the same as type I. Its typical compound composition is:51% (C3S), 24% (C2S), 6% (C3A), 11% (C4AF), 2.9% MgO, 2.5% (SO3), 0.8% ignition loss, and 1.0% free CaO. A limitation on the composition is that the (C3A) shall not exceed 8%, which reduces its vulnerability to sulphates. This type is for general construction exposed to moderate sulphate attack, and is meant for use when concrete is in contact with soils and ground water, especially in the western United States due to the high sulphur content of the soils. Because of similar price to that of type I, type II is much used as a general purpose cement, and the majority of Portland cement sold in North America meets this specification.

Note: Cement meeting (among others) the specifications for types I and II has become commonly available on the world market. Type III has relatively high early strength. Its typical compound composition is: 57% (C3S), 19% (C2S), 10% (C3A), 7% (C4AF), 3.0% MgO, 3.1% (SO3), 0.9% ignition loss, and 1.3% free CaO.

This cement is similar to type I, but ground finer. Some manufacturers make a separate clinker with higher C3S and/or C3A content, but this is increasingly rare, and the general purpose clinker is usually used, ground to a specific surface area typically 50–80% higher. The gypsum level may also be increased a small amount. This gives the concrete using this type of cement a three-day compressive strength equal to the seven-day compressive strength of types I and II. Its seven-day compressive strength is almost equal to 28-day compressive strengths of types I and II.

The only downside is that the six-month strength of type III is the same or slightly less than that of types I and II. Therefore, the long-term strength is sacrificed. It is usually used for precast concrete manufacture, where high one-day strength allows fast turnover of moulds. It may also be used in emergency construction and repairs, and construction of machine bases and gate installations. Type IV Portland cement is generally known for its low heat of hydration. Its typical compound composition is: 28% (C3S), 49% (C2S), 4% (C3A), 12% (C4AF), 1.8% MgO, 1.9% (SO3), 0.9% ignition loss, and 0.8% free CaO.

The percentages of (C2S) and (C4AF) are relatively high and (C3S) and (C3A) are relatively low. A limitation on this type is that the maximum percentage of (C3A) is seven, and the maximum percentage of (C3S) is thirty-five. This causes the heat given off by the hydration reaction to develop at a slower rate. However, as a consequence the strength of the concrete develops slowly. After one or two years the strength is higher than the other types after full curing. This cement is used for very large concrete structures, such as dams, which have a low surface to volume ratio. This type of cement is generally not stocked by manufacturers, but some might consider a large special order. This type of cement has not been made for many years, because Portland-pozzolan cements and ground granulated blast furnace slag addition offer a cheaper and more reliable alternative.

Type V is used where sulphate resistance is important. Its typical compound composition is: 38% (C3S), 43% (C2S), 4% (C3A), 9% (C4AF), 1.9% MgO, 1.8% (SO3), 0.9% ignition loss, and 0.8% free CaO. This cement has a very low (C3A) composition which accounts for its high sulphate resistance. The maximum content of (C3A) allowed is 5% for type V Portland cement. Another limitation is that the (C4AF) + 2(C3A) composition cannot exceed 20%. This type is used in concrete to be exposed to alkali soil and ground water sulphates which react with (C3A) causing disruptive expansion.

It is unavailable in many places, although its use is common in the western United States and Canada. As with type IV, type V Portland cement has mainly been supplanted by the use of ordinary cement with added ground granulated blast furnace slag or tertiary blended cements containing slag and fly ash. Types Ia, IIa, and IIIa have the same composition as types I, II, and III. The only difference is that in Ia, IIa, and IIIa, an air-entraining agent is ground into the mix. The air-entrainment must meet the minimum and maximum optional specification found in the ASTM manual.

These types are only available in the eastern United States and Canada, only on a limited basis. They are a poor approach to air-entrainment which improves resistance to freezing under low temperatures. Types II(MH) and II(MH)a have a similar composition as types II and IIa, but with a mild heat.

Aggregates

Aggregates accounts for up to 75% of concrete by volume thus have a significant effect in its properties and performance. Cement without aggregates can only be applied to a few special purposes, a majority of concrete applications are only possible due to the presence of aggregates. Modern construction has seen the use of aggregates of various types with the evolution of technology. This has led to development of highly complex mixtures which may consist of several binders, admixtures and aggregates of different types and sizes. In short, the use of aggregates has become a little more than simply being a bulk constituent for mass and economy.

According to (Odero, 2015), aggregates have functions in concrete such as:

1. They contribute to concrete strength through mechanical linking between aggregate particles hence making the concrete stiff and rigid. This property is necessary for its engineering uses.
2. They reduce moisture related deformations in concrete such as shrinkage hence providing volumetric stability to the concrete.
3. They provide durability to the concrete as they are generally more stable of all the constituents in concrete.
4. Provide bulk of concrete allowing it to be placed.
5. Impart wear resistance to concrete making it suitable for use on pavements and hydraulic structures.
6. They restrain creep and thus aid in limiting long term deformations.

Classification of aggregates can be based on size, specific gravity or source of the aggregates. Classification by sizes gives two groups namely:

Fine aggregates having particle size less than 4.75mm and are retained on 75µm sieve and coarse aggregate have particle size more than 4.75mm.

Fine Aggregates

Fine aggregates are basically sands won from the land or the maritime environment. They generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve.

For the sake of this project, I worked with sharp sand (river side/bank sand). It is whitish grey in colour and it's the best sand for construction activities. It is widely used for constructions.

Properties of fine aggregate

1. It should be clean and coarse.
2. It should be free from any organic or vegetable matter.
3. Maximum permissible clay content should be 8% in sand.
4. It should be chemically inert.
5. It should contain sharp, angular grains.
6. It should be able to mix with binding materials easily.
7. It should not contain salts which attract moisture from the atmosphere.

Coarse aggregates

It is an integral part of many construction applications, sometimes used on their own, such as a granular base placed under a slab or pavement, or as a component in a mixture, such as asphalt or concrete mixtures. Coarse aggregates are generally categorized as rock larger than a standard No. 4 sieve (3/16 inches) and less than 2 inches. Coarse aggregate is mined from rock quarries or dredged from river beds, therefore the size, shape, hardness, texture and many other properties can vary greatly based on location. Even materials coming from the same quarry or pit and type of stone can vary greatly.

Most generally, coarse aggregate can be characterized as either smooth or rounded (such as river gravel) or angular (such as crushed stone). Because of this variability, test methods exist to characterize the most relevant characteristics, since exact identification would be impossible. Several key characteristics that are frequently used to describe the behavior of coarse aggregates include relative density (or specific gravity), bulk density, and absorption. Most frequently, the density of coarse aggregate is described using the specific gravity, otherwise known as the relative density, of the coarse aggregate. It consists of small angular or rounded grains of silica.

Grading of fine aggregates has a great influence on the workability of a concrete mix. This is because it influences the total aggregate area to be wetted and the relative aggregate volume in the mix. In order to ensure proper workability, one should conform to standard grading which ensures that the voids left by one particle are filled by particles of the next smaller size. Apart from workability, finer fractions of fine aggregates with sizes less 150µm have a great influence on the segregation and bleeding of the concrete. This is because they are light and are easily separated from other concrete constituents. Fine aggregates act as filler and fill the voids between the coarse aggregates. They are smaller, hence, are able to occupy the small voids between the larger coarse aggregates. They also reduce porosity of concrete. Porosity in concrete results due to presence of voids which can adequately be filled by well graded fine aggregates as smaller particles are able to occupy the very tiny voids.

Binders

Binders are fine, granular materials that form a paste when water is added to them. This paste hardens and encapsulates aggregates and reinforcement steel. Immediately after water is added, cement paste begins to harden through a chemical process called hydration. Hydration takes place at different rates according to the different properties of the binders and admixtures used, the water-to-cement ratio and the environmental conditions under which the concrete is placed.

Water

Water is an inorganic, transparent, tasteless, odourless, and nearly colourless chemical substance, which is the main constituent of Earth's hydrosphere and the fluids of all known living organisms (in which it acts as a solvent). It is vital for all known forms of life, even though it provides no calories or organic nutrients. Its chemical formula is H_2O, meaning that each of its molecules contains one oxygen and two hydrogen atoms, connected by covalent bonds. Two hydrogen atoms are attached to one oxygen atom at an angle of 104.45°.

"Water" is the name of the liquid state of H_2O at standard conditions for temperature and pressure. It forms precipitation in the form of rain and aerosols in the form of fog. Clouds consist of suspended droplets of water and ice, its solid state. When finely divided, crystalline ice may precipitate in the form of snow. The gaseous state of water is steam or water vapour.

Water covers 71% of the Earth's surface, mostly in seas and oceans. Small portions of water occur as groundwater (1.7%), in the glaciers and the ice caps of Antarctica and Greenland (1.7%), and in the air as vapour, clouds (consisting of ice and liquid water suspended in air), and precipitation (0.001%). Water moves continually through the water cycle of evaporation, transpiration (evapotranspiration), condensation, precipitation, and runoff, usually reaching the sea. Water is the key ingredient, which when mixed with cement, forms a paste that binds the aggregate together.

The water causes the hardening of concrete through a process called hydration. Hydration is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates or hydration products. Details of the hydration process are explored in the next section. The water needs to be pure in order to prevent side reactions from occurring which may weaken the concrete or otherwise interfere with the hydration process.

The role of water is important because the water to cement ratio is the most critical factor in the production of "perfect" concrete. Too much water reduces concrete strength, while too little will make the concrete unworkable. Concrete needs to be workable so that it may be consolidated and shaped into different forms (i.e. walls, domes, etc.). Because concrete must be both strong and workable, a careful balance of the cement to water ratio is required when making concrete.

The common specification regarding quality of mixing (construction) water is that it should be fit for drinking. Such water should organic solid less than 1000ppm. Some water which are not portable may be used in making concrete with any significant effect. Dark colour or bad smell water may be used if they do not possess deleterious substances. The pH of water to even 9 is allowed if it does not taste brackish.

2.2.6 Compaction of concrete

Compaction of concrete is the process that expels air entrapped air from freshly placed concrete and packs together the density of the concrete, significantly increases the ultimate strength of the concrete and bonding with reinforcement.

The earliest means of achieved with a rod or ramming or by vibrating, the experiment studies have shown that 1% air in concrete reduces strength by about 6% (Bergold, 2013). Thus the aim of compacting the concrete is to acquire a dense mass without any voids, permitting the concrete to surround all reinforcements and fill the corners.

Purpose of compaction of concrete

1. To remove air bubbles trapped in concrete
2. To achieve high density
3. Also, to improve strength and durability
4. To eliminate honeycomb and other defects

2.2.7 Age of concrete

Concrete strength increases with age as long as moisture and a favourable temperature are present for hydration of cement. Rate of gain of strength is faster to start with and rate get reduced with age. It is customary to assume the 28 days strength as full strength of concrete. But actually, concrete develops strength beyond 28 days also.

2.2.8 Curing of concrete

Concretes harden because of the hydration of the chemical reaction between Portland cement and water. Each bag of Portland cement needs three gallons of water for hydration Excessive evaporation of water from newly placed concrete can cause the cement hydration to stop too soon. To prevent loss of water the placed concrete should be protected and needs to be cured. A rapid loss of water causes the concrete to shrink and create tensile stresses when the surface is dried. The stresses may result in plastic shrinkage and cracks.

Methods of curing

Concrete can be kept moist by a number of curing methods the adoption of a particular method depends on the nature of work and climate conditions. The methods can be grouped into two.

1. Method which supply additional moisture to the concrete
2. Method which prevents loss of moisture from the concrete by sealing the surface

Curing by water

This is the best and most effective method of curing concrete. It is done by floating ponding or sparing. Continuous sprinkling of water is also an excellent method of curing.

Water retaining methods

These methods involve the use of covering that are kept continuously wet, such as sand , canvas or straw Concrete cured by either of the methods, the entire concrete surface is covered. The materials used to retain the water must be damp during the curing period in vertically formed concrete members the best way of curing is by leaving the frame work in place for some time.

2.3 RICE HUSK ASH

Rice husk is a by-product of agriculture. It is the hard protective coverings of rice grains which are separated from the grains during milling process(Tran et al., 2011). Rice husk is an abundantly available waste material in all rice producing countries, and it contains about 30%-50% of organic carbon. It can be used for partial replacement of cement or sand in light weight concrete.

Rice husks have been attracted as value added material towards waste utilization and cost reduction in domestic and industrial processing. Rice husk (RH) is widely available in rice producing countries like China and India which contributes 33% and 22% of global rice production respectively, as by-product of the rice milling. RH content ranges from 16-25% of paddy (Della et al., 2002). Every year approximately 500 million tonne paddy produced by world and 120 million tonnes of paddy produced by India, it gives around 24 million tonnes of RH per year (Trejo et al., 2014).

Rice husk ash (RHA) is the by-product of RH, when it burnt in ambient atmosphere. Due to low density and less commercial interest of RH, handling as well as transportation it is problematic, which creates disposal and serious environmental problems (Pode, 2016).

High-value applications such as the use of Rice husk ash in synthesis of silica, activated carbon, silica gels, porous carbon, zeolites, silicon carbide, silicon nitride, manufacturing of silicon chip and light weight construction materials insulations, catalysts, cordierite, ingredients for lithium ion batteries, graphene, energy storage/capacitor, carbon capture.

Rice is staple food of more than half world. Therefore, rice processing and associated business are growing vigorously. Rice husk obtain from rice milling process as by product. It is attracting as value added material for domestic and industrial processing such as preparing valuable silicon based materials, cement, as source of pet food fibre and as source of dietary fibre, preparation of activated carbon, refractory industry, polymer, rubber, preparing sorbent for waste water treatments, in bio ethanol production, to control of insect pests in stored food stuffs, ceramic industry and biosynthesis of silica nano-particles.

Extensive research has been done to utilize important properties of rice husk and its ash for industrial applications. Summarizing all these data could be helpful for smooth future research on rice husk and rice husk ash. Due to lack of awareness of its properties and applications, rice husks are not being utilized effectively. Therefore, application of RH and RHA in domestic and industrial processing not only useful to increase farm income in directly and indirectly way but also it is the alternative solution to disposal problem of RH.

Rice husk is composited of hemicelluloses 24.3%, cellulose 34.4%, lignin 19.2%, ash 18.85%, and the other trace elements 3.25%. Hemicelluloses used as recourse of activated carbon, xylose and silicon dioxide. RH contents main elemental components as Carbon 37.05%, Hydrogen 8.80%, Nitrogen 11.06%, Silicon 9.01% and Oxygen 35.03 % (Prasittisopin et al., 2014). Husk contains 17-25% silica. Rice husks have bulk density of 96-100 kg/m3, hardness (Mohr's scale) 5-6, ash 22.29%, Oxygen 31-37%, Nitrogen 0.230.32%, Sulphur 0.04-0.08%, Hydrogen 4-5% (Muthadhi et al., 2010). The composition of RH depends on many factors such as rice variety, type of fertilizer used, soil chemistry, and even the geographic localization of the production (Basha et al., 2005).

Rice husk is high in ash content as compared to other biomass fuels ranging 14-25% (Adam et al., 2006). Presence of high amount of silica makes it a valuable material for use in industrial applications (Rozainee et al., 2008).

Table 2.1: Chemical composition of RHA (Mohamed et al., 2015).

CHEMICAL COMPOSITION	RICE HUSK ASH (%)
SiO	89
FeO_3	1.28
Al_2O_3	1.20
C	18.24
CaO	1
K_2O	1.22

There are various factors which affects the ash properties such as, incinerating conditions (temperature and duration), rate of heating, burning technique (Mansaray et al, 1999).RHA plays important role in various industrial applications such as processing of refractory industry, ceramic, cement, fillers of rubber and plastic composites, cement, adsorbent and support of heterogeneous catalysts (Sevdalina et al., 2012).

Plate 2.3: Rice husk ash

2.4 REVIEW OF EXISTING WORKS RELATED TO THE STUDY

Dahiya et al. (2015) carried out partial replacement of grade 42.5 Portland cement with 20% RHA. In their result, they discovered that the initial setting time increased from 30 minutes to 60 minutes. The concrete samples were cast using 150mm x 150mm x 150mm mould, and the target strength was M20. The Compressive Strength of M20 (0% RHA) concrete at 3, 7 and 28 days are 14.50 MPA, 20.50 MPA and 30.3 MPA respectively. Whereas on replacing cement with 20% of RHA it comes out to be 13.40 MPA, 21.60 MPA and 30.70 MPA respectively. In the highlight of his research, water-cement ratio increased from 0.6 to 0.8 to achieve a slump of 75mm-100mm, but strength gain was almost the same at 20% replacement.

Naveen et al. (2015) carried out a research on the effect of RHA on compressive strength of concrete. He worked on target strengths of M30 and M60. Grade 53 ordinary Portland cement was used for this research, and water to cement ratio of 0.43 and 0.35 were used. The mould size employed was 150mm x 150mm x 150mm, and 60 specimens of this was prepared. From his research, the maximum compressive strength was obtained at 10% replacement. The result was also the same considering M60 grade of concrete.

Bolla et al. (2015) carried out a research on the effect of partial replacement of cement with RHA on concrete. The cement has been replaced by rice husk ash accordingly in the range of 0%, 5%, 10%, 15%, and 20% by weight of cement for the mix. Concrete mixtures were produced, tested and compared in terms of compressive strengths with the conventional concrete. These tests were carried out to evaluate the mechanical properties for the test results of 7, 28, and 60curing days for compressive strengths. The cement used for this test was grade 53, and cube size of 150mm x 150mm x 150mm was adopted. From results, the maximum compressive strength was attained at 10% replacement. The author reported that the RHA has a minimum silicon dioxide of 90%.

Emmanuel and Akaangee (2015)collected 4.7kg of RH and weighed it using Sartorius-2 weighing scale. 1.085kg of rice hush ash was obtained after an open burning of the rice husk in a local furnace for two hours at a temperature range of 600°C to 700°C. The finely divided ash was left to cool for 24 hours inside the furnace. It was then grounded for four minutes to obtain a finer particle size with the aid of a disc-mill, sieved manually using a 45 micro meter sieve to ensure proper fineness of the ash. Haven casted and crushed the cubes, the results obtained showed that compressive strength of the cubes decreases as the percentage of rice husk ash content increases. The major setback in their research work was that 40mm x 40mm x 160mm moulds were used to prepare the concrete samples, and the target design strength was not specified, including the mix ratio adopted. But the major highlight of the research work was that maximum compressive strength was obtained at 15% replacement of OPC with RHA.TY -
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Oyewumi et al (2014) [Nigeria) investigated the effect of RHA in concrete and the proportion of materials.From the result, it can be seen that none of the partial replacement met or the control target strength of 27.47 Mpa. The closest for 28 day strength however came at 10% partial replacement. This is in contrast with two previous results.

Tsado et al (2014) (Nigeria) carried out the comparative analysis of properties of some artificial pozzolana in concrete production, which included rice husk ash, corn cub ash, and sheanut shell ash. However, we will focus on the result from RHA. A little consideration from his research showed that the silicon dioxide content of the RHA was too low at 48.44% (Bida, Niger state Nigeria). The sample was prepared as 1:2:4 mix ratio, with a water to cement ratio of 0.6.60 number of 150mm cubes were prepared, and the result. The sample was prepared as 1:2:4 mix ratio, with a water to cement ratio of 0.6.60 number of 150mm cubes were prepared. From the result, none of the partial replacement met the 28 days strength of the control mix design. The closest with considerable value came at 10% partial replacement.

Zareel et al (2017) [Iran] evaluated the durability and mechanical properties of rice husk ash as a partial replacement of cement in high strength concrete containing micro silica. The research presented resulted from various ratios of rice husk ash (RHA) on concrete indicators through 5 mixture plans with proportions of 5, 10, 15, 20 and 25% RHA by weight of cement in addition to 10% micro-silica (MS). This was compared with a reference mixture with 100% Portland cement. Tests results indicated the positive relationship between 15 % replacement of RHA with increase in compressive strengths by about 20%. The optimum level of strength and durability properties generally gain with addition up to 20%, beyond that is associated with slight decrease in strength parameters by about 4.5%. In the batching, 8 cubes of 100mm x 100mm x 100mm samples were prepared, and a water to cement ratio of 0.4 was maintained throughout the test.

From the result, you can see that the maximum compressive strength was obtained at 20% replacement. Note that this research is aimed at high strength concrete, and Micro-Silica (MS) has been added.

2.5 SUMMARY OF LITERATURE REVIEW

1. Optimum replacement of cement with RHA occurs between 10 – 20% replacements.
2. Concrete performance in terms of increased compressive strength increases when plasticizers are used.
3. Water requirement increases as the percentage of RHA increases. Best performance was observed at water to cement ratio of 0.4.
4. Plasticizer is recommended when using RHA in high volume for concrete production.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 INTRODUCTION

This research is aimed at determining the concrete properties by partially replacing cement with rice husk ash sample obtained from Anaku and Omor town, Anambra state. The practical/ experiment was conducted at Nnamdi Azikiwe University concrete laboratory, Awka, Anambra state. The materials, apparatus, equipment to be used regarding this research will be discussed in this chapter with the set of standards, as well operations.

Concrete is the most versatile construction materials and one of the most viable materials for infrastructural development of any nation – concrete is achieve here by mixing cement (BUA), fine aggregation, coarse aggregate, water and some percentages of the Agro-waste such as rice husk ash in a proper proportions.

3.2 MATERIALS

The materials used in this project work include the following below:

3.2.1 Cement

Cement (BUA) was used in the course of this project. These type of cement are normally sold in Awka within Anambra State. In the course of this project, the Portland cement used was bought at Eke-Awka market (ring road). The Cement was taken into a concrete laboratory and was carefully kept away from water to avoid setting.

Plate 3.1: Cement

3.2.2 Coarse Aggregate

This is to be used as coarse aggregate, during the course of this project, a mixture of 3/4 to ½ inch (19mm to 12.5mm) crushed granite size was used in order to allow easy compaction and it is readily availability in the market. The granite used was bought from Agu-Awka, Anambra State.

Plate 3.2: Coarse aggregate (crushed granite)

3.2.3 Sand (Fine Aggregate)

The fine aggregate used for this project work is shape sand. These type of fine aggregate was obtained here at Agu-Awka, Anambra State. The sand are normally batch by bags where sufficient quantities was obtained and spread out for few days before use to dry in order to removing dampness and moisture content in order to maintain consistent when batching.

Plate 3.3: Sand (Fine Aggregate)

3.2.4 Water

Water is the key ingredient, it is normally mixed with cement to form a paste that binds aggregates together. The water causes hardening of concrete through the process known as hydration. The water used was obtained from the tank at concrete lab. The water is colourless, odourless, and generally satisfactory for the work to be carried.

3.2.5 Rice Husk Ash

Rice husk is the agro-waste product partially replacing cement in the concrete mixture. The Rice husk sample was obtained from rice mill factory located in Anaku and Omor town in Anambra State. It was found suitable for the purpose of this experiment work.

Plate 3.4: (a) Rice Husk and (b) Rice Husk Ash

Preliminary preparation of Rice husk sample

The Rice husk was sun dried for 3 weeks so that it would lose all its water content before it was burnt to ash. The following equipments were set-up; a drum, pan, wire mesh and charcoal. Charcoal was lighted and heated up, after which it was put inside the drum. The wired mesh containing the Rice husk was placed inside the drum which contains heated charcoal.

The specimens of rice hush ash was obtained after an open controlled burning of the rice husk in a local furnace for four hours at a temperature range of 600°C to 700°C which was measured with pyrometer. The finely burnt ash was left to cool for 24 hours inside the furnace. It was then grinded for five minutes to obtain a finer particle size with the aid of a stone.

Plate 3.5: Local furnace equipment

3.3 METHODOLOGY

3.3.1 Test and Analysis of Concrete Specimens

Using a mix ratio of 1:2:4 and water cement ratio of 0.55 ,concrete cubes with a dimension of 150mm x 150mm x 150mm were produced by partially replacing cement (BUA). Rice husk ash (RHA) variation is at 0%, 2.5%, 5%and 7.5%, the cube samples were cured in water for 7, 14, 21 and 28 days and subjected to compressive strengths. The constituent materials were batched by weight. The mix produced at 0% Rice Husk Ash replacement served as the control mix.

3.3.2 Methods and Test Equipments

The following equipments in the concrete laboratory are to be used in the course of this study for the experiments:

1. Weighing machine/weighing balance.
2. B.S. Sieves
3. Moulds

4. Rammer/Tamping rod
5. Universal testing machine (compressive strength test).
6. Slump cone for workability.

Weighing Balance

Weighing balance (weighing scale) is a device to measure weight or mass. A pan are normally placed on top of the weighing balance and before any reading will be taken the weight of the empty pan will be taken first. The weighing balance are normally graduated from 0kg – 20kg. In a situation where any of the sample want to measure pass 20kg in size, then it will be measured in batch by batch. It is also used for weighing the cubes after curing and before curing.

Mould

An open cast-iron or steel square comprising of four sides and a base plate to which the mould is damped. They are of size 150mm by 150mm by 150mm. These moulds can be used to form specimens for testing compressive strength.

Rammer/Tamping Rod

This is a steel bar about 24inches in length (i.e. 600mm) having the tamping end or both ends rounded to a hemispherical tip, the diameter which is 5/8inch approximately 16mm. It has 1.8kg mass and bottom ramming face $25mm^2$ which is used to tap the concrete to achieve good compaction to avoid honey comb.

Sieve Analysis Gradation of Constituent Aggregates

This test was carried out to obtain the range of particles size of an aggregate, to obtain the normal size of the particles and its suitability as aggregate and to be free from impurities like solid particles. Grading of aggregate is important in the proportioning of the concrete mixes. Grading is done to avoid adverse effect on the consistency of the concrete, which would invariably affect the strength of the concrete.

Apparatus needed for the test includes:

1. Stack of sieve (IS sieve size; 31.5mm, 26.5mm, 19mm, 14mm, 12.5mm, 10mm, 4.75mm, 2mm, 1.18mm, 0.6mm, 0.425mm, 0.3mm, 0.15mm, 0.075mm) including tray and cover
2. Weighing balance (accuracy to 0.01g)
3. Sieve brushes (soft and hard)
4. Mechanical sieve shaker

Procedure

1. A representative weighed sample is poured in sieve
2. The sample is sieved using a set of IS sieve agitated by the mechanical shaker
3. On completion of sieving, the material on each sieve is weighed
4. Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.
5. Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100

Percentage retained, cumulative percentage retained, cumulative percentage passing and percentage passing were calculated, tabulated and plotted using a semi-log graph. The values were obtained as follows:

Percentage retained on any sieve = $\frac{\text{Mass retained}}{\text{Total mass of sample}}$ X 100 (1)

Cumulative % retained on any sieve = sum of % retained on all sieves with greater aperture (2)

Percentage finer than any sieve = 100% - (cumulative % retained) (3)

Determination of the Workability of Concrete

Slump Test

Concrete slump test is an empirical test that measures the workability of fresh concrete. The test is performed to test the consistency of freshly mixed concrete in a specific batch. Consistency refers to the ease and homogeneity with which the concrete can be mixed, placed, compacted and finished. This test is most widely used due to simplicity of apparatus and simple test procedure. The slump test gives a satisfactory result for the concrete mix of medium to high workability and unfortunately, it does not give the correct indication of low workability, which may give zero slump. This test is also known as slump cone test.

The apparatus consists of a mould in the shape of a frustum of a cone. The mould is filled with concrete in three layers of equal volume. Each layer is compacted with 25 strokes of tamping rod. The slump cone is lifted and the change in height of the concrete is measured. Often the only type of slump permissible is the true slump where the concrete remains intact and retains a symmetric shape.

A collapsed slump or shear slump is considered out of range of workability that can be determined by the workability test. Concretes with the same slump can exhibit different behaviour when tapped with a tamping rod. For example few fines concrete will tend to fall apart when tapped. Such concrete is only suitable for applications such as pavements or mass concrete.

This can be a useful basis in evaluating our concrete considering that this study involves partial substitution of fines.

Apparatus

1. Slump cone with a height of 300mm, bottom diameter of 200mm and top diameter of 100mm
2. Standard tamping rod
3. Non-porous base plate
4. Measuring scale
5. Plumb
6. Hand trowel

Types of Slump

True slump: The concrete mass after the test when it slumps evenly all around without disintegration is called true slump.

Shear slump: When one half of the concrete mass slides down the other is called shear slump. This type of slump is obtained in a lean concrete mix.

Collapse slump: When the sample is collapsed due to adding excessive water, it is known as collapse slump.

Zero slump: For very stiff or dry mixes. It does not show any changes after removing the slump cone.

Procedure

1. First, clean the inner surface of the slump cone and then apply oil to it for easy removal.

2. Set the cone on a horizontal non-porous and non-absorbent base plate.
3. Collect a sample of concrete to perform the slump test.
4. Fill the cone fully by pouring freshly mixed concrete in three equal layers.
5. First fill 1/3 the volume of the cone with sample, compact the concrete by tamping 25 times with the standard tamping rod over the cross section.
6. Now fill 2/3 and again tamp 25 times, just into the top of the first layer.
7. Fill to overflowing, tamp again 25 times just into the top of the second layer. Top up the cone till it overflows.
8. Level off the surface with the steel rod using a rolling action.
9. Clean any concrete around the base and top of the cone.
10. Carefully lift the cone straight up without disturbing the cone-shaped concrete.
11. Place the cone beside the concrete and place the plumb horizontally on top of the cone and across the slumped concrete.
12. Measure the difference between the height of the cone and the concrete sample. Take several measurements with measuring scale.

Plate 3.6: Measuring slump value

Slump test was carried out on all samples at different Rice husk ash percentage variation such as 0%, 2.5%, 5% and 7.5%.

3.3.3 Mix Proportion

The concrete material was batched by weight. The ratio of the mix was 1:2:4 with the water cement ratio of 0.55.The mixing was carried out by hand on a bucket to avoid loss of water, clean hard ground surface for mixing with the help of shovel an hand trowel. Measuring cylinder was used to measure the amount of water to be used in the concrete mix. This measuring cylinder is graduated in volume (ml) from 0ml to 1000ml (i.e. 1000ml equal to 1litre). The appropriate size of granite and sand was then measured, while some amount of cement was replaced with RHA. Then the freshly mixed concrete is thoroughly mixed.

Table 3.1: Variation of Rice Husk Ash from Anaku and Omor town

Test	Cement (%)	Rice Husk Ash(%)
1	100	0
2	97.5	2.5
3	95	5.0
4	92.5	7.5

Plate 3.7: Batching of concrete

3.3.4 Casting and Curing of Concrete

Before casting was taken place, the 150mm x 150mm x 150mm steel cube moulds use was tightened, cleaned and oiled. The essence of oiling it is to facilitate easy and smooth demoulding of the concrete after hardening. The concrete mix was then poured into the moulds in 3 layers. The concrete was tamped 25 blows before adding another layer of concrete to the mould. This is to ensure that air bubbles are driven out and that the concrete is properly compacted. Excess concrete on the mould or on the floor was removed in time to avoid it from hardening. The surface of the concrete was then leveled and allowed to harden slightly before being marked for identification. Cement was replaced with 0%, 2.5%, 5% and 7.5% Rice husk ash sample obtained from Anaku and Omor town, and 3 cubes were casted for each Rice husk variation with cement. A total number of cubes casted were 96 cubes and these cubes were cured for 7 days, 14 days, 21days and 28 days.

Plate 3.8: Curing of concrete cube specimens

3.3.5 Compressive strength test

The concrete cubes are tested for their compressive strength at the 7th, 14t, 21th and 28th day of the curing.

Apparatus

1. Compression testing machine

2. Weighing balance

Procedure

The cubes were then removed from the curing tanks, and then allowed to dry under room temperature for a few hours. Each cube was placed centrally on the universal testing machine of 1,000KN, in a position such that the load is applied to the face adjacent to the marked/exposed face during the casting. The cube was loaded uniformly until the maximum failure was achieved. Upon failure, the load applied was determined from the appropriate scale and recorded. The compressive strength is obtained as follows:

$$\text{Compressive strength} = \frac{\text{load (KN)}}{\text{sectional area of cube (m2)}} \quad (4)$$

Plate 3.9: Crushing of concrete cubes with compressive test machine

3.3.6 Proportioning of the Constituent Materials:

The materials used for the concrete casting were batched by weight, the analysis and proportioning are shown below.

i. Density of concrete = 2400kg/m^3
ii. Volume of cube used = 0.15m x 0.15m x 0.15m = 0.00375m^3
iii. Mass = Density x volume
iv. Mass = 2400kg x 0.003375m^3
v. Mass = 2400kg x 0.003375 = 8.1kg.
vi. Mix ratio = 1:2:4
vii. Water-cement ratio (W/C) = 0.55

At 0% (Control):

i. Mass= 8.1kg
ii. Mixed ratio = 1:2:4
iii. Water cement ratio = 0.5
iv. Total of 12 cubes for 0% (7 days, 14 days, 21 days & 28days)
v. 1:2:4 = 7
vi. Where 1 – cement, 2 – sand, 4 = coarse aggregate.
vii. $^1/_7$ x 8.1 = 1.16kg of cement
viii. $^W/_C$ = 0.55
ix. $^W/_{1.16}$ = 0.55
x. W = 0.55 x 1.16 = 0.638 liters of water
xi. W= 638ml

xii. $^{2}/_{7}$ x 8.1kg= 2.31kg of sand

xiii. $^{4}/_{7}$ x8.1kg =4.63 kg of gravel.

To calculate for 2.5% RHA to cement replacement

i. RHA: 2.5/100 x 1.16= 0.029

ii. Cement: 1.16 – 0.029= 1.131kg

To calculate for 5% RHA to cement replacement

i. RHA: 5/100 x 1.16= 0.058

ii. Cement: 1.16 – 0.058= 1.102kg

To calculate for 7.5% RHA to cement replacement

i. RHA: 7.5/100 x 1.16= 0.087

ii. Cement: 1.16 – 0.087= 1.073kg

To Calculate for RHA 0% (7days, 14 days, 21days, and 28days)

Three cubes per replacement for each number of curing days. Hence, 12 cubes were adopted for each mix proportion.

i. Cement= 1.16kg x 12cubes= 13.92kg

ii. RHA= 0kg

iii. Sand= 2.31kg x 12cubes= 27.72kg

iv. Stone= 4.63kg x 12cubes= 55.56kg

v. Water= 638ml x 12cubes= 7656ml

To Calculate for RHA 2.5% (7days, 14 days, 21days, 28days)

Three cubes per replacement for each number of curing days. Hence, 12 cubes were adopted for each mix proportion.

i. Cement= 1.131kg x 12cubes= 13.572kg
ii. RHA = 0.029kg x 12cubes= 0.348kg
iii. Sand= 2.31kg x 12cubes= 27.72kg
iv. Stone= 4.63kg x 12cubes= 55.56kg
v. Water= 638ml x 12cubes= 7656ml

To Calculate for RHA 5% (7days, 14 days, 21days, 28days)

Three cubes per replacement for each number of curing days. Hence, 12 cubes were adopted for each mix proportion.

i. Cement= 1.102kg x 12cubes= 13.224kg
ii. RHA = 0.058kg x 12cubes= 0.696kg
iii. Sand= 2.31kg x 12cubes= 27.72kg
iv. Stone= 4.63kg x 12cubes= 55.56kg
v. Water= 638ml x 12cubes= 7656ml

To Calculate for RHA 7.5% (7days, 14 days, 21days, 28days)

Three cubes per replacement for each number of curing days. Hence, 12 cubes were adopted for each mix proportion

i. Cement= 1.073kg x 12cubes= 12.876kg
ii. RHA = 0.087kg x 12cubes= 1.044kg
iii. Sand= 2.31kg x 12cubes= 27.72kg

iv. Stone= 4.63kg x 12cubes= 55.56kg
v. Water= 638ml x 12cubes= 7656ml

48 number of concrete cubes were recorded for variation of Rice husk sample obtained in Anaku and Omor town.

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 RESULTS

This chapter comprises of the results and analysis of all tests done in the process of this project. These tests include; particle size distribution of sand and rice husk ash, workability test,and compressive strength test.

4.1.1 Particle size distribution

Figure 4.1,4.2, 4.3, and 4.4 reveals the particle size distribution analysis carried out on coarse aggregate, fine aggregate; sand and both rice husk ash samples obtained from Anaku and Omor town, in accordance with the guidelines specified by BS 1377;part 2,1990.

i. Using uniformity coefficient (Cu)= $\frac{D60}{D10}$

ii. Coefficient of Curvature (Cc)= $\frac{D30^2}{D60\ x\ D10}$

Table 4.1: Particle size distribution analysis for coarse aggregate

Sieve Size (mm)	Weight retained (g)	Percentage weight retained (g)	Cumulative Percentage retained (%)	Cumulative Percentage passing(%)
31.5	0	0	0	100
26.5	10.78	1.08	1.08	98.92
19	37.88	3.79	4.87	95.13
14	293.46	29.35	34.22	65.79
12.5	610.44	61.04	95.26	4.745
10	47.45	4.745	100.00	0
4.75	0	0	0	0

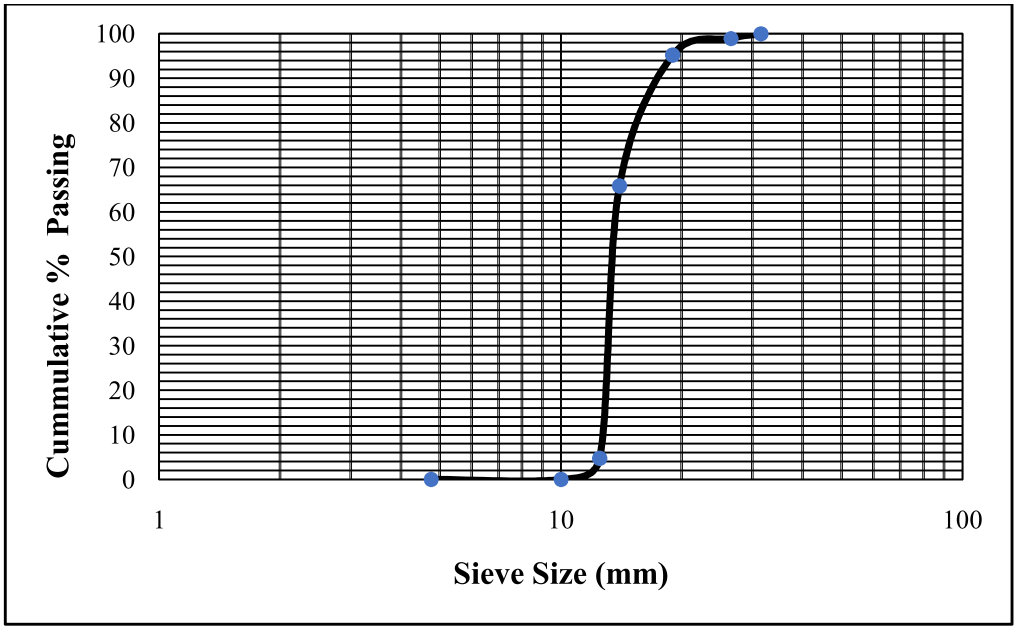

Figure 4.1: Particle size distribution analysis for coarse aggregate

Analysis from the Figure 4.1:

A. Uniformity coefficient for fine aggregate (coarse aggregate)

Cu = $\frac{D60}{D10} = \frac{16}{13} = 1.23$

B. Coefficient of curvature Cc= $\frac{D30^2}{D60\ x\ D10} = \frac{(14.5)^2}{16\ x\ 13} = 1.01$

Table 4.2: Particle size distribution analysis for sand (fine aggregate)

Sieve Size (mm)	Weight retained (g)	Percentage weight retained (g)	Cumulative Percentage retained (%)	Cumulative Percentage passing(%)
2.00	4.73	0.95	0.95	99.05
1.18	21.86	4.37	5.32	94.68
0.60	86.72	17.34	22.66	77.34
0.425	112.57	22.51	45.18	54.83
0.30	162.86	32.57	77.75	22.25

0.15	97.80	19.56	97.31	2.70
0.075	4.86	0.97	98.28	1.72
0	8.61	1.72	100	0

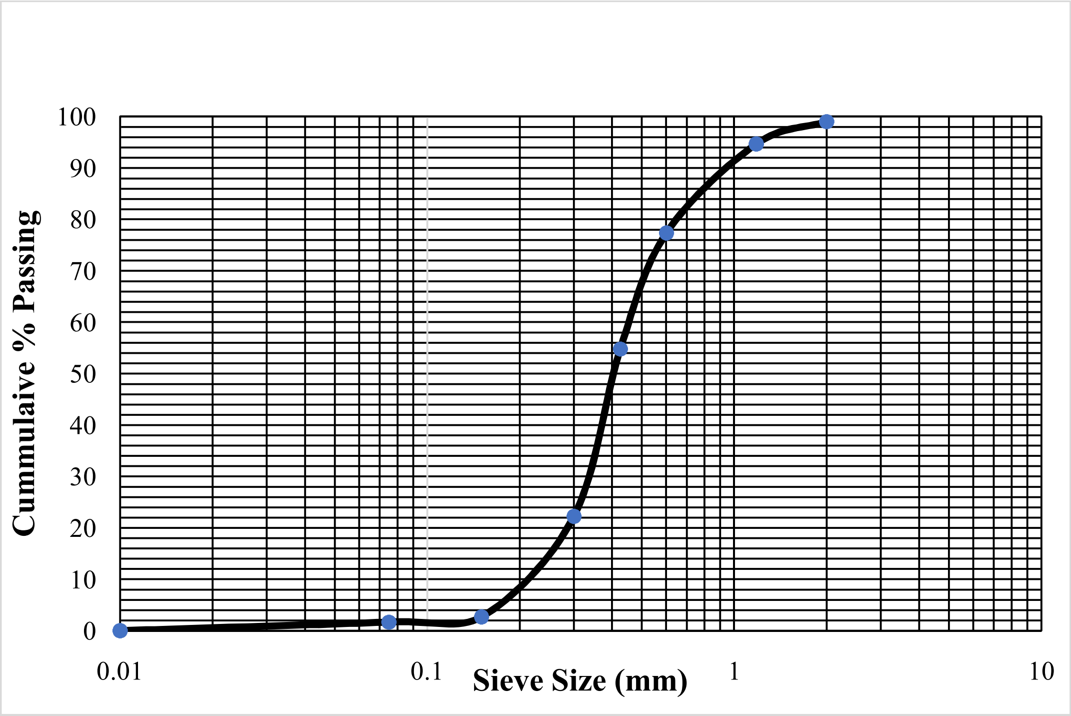

Figure 4.2:Particle size distribution analysis for sand (fine aggregate)

Analysis from figure 4.2:

A. Uniformity coefficient for sand (fine aggregate)

Cu = $\frac{D60}{D1}$ = $\frac{0.45}{0.21}$= 2.14

B. Coefficient of curvature Cc = $\frac{D30^2}{D60\ x\ D10}$= $\frac{(0.33)^2}{0.45\ x\ 0.21}$= 1.15

Table 4.3: particle size distribution analysis for rice husk ash from Anaku town

Sieve Size (mm)	Weight retained (g)	Cumulative retained	Cumulative percentage retained (%)	Cumulative percentage passing (%)
2.00	0.3	0.3	0.1	99.9
1.18	8.2	8.5	3.0	97.0
0.60	20.3	28.8	10.2	89.8
0.425	122.0	150.8	53.4	46.6
0.30	40.2	191.0	67.7	32.3
0.15	66.1	257.1	91.1	8.9
0.075	20.4	277.5	98.3	1.7
Tray	4.8	282.3	100	0.00

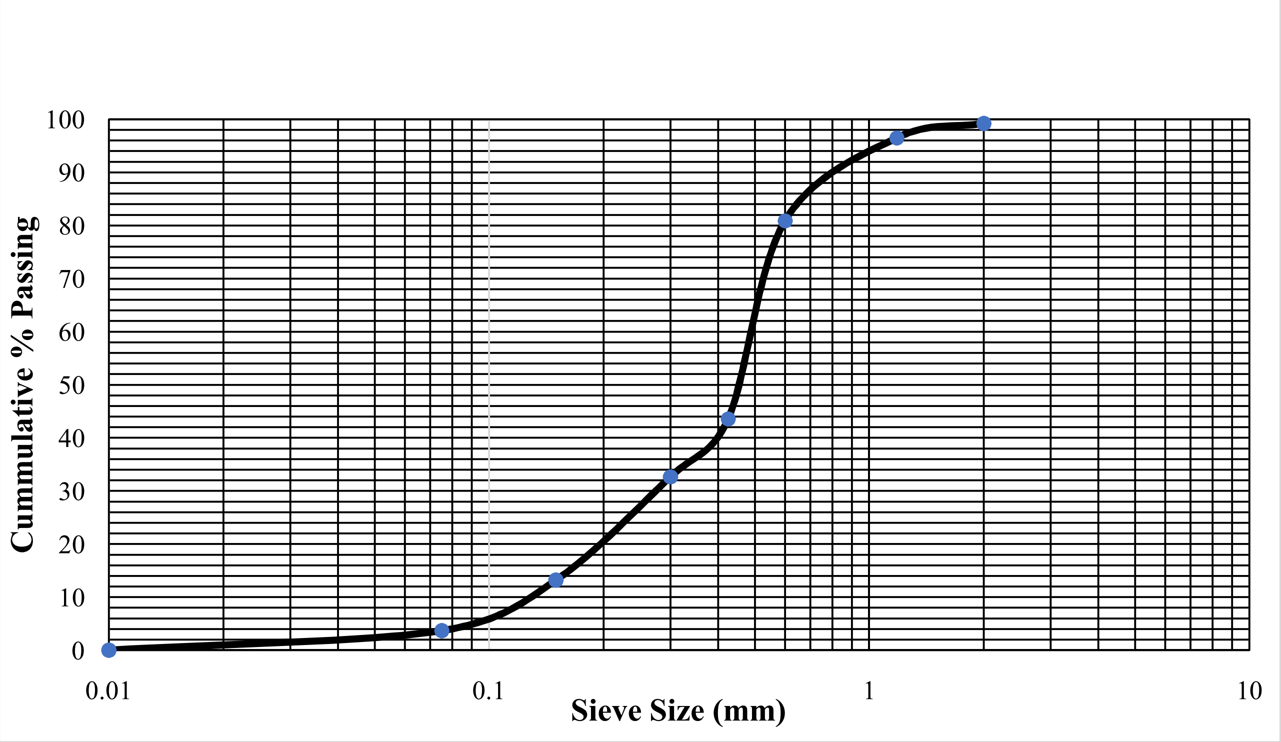

Figure 4.3:Particle size distribution analysis for rice husk ash from Anaku town

Analysis from figure 4.3:

A. Coefficient of uniformity for Rice Husk Ash

Cu = $\frac{D60}{D10}$ = $\frac{0.48}{0.14}$ = 3.4

B. Coefficient of curvature (Cc) $= \frac{D30^2}{D60\ x\ D1} = \frac{(0.28)^2}{0.48\ x\ 0.14} = 1.2$

Table 4.4: Particle size distribution analysis for rice husk ash from Omor town

Sieve Size (mm)	Weight retained (g)	Cumulative retained	Cumulative percentage retained (%)	Cumulative percentage passing (%)
2.00	2.3	2.3	0.8	99.2
1.18	7.6	9.9	3.5	96.5
0.60	43.9	53.8	19.1	80.9
0.425	105.4	159.2	56.4	43.6
0.30	30.7	189.9	67.3	32.7
0.15	55.2	245.1	86.8	13.2
0.075	26.8	271.9	96.3	3.7
Tray	10.4	282.3	100	0.00

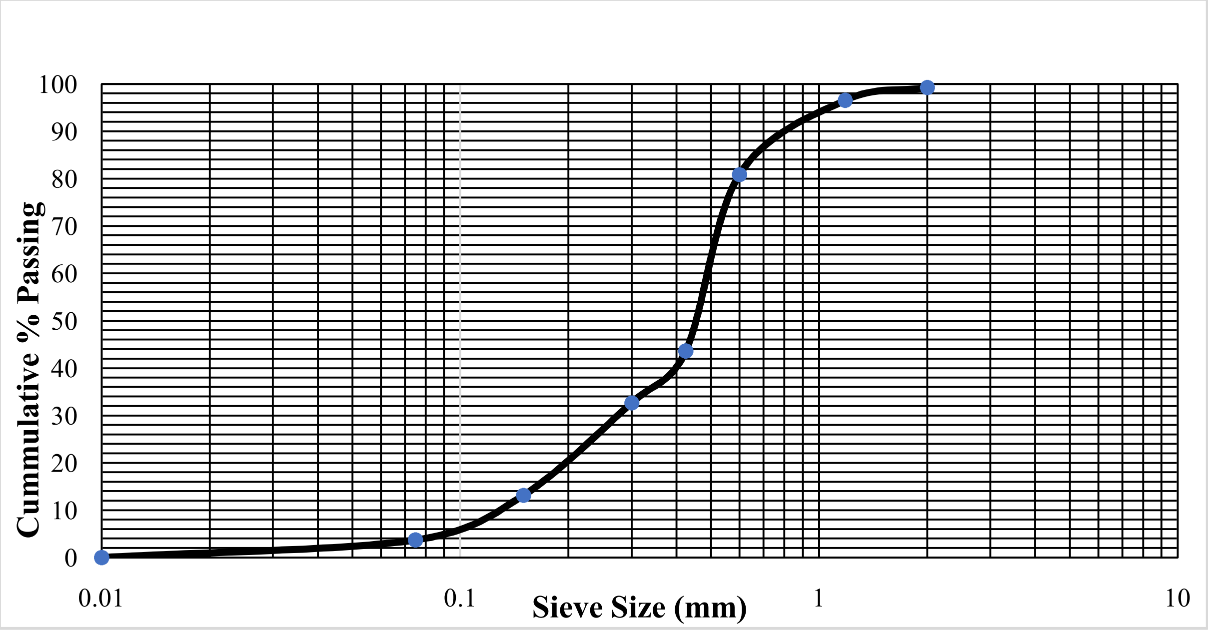

Figure 4.4: Particle size distribution analysis for rice husk ash from Omor town

Analysis from figure 4.4:

A. Coefficient of uniformity for Rice Husk Ash

$$Cu = \frac{D60}{D10} = \frac{0.49}{0.15} = 3.3$$

B. Coefficient of curvature (Cc) = $\frac{D30^2}{D60\ x\ D10} = \frac{(0.28)^2}{0.49\ x\ 0.15} = 1.1$

4.1.2 Slump Test

Table 4.5: Workability test of concrete for Anaku town specimen

Mix Proportion (%)	Height of Slump Cone (mm)	Height of Collapse (mm)	Slump Value (mm)	Water Cement Ratio (mm)
0	300	235	65	0.55
2.5	300	241	59	0.55
5	300	249	51	0.55
7.5	300	256	44	0.55

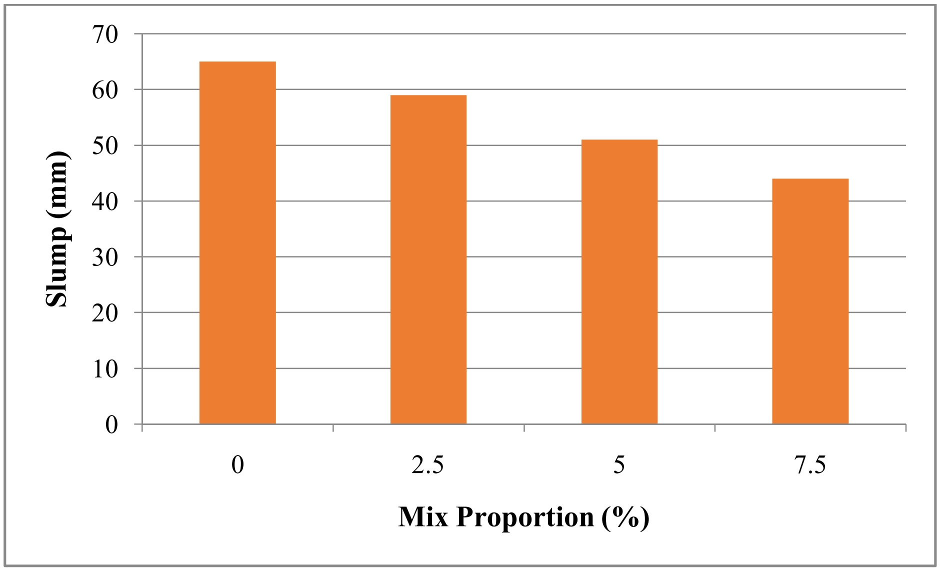

Figure 4.5: Workability test of concrete for Anaku town specimen

The variation of workability of fresh concrete is measured in terms of slump and reported in the Table 4.5 and Figure 4.5. With a water/cement ratio of 0.55, the concrete slumps were recorded for these mixes. The overall workability value of the concrete produced with RHA obtained from both towns, is less compared to conventional concrete. It was observed that the workability of concrete decreased as the percentage of Rice husk ash increased. The highest slump was obtained at 0% Rice husk ash replacement for specimens from both towns, this indicates that RHA has a significant effect on the workability of concrete. Comparing it with the recommended values of slump for various purposes as shown in Table 4.7, it could be deduced that the RHA concrete can be used for canal lining.

Table 4.6: Workability test of concrete for Omor town specimen

Mix Proportion (%)	**Height of Slump Cone (mm)**	**Height of Collapse (mm)**	**Slump Value (mm)**	**Water Cement Ratio (mm)**
0	300	235	65	0.55
2.5	300	245	55	0.55
5	300	252	48	0.55
7.5	300	260	40	0.55

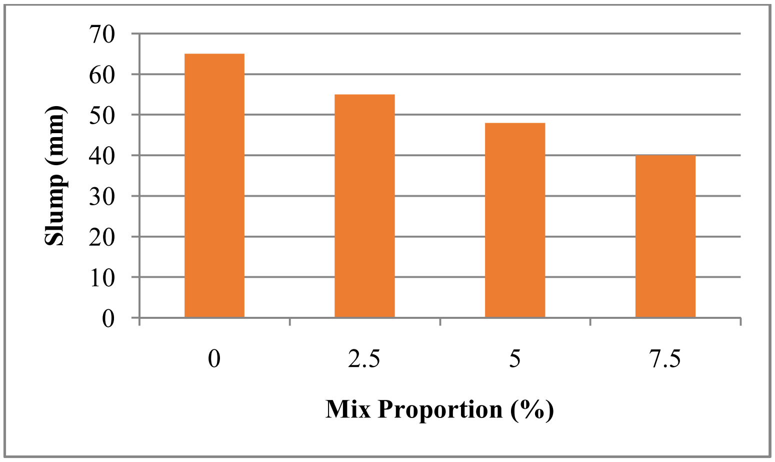

Figure 4.6: Workability test of concrete for Omor town specimen

Table4.7: Recommended values of slump for various purposes

(The constructor-civil engineering home, 2014)

S/N	TYPES OF CONCRETE	SLUMP
1	Concrete for road construction	20 to 40mm
2	Concrete for tops of curbs, parapets, piers, slabs and walls	40 to 50mm
3	Concrete for canal lining	70 to 80mm
4	Normal RCC work	80 to 150mm
5	Mass concrete	20 to 50mm
6	Concrete to be vibrated	10 to 25mm

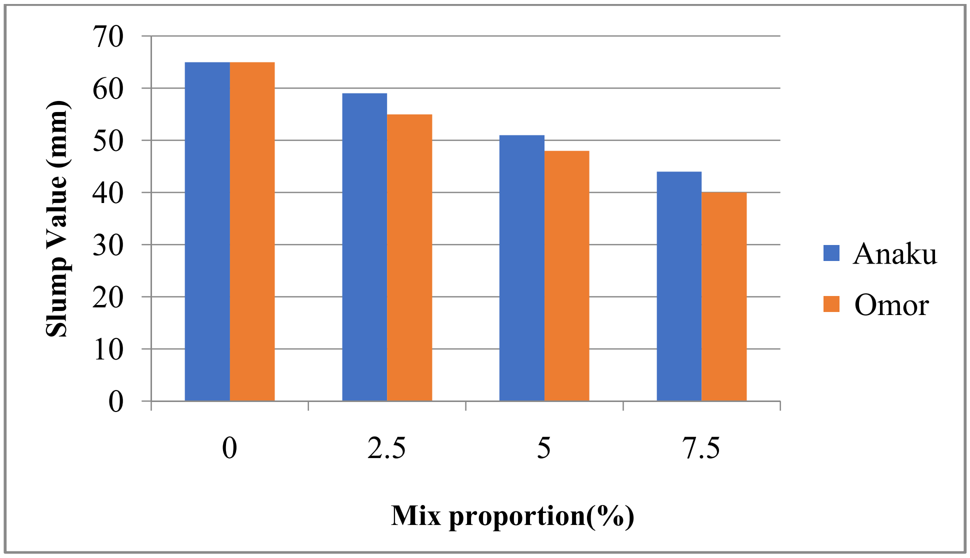

Figure 4.7: Comparing workability test of concrete for Anaku and Omor town specimen

From Figure 4.7, it was observed that concrete workability is inversely proportional to the percentage of rice husk ash content at a constant water- cement ratio for all the specimens from both locations. Concrete specimen produced from RHA obtained from Anaku town has higher workability than concrete specimen produced from RHA obtained from Omor town for 2.5% 5% and 7.5% mix proportions.

4.1.3 Compressive strength of concrete

Compressive strength of concrete for Rice husk ash obtained from Anaku and Omor town

Table 4.8: Compressive strength of concrete for Anaku and Omor town specimen

Mix Proportion (%)	**Curing Time (days)**	**Cross Sectional Area (mm^2) (150×150)**	**Average Crushing Strength (KN) for Anaku specimens**	**Average Compression Strength (N/mm^2) for Anaku specimens**	**Average Crushing Strength (KN) For Omor specimens**	**Average Compression Strength (N/mm^2) for Omor specimens**
Control (0%)	7	22500	445500	19.8	445500	19.8
	14	22500	492750	21.9	492750	21.9
	21	22500	564750	25.1	564750	25.1
	28	22500	598500	26.6	598500	26.6
2.5% RHA	7	22500	429750	19.1	407250	18.1
	14	22500	456750	20.3	434250	19.3
	21	22500	508500	22.6	497250	22.1
	28	22500	528750	23.5	553500	24.6
5% RHA	7	22500	400500	17.8	380250	16.9
	14	22500	411750	18.3	414000	18.4
	21	22500	436500	19.4	474750	21.1
	28	22500	468000	20.8	528750	23.5
7.5%RHA	7	22500	362250	16.1	344250	15.3
	14	22500	382500	17.0	375750	16.7
	21	22500	409500	18.2	434250	19.3
	28	22500	425250	18.9	483750	21.5

Table 4.8 shows the compressive strength results of concrete cubes at different curing ages 7, 14, 21, and 28 (days) for the mixed ratio of 1:2:4 with 0.55 water-cement ratio, mixed with the variation of Rice husk ash obtained from Anaku and Omor towns.

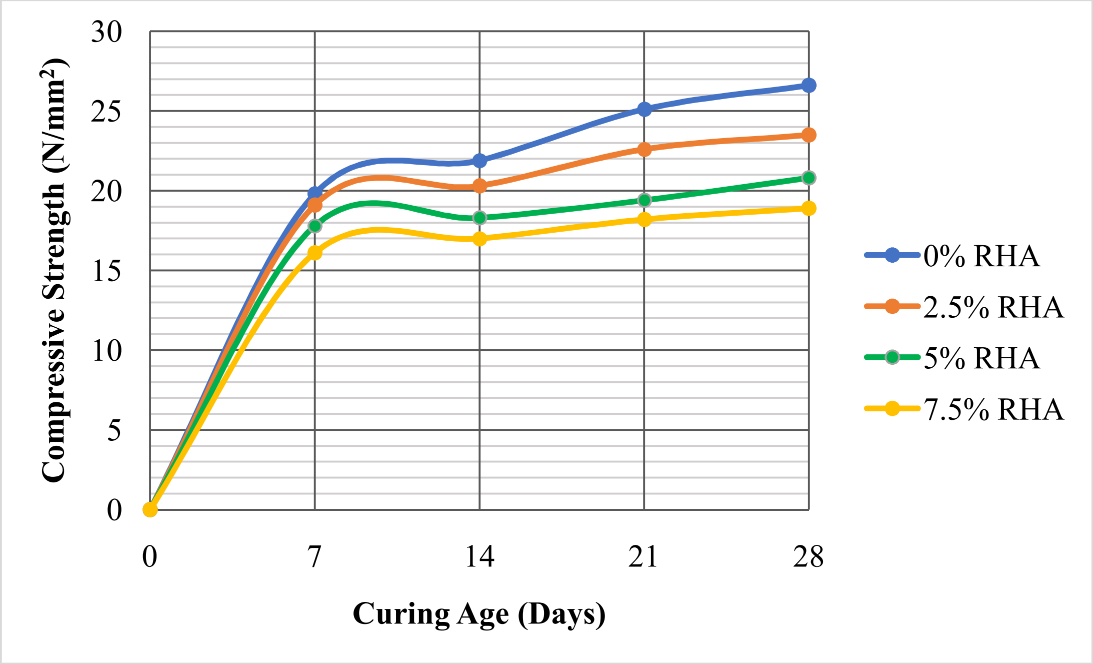

Figure 4.8: Compressive strength against Age of concrete for Anaku town specimen

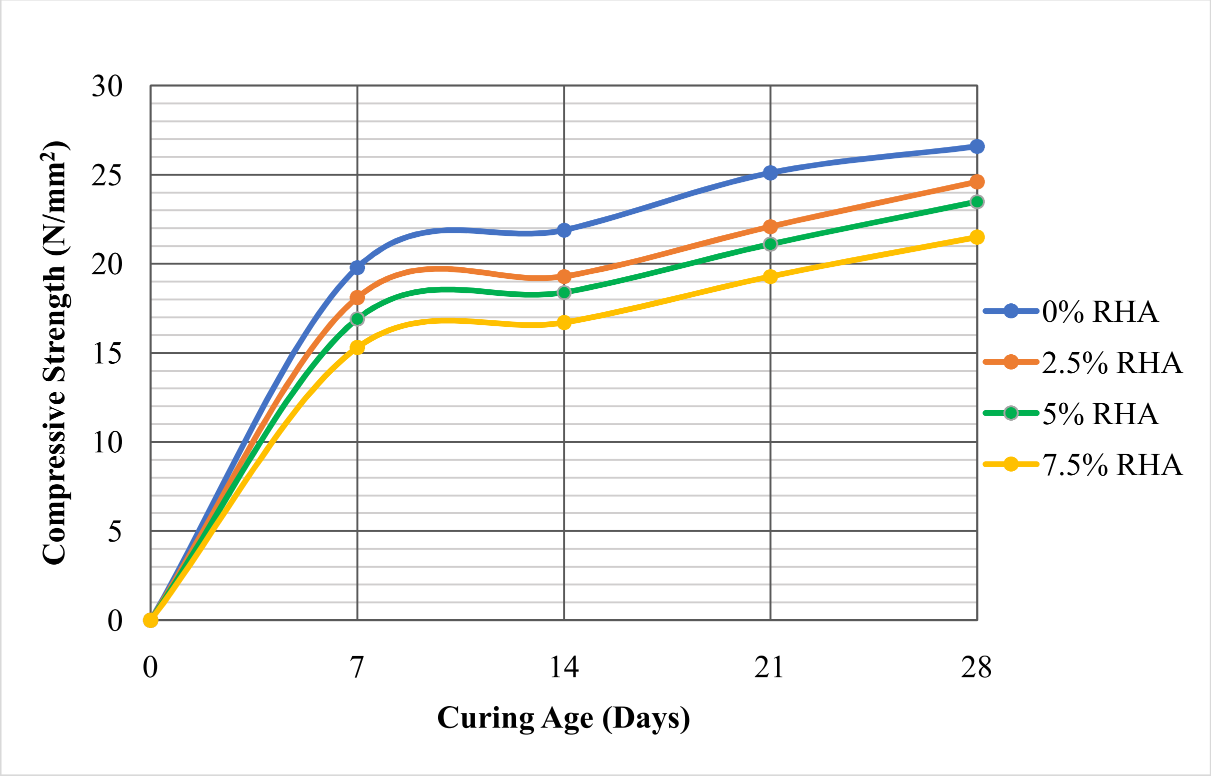

Figure 4.9: Compressive strength against age of concrete for Omor town specimens

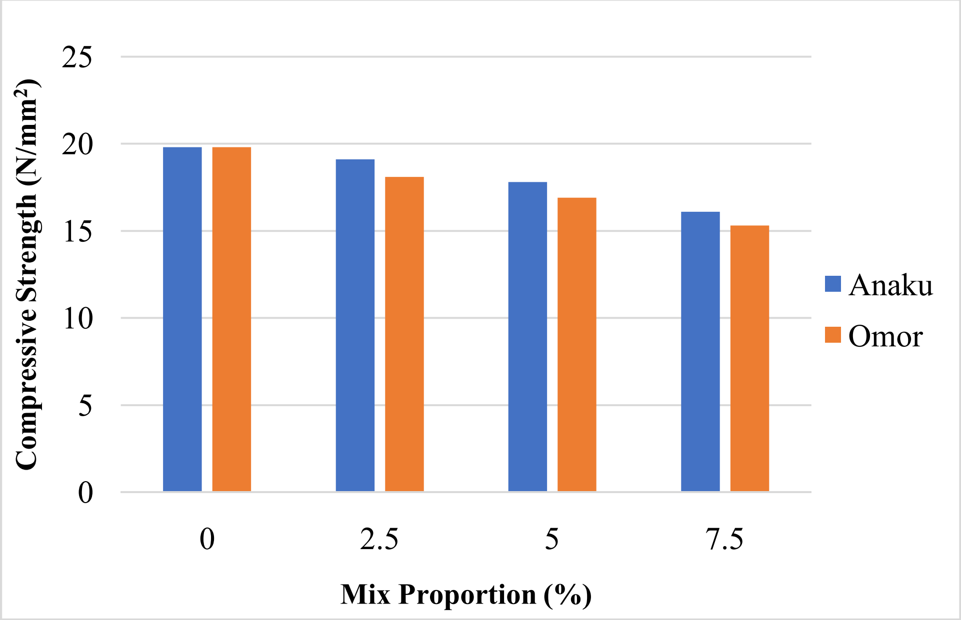

Figure 4.10:Comparison of the compressive strength of concrete specimens on the 7th day of curing for RHA from Anaku and Omor town.

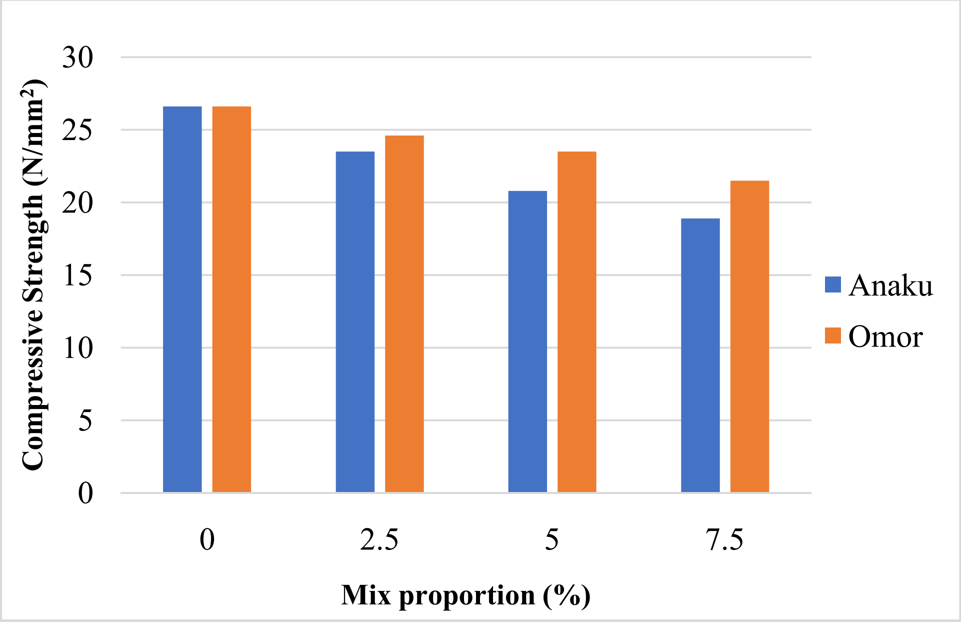

Figure 4.11: Comparison of the compressive strength of concrete on the 28th day of curing for RHA from Anaku and Omor town.

Table 4.8 shows the results of the experiment on partial replacement of cement with Rice husk ash from Anaku and Omor town. These specimens were prepared with a mix ratio of 1:2:4, and a constant water to cement ratio of 0.55. It was observed that on the 28th curing day, the compressive strength for Omor specimens at 0%, 2.5%, 5% and 7.5% mix proportions was 26.6 N/mm^2, 24.6 N/mm^2, 23.5 $N/mm^2$and 21.5 N/mm^2 respectively. However it was observed that they exceeded the conventional concrete design strength target of 20N/mm^2that is attributed to 1:2:4 mix ratio.

While for Anaku specimens, on the 28th curing day, the compressive strength at 0%, 2.5% and 5% mix proportions were 26.6 N/mm^2, 23.5 N/mm^2 and 20.8N/mm^2 respectively. It was observed that the strength of these specimens on the 28th day of curing exceeded the conventional concrete design strength target of 20N/mm^2which is attributed to 1:2:4 mix ratio. However, 7.5% mix proportion gave a compressive strength of 18.9N/mm^2 which is lower than the conventional design strength target of 20N/mm^2.

According to (CivilSir, 2022) Concrete with a design strength of 20N/mm^2 to 30 N/mm^2 can be used in all structural work of building construction in reinforced concrete beam, column, foundation, slab and other reinforced concrete structures; therefore specimen from Omor town at mix proportion of 0%, 2.5%, 5%, 7.5% and that of Anaku at 0%, 2.5%, 5% mix proportion would satisfy these purposes.

The result illustrated in Figure 4.8 and Figure 4.9 shows that compressive strength of concrete increases at increasing curing days for concrete specimens from both Anaku and Omor towns for 0%, 2.5%, 5%, 7.5% mix proportion. It was observed that there was a decrease in compressive strength at increasing Rice husk ash content at 7 days, 14 days, 21 days, 28 days of curing for specimens from both locations. From the result it was observed that the control mix proportion (0% RHA) gave the highest compressive strength at 7days, 14days, 21days and 28days for specimens from both locations. None of the partial replacement met the 28 days strength of the control mix designof 26.6N/mm^2 for both specimens. The closest for 28 days strength however was at 2.5% partial replacement for specimens from both locations. This is in line with the results reported by Bawankule et al. (2015), Oyewumi et al. (2014) and Tsado et al. (2014).

From Figure 4.10, it was observed that the concrete specimens from Anaku town gave early compressive strength gain at the7th curing day when compared with the specimens from Omor town. However, from Figure 4.11, it was observed that the concrete specimens from Omor town gave a higher late compressive strength gain at 28thcuring day with respect to specimen from Anaku town.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

A research has been carried out to study the effect of partial replacement of cement using rice husk ash from different locations on concrete properties. From the results and analysis of the various test results presented earlier, the following conclusions are drawn from the study:

1. Concrete workability is inversely proportional to the percentage of rice husk ash content at a constant water- cement ratio for all the specimens from both locations.
2. Concrete specimens produced from RHA obtained from Anaku town has higher workability than concrete specimens produced from RHA obtained from Omor town.
3. The compressive strength of the concrete specimens decreases with an increase in the proportion of rice husk ash content for specimens from both locations.
4. The compressive strength of the concrete is dependent on the curing period. The compressive strength is directly proportional to the curing period. This was observed from 7 days, 14 days, 21 days and 28 days specimens from both locations.
5. Concrete specimens produced from RHA obtained from Anaku town has early compressive strength gain more than the specimens from Omor. This was observed on the 7th day of curing for 2.5% 5% and 7.5% mix proportions.
6. Concrete specimens produced from RHA obtained from Omor town has higher late compressive strength gain more than specimens from Anaku town. This was observed at the 28th day of curing for 2.5%, 5% and 7.5% mix proportion.
7. The control mix (0% RHA) gave the highest compressive strength at all the curing days when compared with the other RHA mix proportions for both towns.

8. Concrete specimens produced from RHA obtained from Omor town at 0%, 2.5%, 5% and 7.5% mix proportion can be used in all structural work of building construction in reinforced concrete beam, column, foundation, slab and other reinforced concrete structures (CivilSir, 2022).
9. Concrete specimens produced from RHA obtained from Anaku town at 0%, 2.5% and 5% mix proportion can be used in all structural work of building construction in reinforced concrete beam, column, foundation, slab and other reinforced concrete structures (CivilSir, 2022).

5.2 Recommendation

From the results and conclusion the following recommendation are made:

1. Further research is required to investigate the specific gravity of Rice husk ash
2. Further research is required to investigate the water absorption of Rice husk ash
3. I recommend that a mix ratio of 1:2:4 and a water-cement ratio of 0.55 should be maintained while the percentage of RHA content should be reduced in order to ascertain if the resulting strength will be greater than or equal to the control mix strength.
4. A need for change in mix ratio is required to ascertain if the resulting strength will be greater than or equal to the control mix strength.
5. More locations should be explored or investigated to see the potential use of rice husk ash in concrete production.
6. The curing days should be increased to further investigate the effect of rice husk ash on compressive strength of concrete.
7. I recommend that this experiment should be conducted at varying water-cement ratio to check the corresponding result.

8. Further research is required to investigate chemical composition of Rice husk ash to better understand the effects of RHA on concrete.
9. Further research is required to investigate the economic benefit of the use of optimized (RHA) concrete.

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EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH BENTONITE ON COMPRESSIVE STRENTH OF CONCRETE

BY

EZAKA LAZARUS SUNDAY

(NAU/2016224014)

SUBMITTED TO

THE DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING

NNAMDI AZIKIWE UNIVERSITY AWKA.

IN PARTIAL FUFILLMENT OF THE REQUIREMENT FOR THE
AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN ENGINEERING

FEBUARY, 2022s

CERTIFICATION

This is to certify that this project topic titled evaluating the effect of bentonite on compressive strength of concrete was carried out by Ezaka Lazarus Sunday with registration number (NAU/2016224014) in the Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

Ezaka Lazarus Sunday **Date**

(Student)

APPROVAL PAGE

This research work “effect of partial replacement of cement with bentonite on compressive strength of concrete” is an authentic academic work undertaken by Ezaka Lazarus Sunday and is presented to the department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University Awka for approval in partial fulfillment of the requirement for the award of Bachelor of Engineering (B. Eng).

____________________________________ ________________

Engr. Dr. O. Odinaka **Date**

(Project Supervisor)

____________________________________ ________________

Engr. Dr. C.A. Ezeagu **Date**

(Head of Department)

____________________________________ ________________

Engr. Prof.D. Onwuka **Date**

(External Examiner)

DEDICATION

This work is dedicated to the owner of destiny, the creator of the universe, Almighty God for the gift of life and also for guiding me throughout my sojourn in school. I also dedicate this work to my lovely mother Mrs Ezaka Christana who serves as a real source of inspiration toward my academic pursuit.

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ABSTRACT

Environmental concerns both in terms of damages caused by the extraction of raw material and CO2 emissions during cement manufacture, have brought about pressures to reduce cement consumption by use of supplementary materials. The mixture of ordinary Portland cement (OPC) and pozzolan have proven to be beneficial in concrete production. This study investigates the range of ordinary Portland cement - bentonite mix proportion that can be found useful in concrete and block production. Tests were carried out to obtain the Compressive strength, workability and water absorption of the cement – bentonite concrete mix . This involves the partial replacement of cement with (2-10) % of bentonite for 1:2:4 mix ratio using 0.5 w/c ratio. Twelve cubes of concrete were casted for each percentage replacement including the control mix and tested for 7, 14, 28 and 50days curing ages. It was discovered that 10% replacement of cement with bentonite gave the highest sump value. The compressive strength of concrete decreased on addition of bentonite as compared to control cubes, but at 50days curing age, the compressive strength of the concrete with up to 10% bentonite gained strength that is approximate to the control mix at 28days. It was also observed that concrete cube with 10% bentonite at 50days absorbed more water.

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LIST OF SYMBOLS & ABBREVIATIONS

AASHTO – American Association of State Highway and Transportation Officials

USCS – Unified Soil Classification System

ASTM – American Society for Testing and Material

D_{10} – Particle Size such that 10% is finer than the Size

D_{30}- Particle Size such that 30% is finer than the Size

D_{60}- Particle Size such that 60% is finer than the Size

C_U – Coefficient of Uniformity

C_C – Coefficient of Curvature

SC – Clayey Sand

BNT- Bentonite

OPC- Ordinary Portland cement
SD - Sand

CHAPTER ONE

INTRODUCTION

1.1 Background of study

The construction industry has taken considerable strides forward over the last two or three decades with regard to trials in the use of one or another cementitious material generally identified as pozzolans, for the compounding of various cement-based products. This have not only resulted an improving the compressive strength value attained thereby but also in qualities like ability to set and harden under water. Among these coal fly-ash, blast furnace slag, rice husk ash, silica fume, or metakaolin are the most common ones. Other like gypsum, gypsum fines, Portland cement, cement kiln dust, lime dust, stone dust, and calcined clay are also in use, Due to economic and environmental concerns, different methods of making cement products are being considered. One method to achieve the goal of reducing carbon dioxide emissions and greenhouse gases is to formulate cements using a lower portion of calcinated material, thereby reducing carbon dioxide emissions per unit of product. Another approach is that of including a lower percentage of cement and or gypsum than it is common with standard cement or gypsum and to ensure an increased compressive strength and or flexural strength is yet attained thereby. This as one which is durable, and suitable for all types of applications, also benefits the environment. Additionally, a need exists for improved cement and gypsum products that permit the use of less expensive aggregates to reduce the cost of the cement product. S.Targan (2002) had result showed that setting time of cements was generally accelerated when bentonite replaced a part of the cement. Bentonite is a form of metakaolin clay (i.e., clay that has gone through heat process to be in its powder form) that consists of a primary mineral called montmorillonite which gives it its properties. Metakaolin clay seems to have the greatest overall potential as alternative pozzolanic material for concrete due to its availability in large quanta and the relatively cheap price. Poon, C. S. et al., (2005), had studied about mechanical and durability properties by used metakaolin clay and silica fume in cement concrete. Though the mineralogy of clays varies a lot, which may influence the reactivity, its interaction with CSH gel formed during ordinary Portland cement has been found beneficial to the final form of the hardened concrete. The benefit of it being used as partial replacement of a portion of the ordinary Portland cement has been found not only on strength improvement, but more on durability enhancement. Al-Akhras, N. M. (2006), have investigated the effect of metakaolin (MK) replacement of cement on the durability of concrete to sulfate attack and also studied the experimental parameters were water to binder ratio (0.5 and 0.6). Blended cements containing higher amount of natural pozzolans shows excellent ability to reduce the alkali-silica expansion and yields almost equal strength to Portland cement at the age of 91 days. Research has also been carried out on the use of bentonite clay as replacement of cement. Hassan et al. (2003) found out the reactivity index of mortar cubes containing Jehangira bentonite as replacement of cement. He concluded that 40 percent replacement of bentonite in mortar and 25 per cent replacement in concrete yielded satisfactory results when used as such (without any heat treatment). Badshah (2003) found out the optimum replacement of Jehangira bentonite as pozzolana on the basis of XRD diffraction analysis and compressive strength results. He also studied the sulfate resistance of concrete utilizing Jehangira bentonite. He concluded that 20 per cent of Bentonite replacement in concrete yields satisfactory results but any further addition reduces strength. Drastically Sulfate resistance of concrete increases as the pozzolana replacement increases. At 20 percent of bentonite replacement, a maximum resistance to sulfate resistance of mortar in 2 per cent sulfate solution is achieved. The mixture including 10% bentonite + 90% sand is the most economical solution that satisfies the limits values needed for clay core of earth fill dams and clay liners of solid waste storage areas was studied by Devrim Alkaya and A. Baris Esener (2011).

1.2 Statement of problem

Environmental concerns both in terms of damages caused by the extraction of raw material and CO2 emissions during cement manufacture, have brought about pressures to reduce cement consumption by use supplementary materials. In addressing environmental problems and economic advantages, mixtures of Portland cement (PC) and pozzolan are very commonly used in concrete production [Sabir et al., 2001]. To this end, this project intends to investigate the range of ordinary Portland cement – bentonite mix proportion that can be found useful in construction industriesfor concrete and block production.

1.3 Aim and Objectives

The aim of this project is to evaluate the effect of partial replacement of cement with bentonite on the compressive strength of concrete also to study the pozzolanic effect of bentonite on ordinary Portland cement concrete.

The purpose of studying bentonite as partial replacement of cement in concrete is as follow:

1. To investigate the workability of the fresh concrete mix with bentonite.

2. To investigate water absorption of cement- bentonite concrete.

3. To make relevant recommendations with regards to use of bentonite in concreting as regards mixes, water cements ratio and percentage of replacement.

4. To investigate the best or economic mixture of cement- bentonite that can be used for concrete and block production.

5. To investigate the effect of Portland cement-bentonite on the compressive strength of concrete.

1.4 Scope of study

This project is only concerned with the study of the effect of bentonite when partially replaced with ordinary Portland cement in a prescribed mix. This is as related to hydration properties, workability and compressive strength properties of resulting concrete only. Comparisons of the blended mixes would be made with ordinary Portland cement mix [as a control at the chosen water-cement ratios].

This entails preparing and casting concrete cubes of 150mm x 150mm x 150mm using 1:2:4 mix ratio. Replacing cement with 2%-10% variations of bentonite with water cement ratio of 0.5. For each of the concrete mix (that is 0%, 2%, 5%, and 10%) bentonite, three concrete cubes each were cast and the slump test taken to check for the workability of the fresh concrete and cubes were cured for a period of 7, 14, 28 and 50 days to determine respectively the compressive strength of the concrete cubes.

1.5 Significance of study

This project aims as serving as a guide for Nigerias in the construction industry. Contractors, structural Engineers can use the success of this research to determine the actual grade of concrete to be used during structural designs of concrete structures. This will incorporate the actual safety factor needed for the concrete so that the designed structure will carry the required load. And also be constructed at a reasonable cost. It will serve as a guide to state whether or not to incorporate bentonite as an admixture to concrete.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction to Concrete

Concrete can be defined as the composite material composed of the binding medium such as the mixture of cement, water, and different fine and coarse aggregates. Many people do consider cement as concrete, but cement is just a part of concrete. Concrete structures that have been built around the world are subject to a wide range of different conditions of use and acquaintance to environmental conditions comprising erosion, weather, and pollution.

All environmental conditions found concrete as the long-lasting and the best binding material. Besides whatever the conditions might be, concrete is expected to provide satisfactory performance for the wholeness of their service life with very little care. Because of its convenient use, it is not only used in building construction but also in other civil engineering areas such as; roads, bridges and many more. The use of concrete is very wide. It is one of the most important construction materials. It is comparatively economical, easy to make, offers continuity solidity and indeed it lays the role of developing and improving our modern society. Nowadays concrete is most widely used man-made construction material in mostly every type of engineering and architectural structure all round the world. According to simmons (2007), the usage of concrete can trace back an early as third century B.C. where the Romans were using concrete made with lime, broken stones and sand to build temples and other buildings. First, the surface of the concrete was left rough and finished with a form of stucco. Later on, they began to produce a decorative finish by embedding small stones in the concrete surface. Finally, they incorporated broken terra cotta roof tiles by embedding it at the surface of the concrete and this led to the manufacture of the clay bricks. After the collapse of the roman Empire, the concrete technology fell into disuse and has remained unknown until the time of Renaissance. Around 15th century, 'De architectura', the book series written by Roman architect and engineer marcus vitruvius polio became a famous object to be studied. But it was until the end of 18th century that the research in the concrete technology was resumed and by the year of 1824, that essential ingredient in the modern concrete was just discovered.

2.2 Concrete ingredients or constituents of concrete

What makes the monster so much rigid, long-lasting, and powerful enough to support every condition? To answer this, one has to look into the ingredients of concrete. This composite material is composed of various ingredients. The properties and functions of this binding material depend upon its constituents. If the constituents have more strength, then concrete will be more sustainable. Have a look at concrete ingredients:

Concrete = Filler (Aggregates)+ Binder (Cement)+Water +Admixture (Optional)

2.3 Binding materials

In concrete, Portland cement is generally used. It gives strength and its selection is a function of concrete durability and functioning. According to the American Society for Testing and Materials (ASTM) there are five types of cement, but in the manufacturing of concrete Type I. Type III cement is used maximum time.

2.4 Types of concrete

There is various type of concrete available in the market based on its functionality, strength and structure. For construction purposes, if someone goes to the market to buy the concrete for his/her building-it is available in two forms:

1. Normal mix concrete
2. Design mix concrete.

However, on the basis of material used and the construction required and design purpose there are also further three types of concrete.

(i) Plane cement concrete

(ii) Reinforced Cement concrete

(iii) Pre-stress Cement Concrete

According to binding Material concrete can be classified as

(i)Cement concrete

(ii)Lime Concrete

Based on Weight, Concrete can be classified into 4 categories they are

(i) Ultra-Light Weight Concrete

(ii) Light Weight Concrete

(iii)Normal Weight Concrete

(iV) Heavy Weight Concrete

Based on Strength, Concrete can also be classified into Four Categories

(i) Low-strength concrete

(ii) Moderate-strength concrete

(iii) High-strength concrete

(iv) Compressive strength

(V) Ultra high-strength concrete

Based On Additives

(i) Normal concrete

(ii) Fiber Reinforced Concrete

(iii) Polymer concrete

(iv) Ready-Mix Concrete

(V) Green Concrete

(Vi) High-Performance Concrete

(Vii) Ultra-High-Performance Concrete

(Viii) Rapid Strength Concrete

(ix)Shrinkage Compensating Concrete

(X) Fiber-Reinforced Concrete

(Xi) Asphalt Concrete

(Xii) Polymer Concrete

(Xiii) Gypsum Concrete

(Xiv) Vacuum Concrete

2.4.1Normal mix concrete:

It is a type of concrete that is prepared according to the specific considerations of design. Common ingredients used here are cement, water, and aggregate. Setting time could be varied from 20 to 80 minutes. If one looks at 28 days formula for concrete, it provides more than 80% strength to concrete which should be more than 95%.

2.4.2 Design mix concrete:

Concrete is not prepared on a hit and trial basis. Ingredient's' ratio is carefully selected after doing a lab test. After performing a different test on the different proportions of material, the best design is selected. Design mix or simply mix designs are prepared according to the strength required for the structure.

2.5 Limitation of concrete

According to U. S. Department of Army (1999), there are some limitations of the concrete which causes cracking and other weakness in the structures that detract from the appearance, serviceability, and useful life of the concrete structures due to its 'low tensile strength'. Concrete is good at compressive strength. So concrete members which are subjected to the tensile stress must be reinforced with the steel bars or in this case, with an additive such as steel fiber to prevent cracking and failure during construction. Concrete also has a long curing time (I.e.) it takes about a month to reach its maximum strength.

2.6 properties of concrete

Freshly mixed concrete should have the following properties

- Workability
- Segregation
- bleeding
- Harsh

In the harden state of concrete, should have the following properties

- Strength
- Durability
- Impermeability
- Shrinkage
- creep
- Thermal expansion
- Modulus of Elasticity

2.7 Strength of concrete

According to Love and U.S. Department of Army (1999), the strength of the concrete is the concrete's ability to resist the load in the compression, flexural or shear. The strength of concrete is mainly determined by the water-cement ratio (w/cm), the design constituents and the mixing, placement and curing methods employed. Concrete with lower water - cement ratio makes stronger Concrete than that with a higher ratio (RAJU, 1988). By allowing additional water into the mixing process means to thin the paste and to allow it to coat more particles. But, if the water is too much, then it would affect the concrete's strength by reducing it due to the dilution of the paste.

2.7.1 Compressive strength

Compressive strength of concrete is the Strength of hardened concrete measured by the compression test. The compression strength of concrete is a measure of the concrete's ability to resist loads which tend to compress it. It is measured by crushing cylindrical concrete specimens in compression testing machine.

The compressive strength of concrete can be calculated by the failure load divided with the cross-sectional area resisting the load and reported in pounds per square inch in US customary units and mega pascals (MPa) in SI units. Concrete's compressive strength requirements can vary from 2500 psi (17 MPa) for residential concrete to 4000psi (28 MPa) and higher in commercial structures. Higher strengths up to and exceeding 10,000 psi (70 MPa) are specified for certain applications.

Importance of Determining the Compressive Strength:

Compressive strength results are primarily used to determine that the concrete mixture as delivered on site meets the requirements of the specified strength, fc', in the job specification. Cylinders tested for acceptance and quality control are made and cured in accordance with procedures described for standard-cured specimens in ASTM C-31 (which is the Standard Practice for Making and Curing

Concrete Test Specimens in the Field). For estimating the in-place concrete strength, ASTM C-31 provides procedures for field-cured specimens. Cylindrical specimens are tested in accordance with ASTM C-39 (which is standard Test Method for Compressive Strength of Cylindrical Concrete Specimens).

A test result is the average of at least two standard-cured strength specimens made from the same concrete batch and tested at the same age. In most cases strength requirements for concrete are at 28 days.

2.8 Factors that Affect the Strength of Concrete

•Quality of raw materials

•Water/Cement Ratio. The ratio of the weight of water to the weight of cement is called

•Water/Cement ratio.

•Compaction of Concrete.

•Ingredients of Concrete.

•Curing of Concrete.

•The Shape of Aggregate.

•Maximum Size of Aggregates.

•Grading of Aggregate. ...

•Weather Condition.

2.9 Quality of raw material

2.9.1 Cement:

As far as cement conforms to the appropriate standard and it has been stored correctly (i.e., in dry condition), it should be suitable for use in concrete. The influence of cement on the strength of concrete for a given mix proportion is determined by its fineness and chemical composition through the process of hydration. Generally, cement can be described as binder material with adhesive and cohesive properties which makes it capable of holding material fragments into a compact whole. Cement used in construction works can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to be used in the presence of water. The chemical reaction results in hydrates that are not very water-soluble and so are quite durable in water and are free from chemical attack. Non-hydraulic cement and plasters do not harden in wet conditions.

The role of the chemical composition of cement in the development of concrete strength can always be appreciated. It is apparent that cement which contain a high percentage of tricalcium silicate (Ca3S) gain much more strength rapidly than those rich in dicalcium silicate (Ca2S). The sulphate resistance of concrete can be improved by the use of sulphate-resisting cement which has low tricalciumaliumunate (Ca3A) content (Seeley, 1995). The most important uses of cement are as ingredient in the production of mortar in masonry, and of concrete, a combination of cement and aggregate to form a strong building material. The most common cement used for construction works is ordinary Portland cement (OPC), which is low heat cement. The specification for Portland cement is the BS 12:1991 of the British standards institution.

2.9.2 Water

Water when add in concrete plays a critical role in the strength of concrete, particularly the amount used.

The strength of concrete increases when less water is used to make concrete. Frequently the quality of the water is covered by a clause stating "...the water should be fit for drinking.". This criterion though is not absolute and reference should be made to respective codes for testing of water for construction purposes. A concrete mix containing the minimum amount of water required complete hydration of its cement, if it could be fully compacted would develop the maximum attainable strength at any given age. The hydration itself consumes a specific amount of water. A water-cement ratio of approximately 0.5 (by weight) is required for full hydration of the cement but with this water content normal concrete mix would be extremely dry and virtually impossible to compact. Concrete is actually mixed with more water than is needed for the hydration reaction. This extra water is added to give concrete sufficient workability. In practice if the ratio of water to cement increases, the strength of the concrete decreases. BS EN 1008:2002 specifies mixing specification for water in concreting.

2.9.3 Aggregate

The strength of concrete is determined by the quality, it's size, texture, strength etc.

The presence of salts (chlorides and sulphates), silt and clay also reduce the strength of concrete. Aggregate is an important ingredient in concrete, which is generally regarded as an inert material distributed in a cement paste to form a rigid mass that could be molded or cast into various shapes. It is also regarded as the skeleton of the concrete. When a concrete mass is stressed, failure may originate within the aggregate, the matrix or at the aggregate-matrix interface is an important factor determining concrete strength. Band strength is influential by the shape of the aggregate, its surface texture and cleanliness.

Surface texture is generally only considered in relation to concrete flexural strength, which is found to reduce with increasing particle smoothness (Feldman, 1969). However, inadequate surface texture can similarly adversely affect compressive strength in high strength concrete (<50N/mm2) when the bond with the cement matrix may not be sufficiently strong enough to enable the maximum strength of the concrete to be realized.

According to the weight of aggregate, there are three main types of aggregate, namely;

• **Light Weight aggregate:** Lightweight aggregates (LWA) are defined as construction materials that have a bulk density lower than that of common construction aggregates (Choudhry and Hadley, 2009). It is possible to manufacture LWA and ultra LWA from gasification slag and fly ash, according to Choudhry and Hadley (2009) and Sloss (1996).

• **Medium weight aggregate:** They include sand, gravel, broken bricks, crushed stones and blast furnace slay. They are commonly used in the manufacture of quality concrete. The fine aggregate often called sand is not larger than 5mm.

• **Heavy weight aggregate:** For normal strength concrete, the aggregate strength is seldom a concern. However, in the development of high strength concrete, it is important to select aggregate higher than that of the hardened paste. Heavyweight aggregate includes steel punches, magnetite and scrap iron. They are used for high density concrete construction to shut off or screen against x-rays and neutrons (Taylor, 1983).

Good concrete can be made by using different types of aggregates like rounded and irregular gravel and crushed rock which is mostly angular in shape

2.9.4 Coarse / Fine Aggregate Ratio

The important points to be noted for coarse /fine aggregate ratio;

• Assuming the water demand has increased, the water - cement ratio will increase.

• Since the water - cement ratio has increased, the compressive strength will decrease.

• If the proportion of the fine aggregate is increased in relation to the Coarse aggregate, the overall aggregate surface area will increase.

• If the surface area of the aggregate has increased, the water demand will also increase.

2.9.5 Water / Cement Ratio

W/C ratio is one of the most important parameters governing the strength of concrete. The density of hardened cement (in terms of a gel/space ratio) is governed by the water/ cement ratio. With higher w/c ratio, the paste is more porous and hence the strength is lower. The strength continues to increase with decreasing w/c ratio only if the concrete can be fully compacted. For concrete with very low w/c ratio, if no water- reducing agent is employed, the workability can be so poor that a lot of air voids are entrapped in the hardened material. The strength can be lower than that for concrete with higher w/c ratio. For a given set of material and environment conditions, the strength of concrete age depends only on the water - cement ratio, providing full compaction can be achieved. The standard water / cement ratio is 0.5.

2.9.6 Age of concrete

The degree of hydration is synonymous with the age of concrete provided that the concrete has not been allowed to dry out or the temperature is too low. In theory, provided that the concrete is not allowed to dry out, then it will always be increasing albeit at an ever-reducing rate. For convenience and for most practical applications, it is generally accepted that the majority of the strength has been achieved by 28days. The 7th day strength can range from 60 - 80% of the 28th day strength, with higher percentage for a lower w/c ratio. After 28 days, the strength can continue to go up. Experimental data indicates that the strength after one year can be over 20% higher than the 28 days strength. The reliance on such strength increase in structural design needs to be done with caution, as the progress of cement hydration under real world conditions may vary greatly from site to site.

2.9.7 Compaction of concrete

Once the concrete is been placed, it is ready to be compacted. The purpose of compaction is to get rid of the air voids that are trapped in loose concrete. Air voids reduce the strength of the concrete.

For every 1% of entrapped air, the strength falls by somewhere between 5% and 7% (Gambhir, 1999). This means that concrete containing a mere 5% air voids due to incomplete compaction can lose as much as one third of its strength. Air voids also increase concrete's permeability. That in turn reduce its durability. If the concrete is not dense and impermeable, it will not be watertight. It will be less able to withstand aggressive liquid and its exposed surfaces will weather badly. The difference between air voids and entrapped air bubbles should be noted at the stage. The air bubbles that are entrained are relatively small and spherical in shape, increase frost resistance. Entrapped air on the other hand tends to be irregular in shape and is detrimental to the strength of the mix. In order to remove both, the concrete must be properly compacted.

2.9.8 Curing of concrete

According to Neville (1981), curing is the process used for promoting the hydration of cement and consists of a control of temperature and of the moisture movement from and into the concrete; with the aim of keeping the concrete saturated or as nearly saturated as possible until the originally water-filled space in the fresh cement paste has been filled to the desired extent by the products of cement hydration. The goal of curing is to ensure that air-filled void is filled with the products of hydration of cement as time progresses (Mannan et al., 2002).

Previously, investigations from the researches done by Gonnerman and Shuman (1928) and Price (1951) have shown that concrete continuously cured in air had lower compressive strength compared to water cured concrete at all the ages tested.

Increase in compressive strength, permeability, durability and other mechanical properties of concrete by continuous water curing are attributable to improved gel/space ratio in concrete (Neville, 1981). Mannan et al., (2002) observed that among the factors influencing the strength development of concrete is the curing environment where the specimens are put after being demounded. They stated that curing is usually done in a fully saturated environment to ensure proper hydration of the cement over time thereby leading to significant strength development. The authors observed that for concrete to achieve best performance, the temperature and humidity under which it is cast and cured are part of the major considerations.

The authors also reported that at higher temperatures, the rate of cement hydration is negatively affected and lower temperatures retard the hydration process leading to poor strength development. Çakir and Akoz, 2008; Mannan et al., (2002) have also shown that the method employed in curing concrete also has significant effect on its mechanical properties.Price (1991) refers to curing as the process of protecting concrete for a specified period of time after placement, to provide moisture for hydration of the cement, to provide proper temperature and to protect the concrete from damage by loading or mechanical disturbance. Curing is designed primarily to keep the concrete moist by preventing loss of moisture from it during the period in which it is gaining strength. Curing can be achieved by keeping the concrete element completely saturated or as much saturated as possible until the water-filled spaces are substantially reduced by hydration products (Gowripalan et al., 1992). The chemical reaction which curing aims at continuing, termed hydration of cement, virtually ceases when the relative humidity within capillaries drops below 80percent (Neville, 1996). Nilsson, (1980) in his experimental investigation into hygroscopic moisture in concrete had observed a substantial decrease in the rate of hydration when the ambient humidity fell below 80percent. It’s important to note that if concrete is not cured and is allowed to dry in air, it will gain only 50percent of the strength of continuously cured concrete. As a result, if concrete is cured for only three days, it will reach about 60percent of the strength of continuously cured concrete; if it is cured for seven days, it will reach 80percent of the strength of continuously cured concrete. If curing stops for some time and then resumes again, the strength gain will also stop and reactivate

(Mamlouk and Zaniewski, 2006). However, long period of moist curing has been reported to reduce the incidence of cracking (Kong and Evans, 1994). If concrete is not well cured, particularly at the early age, it will not gain the required properties at desired level due to a lower degree of hydration, and would suffer from irreparable loss (Ramezanianpour and Malhotra, 1995; Zain et al., 2000). Wojcik and Fitzgarrald (2001) also observed that improper curing would entail insufficient moisture and this has been found to produce cracks, compromise strength, and reduce long-term durability. The strength development and permeability of concrete is greatly affected by the processes of hydration, leaching and curing.

2.9.9 Compaction of concrete

As soon as concrete is been placed, it's ready to be compacted. The purpose of compaction is to get rid of the air voids that are trapped in loose concrete. Air voids reduce the strength of the concrete. For every 1% of entrapped air, the strength falls by somewhere between 5% and 7% (Gambhir, 1999). This means that concrete containing a mere 5% air voids due to incomplete compaction can lose as much as one third of its strength. Air voids also increase concrete's permeability. That in turn reduces its durability. If the concrete is not dense and impermeable, it will not be watertight. It will be less able to withstand aggressive liquids and its exposed surfaces will weather badly. The difference between air voids and entrapped air bubbles should be noted at this stage. The air bubbles that are entrained are relatively small and spherical in shape, increase frost resistance. Entrapped air on the other hand tends to be irregular in shape and detrimental to the strength of the mix. In order to remove both, the concrete must be properly compacted.

2.10 Admixtures in concrete

Admixtures are those ingredients in concrete other than Portland cement, water, and aggregates that are added to the mixture immediately before or during mixing. Admixtures are equally known as additives. So often, instead of using special cements, it is possible to change some of the properties of the more commonly used cements by incorporating a suitable additive or Admixtures (Chen, 2004). These days, concrete is being used for so many purposes in different conditions. In these conditions ordinary concrete may fail to exhibit the required quality or durability. In such cases admixtures are used to modify the properties of ordinary concrete so as to make it more suitable for any situation (Liu, 2004). Despite these considerations, it should be borne in mind that no admixture of any type or amount can be considered a substitute for good concreting practice. The effectiveness of an admixture depends upon factors such as type, brand, and amount of cementing materials; water content; aggregate shape, gradation, and proportions, mixing time, slump, and temperature of the concrete. Admixtures being considered for use in concrete should meet applicable specifications such as; Trial mixtures should be made with the admixture and the job materials at temperature and humidity anticipated on job. In this way the compatibility of the admixture with other Admixtures and hob materials, as well as the effects of the admixture on the properties of the fresh and hardened concrete, can be observed. The amount of Admixture recommended by the manufacturer or the optimum amount determined by laboratory tests should be used.

2.10.1 The major reasons for using admixtures

- To reduce the cost of concrete construction.

To achieve certain properties in concrete more effectively than by other means.

To maintain the quality of concrete during the stages of mixing, transporting, placing, and curing in adverse weather conditions.

To overcome certain emergencies during concreting operations.

Admixtures are classified by the BS5075: part 1: 1982 in various types according to the requirements of characteristics strength and function of concrete. They range from Retarders, plasticizers, water reducers, air-entraning admixtures, bonding admixtures, accelerators, coloring agents, water proofing, miscellaneous agents etc. But commonly used admixtures are: accelerators, Retarders, plasticizers/super plasticizers, air entraining coloring agents, and are usually available at any local concrete supply retailer.

2.11 Bentonite as admixtures

Bentonite is a clay mineral which exhibit little bit swelling behavior as well as obeys Pozzolanic properties. Large quantities of bentonite resources are available throughout the world. It has major Revised Manuscript Received on December 22, 2018.M. Achyutha Kumar Reddy, Research Scholar, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, A.P., India.V. Ranga Rao, Professor, Department of Civil Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, A.P., India. applications in fields like drilling fluids, foundry bonds, absorbents, adhesives, bleaching earths, ceramics etc. J. Mirza Initiated the research work by using bentonite as substitute material to cement in concrete in 2009. Plenty of investigations were carried out by researchers from different locations throughout the globe. They reported some facts related to bentonite utilization based on the experimental results. Majority of the authors used Pakistani bentonite available from different locations of Pakistan. employed Jahangira bentonite, used Karak bentonite, utilized Khyber bentonite, used Telangana bentonite & employed bentonite from Amazon region Brazil.

2.11.1 Physical Properties

Bentonite is generally available in various colors and forms. A Few authors reported about the color, greenish gray & browning green, light yellow colored bentonite was of bentonite utilized in research work.

2.11.2 Chemical properties

Chemical composition of cement shows tremendous effect on mechanical properties of concrete. Majority of authors reported higher amount of SiO2 presence Al2O3 accomplish as second major element in bentonite. These leads to occurrence of pozzolanic reaction while hydration process. Chemical properties as per ASTM C618, most of the authors reported as within the limits.

2.11.3 bentonite behavior in cement mortars

A few authors reported the behavior of bentonite in cement mortars like normal consistency, initial & final setting times, strength activity index, and compressive strength.

A. Normal consistency

Bentonite exhibits 75% as normal consistency value whereas OPC attains at 30 – 35%, 21 percentage bentonite-OPC mixture attains 35% consistency was reported by. However, it was observed that the normal consistency is directly proportional to bentonite addition.

2.11.4 bentonite behavior in fresh concrete

H. H. Murry, 2006 initiates 1-2 % addition of sodium bentonite improves the workably as well as segregation of concrete, plenty investigations made after this to measure exact workability.

A. Workability

Drastic decrease in workability was observed at higher percentages (minimum of 20%) of bentonite substitution in concrete]. Bentonite utilization was done in lower percentages (0-21 at 3% interval) by S. A. Memon, 2012, he recommended utilization of super plasticizer needed to enhance workability.

B. Fresh concrete density

Density of fresh concrete was examined by standard procedure ASTM C642, decreasing by addition of bentonite to concrete.

table 2.0: physical properties of dangote cement

Properties	**Cement**
Moisture content (%)	2
specific gravity	3.14
bulk density (kg/m3)	1540
fineness (m2/kg)	–
Ph	9

Table 2.1 Physical Properties of Bentonite

Color	Light Yellow
Size	Pass from 70 microns
Free swell	60% by volume
Nature	Pozzolanic

[Source: Junaid Akbaret al., (2013)]

Table 2.3 chemical properties of dangote cement and bentonite

Constituent (%)	**Percentage by weight of cement (%)**	**Percentage by weight of bentonite (%)**

Al2O3	6.05	21.118
SiO2	19.96	49.634
Fe2O3	2.99	3.235
TiO2	–	0.498
Na2O	2.10	0.449
MgO	1.45	3.591
CaO	64.86	0.65
K2O	2.60	2.091
COLOUR	Gray ash	Light yellow

Source: Dr. M. Swaroop Rani, M. Tejaanvesh (2015), M. Karthikeyan et al. (2015).

2.12 Permeability

Permeability is defined as the property that governs the rate of flow of a fluid into a porous solid. If a concrete is impermeable, corrosive agent cannot penetrate and attack it. Concrete basically has two types of pores, which determines permeability. These are capillary pores (with a diameter varying between 0.01 to 10 micron) in the Cement, paste which coats the aggregate and larger micron voids, between 1mm to 10mm, which are caused by faulty compaction of fresh concrete. When voids are interconnected because of their larger number and size a continuous link is formed, which makes the concrete permeable. There are several factors affecting permeable of concrete. They include

- Water cement ratio
- Compaction and curing.

Concrete will not be vulnerable to water - related destructive phenomena if there is a little or no evaporable water left after drying and provided that the subsequent exposure of the concrete to the environment did not cause pore saturation of the pores. The latter, to a large extend, depends on the hydraulic conductivity, which is also known as the coefficient of permeability (K).

Darcy's law

For steady-states flow, the coefficient of permeability K is determined from Darcy's expression:

$Dq/dt = K (\Delta HA)/(Lv)$

Where Dq/dt is the rate of fluid flow, v the viscosity of fluid, ΔH

The pressure gradient, A the surface area, and L the thickness of the solid.

The mixing water is indirectly responsible for permeability of the hydrated Cement paste because its content determines first the total space and subsequently the unfilled space after the water is consumed by either Cement hydration or evaporation to the environment.

12.13 Sieve analysis

Sieve analysis is a procedure used to assess the particle size distribution of a granular material (sand, gravel). The size distribution is often of critical importance to the behavior of the material during use. Sieve analysis can be performed on any type of non-organic or organic granular material including sand, crushed rock, clay, granite, feldspar and a wide range of manufactured powders, grains and seed down to minimum size depending on the exact method. The standard grain size analysis test determines the relative proportion of different grain sizes as they are distributed among certain size ranges.

The grain size analysis is widely used in classification of soils. The data obtained from the grain distribution curve is used in the design of filters for earth dams and to determine the suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability test is more generally used. Soil gradation is very important to geotechnical engineering; it is an indication of other engineering properties such as shear strength, compressibility and hydraulic conductivity. In a design, the gradation of the in-situ- soil help in the selection of filler material for the construction of highway embankment and it also controls the design and ground water drainage of site. A poorly graded soil (one with predominantly one-sized particle) will have better drainage property than the well graded soil (soil with varieties of particle sizes) because of the relatively higher magnitude of void present. A well graded can be easily compacted more than a poorly graded soil. However, most Engineering project may have graduation requirement that must be satisfied before the soil is to be used is accepted for construction work. When options for ground remediation technique are to be considered the soil gradation is a controlling factor. Soil possesses a number of physical characteristics which can be used as aid to identify it sizes in the field. A handful of soil rubbed through the finger can yield the following:

1. Sand and other coarser particle are visible to the naked eye.
2. Silt particle becomes dusty and are easily brushed off.
3. Clay particle are greasy and sticky when wet and hard when dry and have to be scrapped or washed off hand and boot

For a soil to be well graded the value of coefficient of uniformity (Cu) has to be greater than 4 and 6 for gravel and sand respectively, while the Coefficient of Curvature (C_v) should be in the range of 1 to 3.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials, Sourcing and Preservation.

The materials required for this research work are fine aggregate (river sand) designated as SD. Coarse aggregate (granite) designated as GNT, additive (sodium bentonite) designated as BNT, ordinary Portland cement and water. The mode of sourcing and preservation of these materials are discussed below:

1. Cement

The Portland limestone cement designated as PLC used for this experiment is Dangote 3X cement. The cement brand complied with the requirements of BS EN (1995) and was purchased from local dealer at Awka in Anambra State. The grade of the cement is 42.5R. the cement was conveyed to school laboratory where it was kept in a cool dry place preparatory for various laboratory testing. The cement sample satisfy the requirement for use as one of the major components of concrete in that, it was not caked or baked through visual inspection and quick setting time. The cement is replaced with bentonite.

2. Water

The water sample used for this experiment was collected from the laboratory. The sample passed all the necessary requirement for use as ingredient of concrete based on the fact that it is colorless, devoid of suspended solid particles, contains infinitesimal trace of dissolved solid particles with no trace of turbidity after being subjected to laboratory testing.

3. Sodium Bentonite (BNT).

The sodium Bentonite, a clay-like material with soapy properties which has high swelling properties were bought in Eke Awka market, Anambra, from the borehole materials supplies, and the materials was tested and confirmed.

4. Coarse Aggregate (Crushed Granite).

The granite samples designated as GNT was procured from a ring road Agu Awka in Awka south local government. The granite sample passed all the necessary physical test in that, it has high crushing strength, it is relatively large in size (within range of 4.75mm) and is a representative of granite (chippings) in color. The granite was collected in five bags of cement bag and was conveyed to the school laboratory via public transport.

3.2 Methods of Study

In this project, different test was carried out; test was carried out on different percentages of replacement of sodium bentonite with cement. Below are the detailed descriptions of the experiments.

3.2.1 Sieve Analysis

The apparatus used for this experiment is listed below:

1. Stack of sieves including pan and cover.
2. Mechanical sieve shaker.
3. Weighing balance of 0.01g sensitivity.
4. Hand brush
5. Mortar and pestle (Used for crushing if the sample is conglomerated or lumped)
6. Thermostatically controlled Oven (With temperature of about 80^{O}C-110^{O}C).
7. Masking tape for identification of sample.
8. Exercise book and pen for recording of result.
9. The calculation for attaining Coefficient of uniformity and Coefficient of curvature is outlined below.

Percentage retained (%) =$\frac{massofsoilretainedinthesieve\ (g)}{totalmassofsoilsample\ (g)} \times 100$

Cumulative percentage retained = $\sum percentageretained\ (\%)$

Cumulative Percentage Finer (%) = 100-Cummulative percentage retained

Plate 3.1: Apparatus for Particle Size Distribution Test (Sieve Analysis)

Plate 3.2: Particle Size Distribution Test in progress (Sieve Analysis)

Test Procedure.

1. The stack of sieve used for the experiment was properly cleaned with hard brush.
2. 300g of air-dried soil sample was weighed on a weighing balance.
3. The weighed soil sample was poured into 75um sieve and wash under a steady supply of water until clear water start coming out from the sieve after passing through the soil sample.
4. After washing the washed soil sample was poured into a pre-weighed plate and dry it inside the thermostatically controlled oven at a controlled temperature of 80-110^{O}C for 16-24hrs.

5. The sample was removed from the oven and determines its weight (net weight) by deducting the weight of plate from the weight of plate and soil.
6. The stacks of sieve were arranged in the ascending order, place in a mechanical sieve shaker, and thereafter the sample was poured and connect the shaker for about 10-15 minute.
7. The sieve shaker was disconnected and the mass retained on each of the sieve sizes was determined.
8. The percentage retained, Cumulative percentage retained and Cumulative percentage finer was determined.
9. The graph of sieve Cumulative percentage finer against sieve sizes was plotted and shown in figure 1.
10. D10, D30 and D60 were determined from the plotted graph.
11. The Coefficient of Curvature and Coefficient of Uniformity was determined and the soil was classified using the American Association of State Highway and Transportation Official (AASHTO) and Unified Soil Classification System (USCS) respectively.

Table 3.1: particle size distribution analysis of sand

Sieve Sizes(cm)	Mass Retained	Mass retained2	Cum % Retained	Cum % finer
4.75	1.21	0.40	0.4	99.60
2	7.83	2.61	3.01	96.99
1.18	15.44	5.15	8.16	91.84
0.6	225.21	75.07	83.23	16.77
0.3	40.99	13.66	96.89	3.11
0.15	8.04	2.68	99.57	0.43
0.075	0.62	0.21	99.78	0.22
Tray	0.66	0.22	100.00	0.00
Total	300g			

3.2.2 Batching

This is a process of determining the proportion (quantity) of constituent materials for the concrete mix. The material was measured properly by weight (mass) to satisfy the required mix proportions of the desired concrete grade. Platform weigh batcher was used to measure out the appropriate quantities of cement, aggregates, bentonite and water required for each mix in grams.

Proportion of mix-1:2:4

That means proportion by weight of cement, fine aggregates and coarse aggregates is in the ratio of 1:2:4

Total ratio=7

Volume of mould used-150mms 150mm x 150mm-3:375x10 mm"

Weight Density x Volume

Density of concrete=2400kg/m^3

Weight=8. 1kg

Weight of each mix = Ratio/ total ratio X weight/ 1

For water cement ratio of 0.5 = 0.5 x Quantity of cement

For The Control Cubes

Cement Concrete

Weight of cement in 3:375x10^6mm^-6 of concrete-1/7 X 8.1/1=1.1571kg =1157.14g

Mass of cement in one cube=1.157kg

To get the mass for twelve cubes=1.157kg × 12=13.884kg

For Sand

Mass of sand in one cube=2.314kg

Mass of cement in twelve cubes =12 × 2.314 = 27.768kg

For Coarse Aggregate

Mass of aggregate in one concrete cube =4.628kg

Mass of aggregate in twelve cubes= 12 × 4.629kg = 55.548kg

For Water

Mass of water in one concrete cube = 0.5785kg

Mass of water in twelve cubes= 12 × 0.5785kg = 6.942kg
For 2% Replacement
Mass of cement in one cube = 98/100 × 1.157kg = 1.1339kg

Mass of cement in twelve cubes 12 × 1.1339kg = 13.6068kg

Mass of bentonite in one cube = 0.02 × 1.157kg = 0.0231kg

For 5% Replacement

Mass of cement in one cube = 95/100 × 1.157kg = 1.0992kg

Mass of cement in twelve cubes = 12 × 1.0992 = 13.1898kg

Mass of bentonite in one cube =0.05 × 1.157 = 0.05785kg

Mass of bentonite in twelve cubes =12 × 0.05785 = 0.6942kg

For 10% Replacement

Mass of cement in one cube = 90/100 × 1.157kg =1.0413kg

Mass of cement in twelve cubes = 12 × 1.0413kg = 12.496kg

Mass of bentonite in one cube = 0.1 × 1.157kg = 0.1157kg

Mass of bentonite in twelve cubes = 12 × 0.1157kg = 1.3884kg

The concrete material was batched in weight. The ratio of the mix was 1:2:4 with the water cement ratio of 0.5

Table 3.2 variation of the ratio of cement and BNT or partial replacement

Test	Cement%	BNT%
1	100	0
2	98	2
3	95	5
4	90	10

3.2.3: water absorption of concrete cubes

The test was obtained by weighing the weight of the cubes before curing and after curing

3.2.4 Compressive Strength Test of Concrete Cubes

The test method covers determination of compressive strength of cubic concrete specimens. It consists of applying a compressive axial load to molded cubes at a rate which is within a prescribed range until failure occurs.

The Apparatus Used includes:

1. **Testing Machine -** The testing machine used was located in unizik civil engineering lab it was of a reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The permissible error was not greater than ± 2 percent of the maximum load.
2. **Cube Moulds -** The mould was 150 mm size conforming to IS: 10086-1982.
3. Weights and weighing device
4. Tools and containers for mixing,
5. Tamper (circular in cross section)
6. Shovel

Test Procedure.

1. **Measuring and mixing of mortar –** the various measurement was carried out base on the mix design in section 3.2.3 above. Weighing of the materials was achieved using the weighing balance. Mixing was done manually using the hand trowel and the shovel

2. **Casting –** The mixtures were cast in 150*150*150mm molds. Before casting, the interiors of the molds were dried and greased in order to ensure easy removal after setting. They firmly clamped together to avoid leakages. Each cube produced was labeled according to the percentage of bentonite content.

3. **Curing –** After the mortar's cubes were prepared, they were allowed to set for 24hours then the mounds removed. The cubes were then immersed in water filled tank at the laboratory room temperature.

4. **Crushing:** Crushing test was performed on the mortar cubes after 7, 14, 21, and 50days of curing. On removal from the tank, it was weighed to obtain the weight after curing to get the water absorption of the cube, each cube was allowed to dry before compressive test was performed. Compressive load was applied to the cubes using the crushing machine. The maximum loads indicated by the machines dial gauge at cracking were recorded. The compressive strengths of the cubes were obtained as follows;

Compressive Strength (N/mm^2) = $\frac{Appliedload\ (N)}{Areaofcube\ (mmXmm)}$

Where applied load (N) = Force

Now conversion of applied load from Ton force to KN or N.

1 Ton force = 10kN or 10,000N.

For 220kN = 220× 1000 = 220,000N

Area of cube = 150mm×150mm = 22,500mm^2

Compressive Strength = $\frac{220{,}000N}{22{,}500mm2}$ = 9.78N/mm^2

Plate 3.3: cube crushing in progress

3.2.5 Slump Test (Workability Test)

Plate 3.4: Slump test in progress

The procedure for the experiment includes;

i. The internal surface of the mound was thoroughly cleaned and applied with a light coat of oil.

ii. The mound was placed under a smooth, horizontal and non- absorbed surface with the smaller opening at the top.

iii. The mound was filled in three layers with freshly mixed concrete each approximately to one-third of the height of the mound.

iv. Each layer was then tampered 25 times with a standard 16mm diameter steel rounded end and tamping rod (strokes are distributed evenly over the cross-section).

V. After the top layer was rodded, the concrete was struck off the level with a trowel.

vi. The mound was removed from the concrete immediately by raising it slowly in the vertical direction

vii. The difference in level between the height of the mound and that of the highest point of the subsided Concrete is measured.

viii. The difference in height is the slump of the concrete.

CHAPTER FOUR

RESULT AND ANALYSIS

4.0 Test Results

The obtained results considered in the following analysis include;

Particle size distribution

Slump test

Water absorption test

Compressive strength test

4.1 Particle size distribution 0f fine aggregate

Table 4.1: Particle size Distribution of fine aggregate (Onitsha River sand)

Sieve Sizes(cm)	**Mass Retained**	**Mass retained2**	**Cum % Retained**	**Cum % finer**
4.75	1.21	0.40	0.4	99.60
2	7.83	2.61	3.01	96.99
1.18	15.44	5.15	8.16	91.84
0.6	225.21	75.07	83.23	16.77
0.3	40.99	13.66	96.89	3.11
0.15	8.04	2.68	99.57	0.43
0.075	0.62	0.21	99.78	0.22
Tray	0.66	0.22	100.00	0.00
Total	300g			

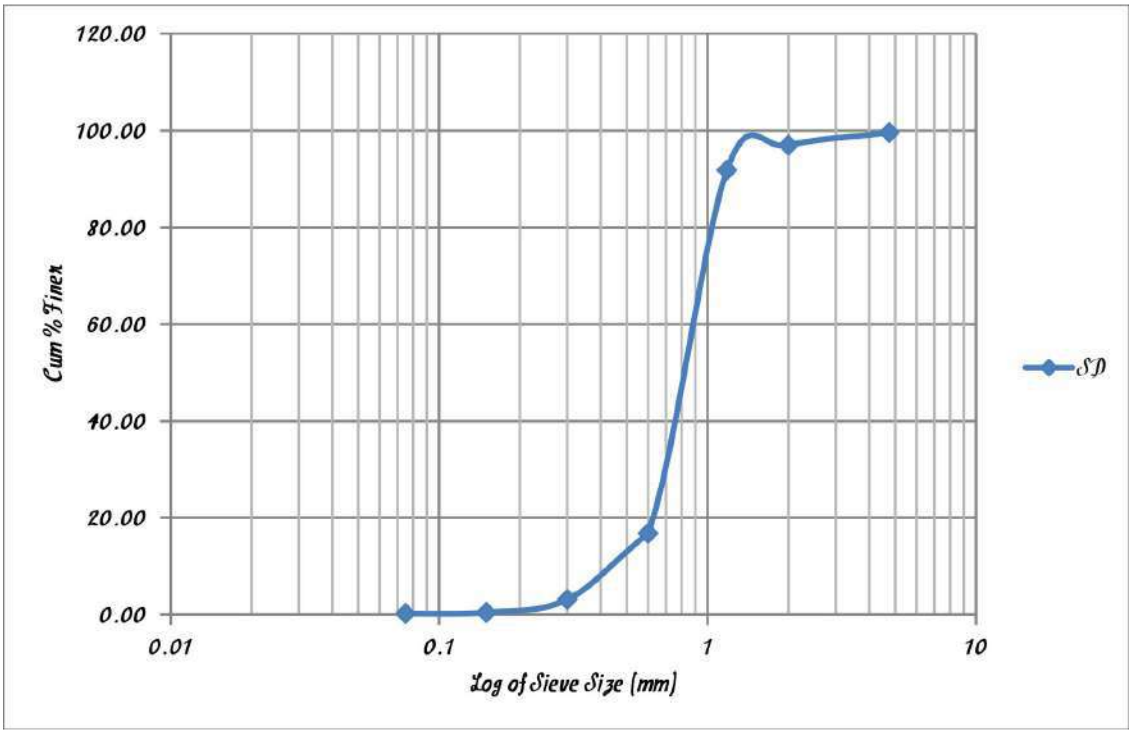

Fig. 4.1 Particle size distribution 0f fine aggregate (Onitsha River sand)

Fine aggregate parameters

Effective size: this is the diameter in a particle size distribution curve corresponding to 10% finer and is denoted as D10

D10 = 0.5mm (from particle size curve fig 4.1)

Uniformity co-efficient: denoted by Cu and is expressed as

Cu=D60/D10

Where D60= Diameter corresponding to 60%finer=0.9

D10=0.5, D60=0.9, Therefore Cu= 0.9/0.5 = 1.8

Co-efficient of Gradation: denoted by Cc and is given by

Cc =(D30)2/(D60 X D10)

Where D30 = Diameter corresponding to 30% finer

From the particle size distribution curve, D30 = 0.7 and from values of D60 and D10 above, Cc= 1.08 < 3.

Since the co- efficient of gradation is less than 3, it conforms to the limit given in the BS 1377: PART 2; 1990 for well- graded soils. Hence, the fine aggregate can be said to be well graded.

Figure 4.1 is the semi logarithmic plot of the particle size distribution of the SD. Result recorded shows that for SD, the percentage passing through sieve size 0.075mm and 4.75mm for SD are 99.6 and 0.0033 respectively and according to AASHTO Classification system, it is classified as A-2-4 and SC (clayey sand) according to USCS Classification system. This material constitutes a good sub-grade material for road construction.

4.2 Slump (Workability Test).

Table 4.2: slump value of concrete cast with various percentages of BNT

Percentage Replacement of BNT	Slump Value at 0.5w/c ratio (mm)	Slump Type
0	26	True slump
2	33	True slump
5	35	True slump
10	38	True slump

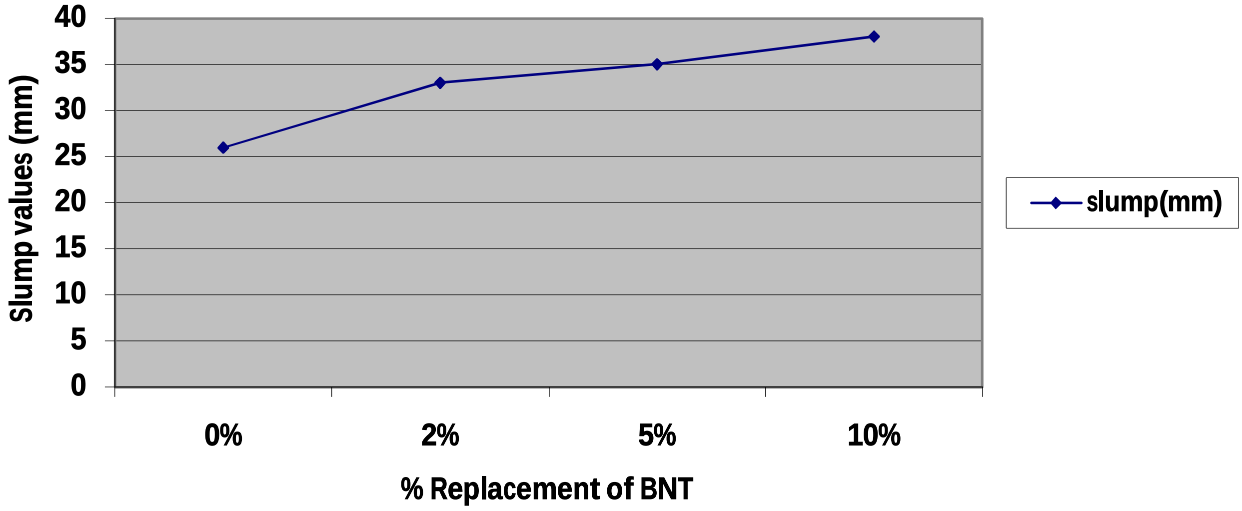

Figure 4.2a: Graph of Slump value against % Replacement of BNT

Table 4.2and fig 4.2a presents the slump test result of CEMENT-BNT concrete. Slump test was carried out to check the effect of BNT on the workability of fresh concrete. The test was carried out in accordance with the requirements of BSEN, (1995). From the result recorded, it was observed that the slump value increases with consistent replacement of BNT from 2% to 10% for w/c ratio (0.5) with the highest slump recorded at 10% replacement of BNT.

4.3 Compressive Strength Test.

Table 4.3: Compressive Strength Test Result on Concrete Cubes for 7days curing age

percentage replacement of BNT	**Mix by Volume**	**Failure Load (KN)**	**Compressive Strength (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
0%	1:2:4	362.50	16.11	16.6
		363.23	16.14	
		358.64	15.94	
2%	1:2:4	263.50	11.71	10.69
		193.37	8.59	
		265.15	11.78	
5%	1:2:4	175.45	7.80	8.7
		210.60	9.36	
		201.11	8.94	

10%	1:2:4	591.00	8.02	8.27
		570.10	8.01	
		599.5	8.77	

Table 4.3.1: Compressive Strength Test Result on Concrete Cubes for 14days curing age

Percentage replacement of BNT	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
0%	1:2:4	488.34	21.70	21.79
		479.29	20.98	
		510.43	22.69	
2%	1:2:4	398.32	17.70	15.40
		350.90	15.59	
		291.25	12.9	
5%	1:2:4	298.30	13.26	12.12
		232.19	10.32	
		287.43	12.78	
10%	1:2:4	270.03	12.00	10.93
		237.38	10.55	
		230.53	10.25	

Table 4.3.2: Compressive Strength Test Result on Concrete Cubes for 28days curing age

Percentage replacement of BNT	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
0%	1:2:4	534.23	23.70	22.8
		505.24	22.46	
		500.43	22.24	
2%	1:2:4	437.20	19.4	19.16
		449.67	19.9	
		409.45	18.19	
5%	1:2:4	395.5	17.6	

		347.37	15.44	16.13
		345.64	15.36	
10%	1:2:4	295.82	13.14	13.01
		290.25	12.90	
		292.19	12.99	

Table 4.3.3: Compressive Strength Test Result on Concrete Cubes for 50days curing age

Percentage replacement of BNT	**Mix by Volume**	**Failure Load (KN)**	**Compressive Strength (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
0%	1:2:4	534.19	23.74	23.76
		534.48	23.76	
		535.34	23.79	
2%	1:2:4	525.48	23.35	22.85
		516.50	22.95	
		500.60	22.25	
5%	1:2:4	485.82	21.59	21.89
		510.36	22.68	
		481.56	21.40	
10%	1:2:4	456.48	20.29	20.68
		458.83	20.39	
		480.78	20.37	

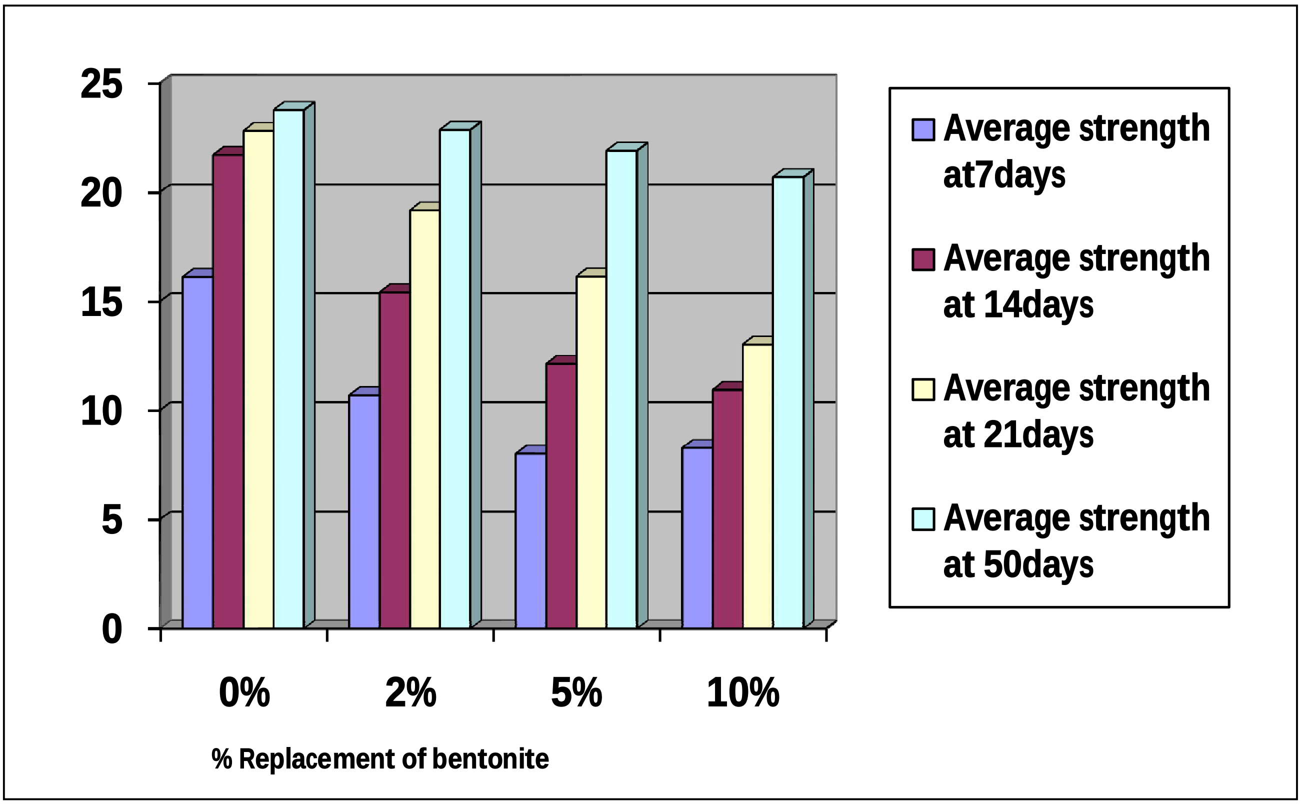

Fig 4.3a: Column chart comparison of Compressive Strength against Curing days

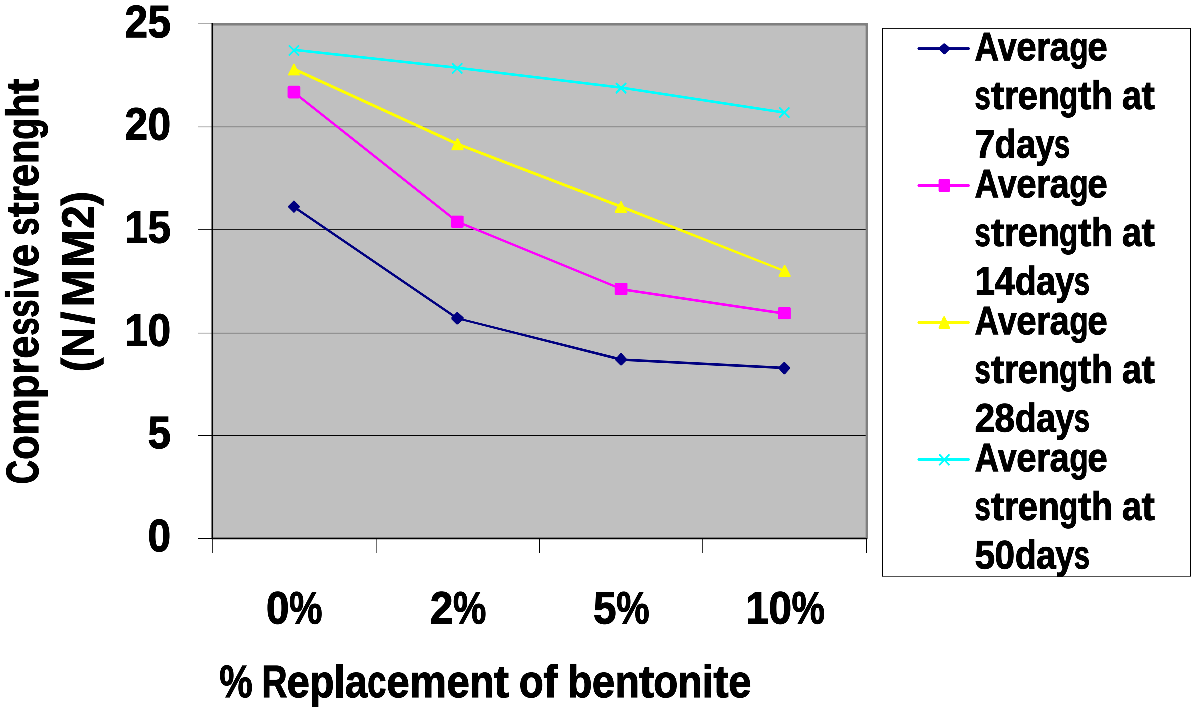

Fig 4.3b: Graph of comparison of the strength of concrete from 7days to 50days

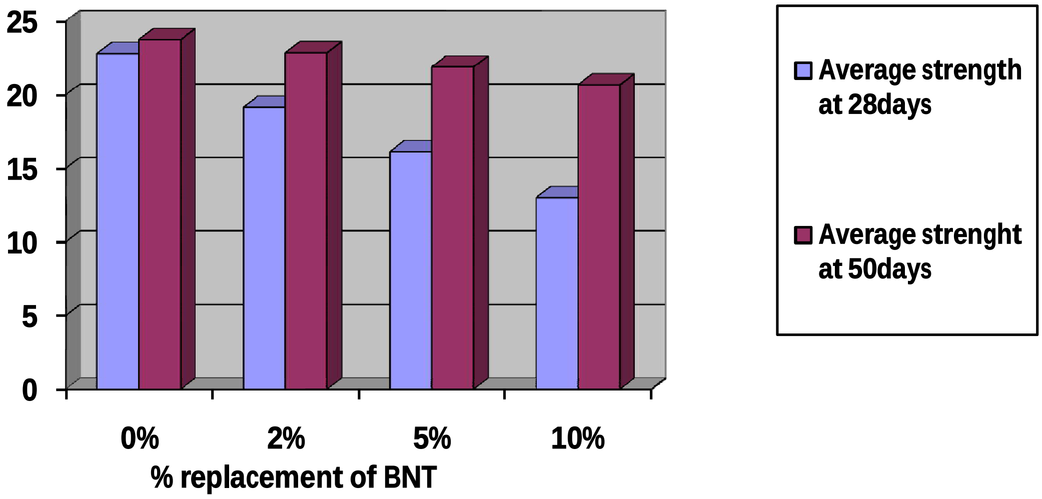

Fig 4.3c: Column chart comparison between 28days and 50days

The results obtained from the compressive test performed on the hardened concrete cubes are presented in Table 4.3 to 4.3.3 and Fig 4.3a and 4.3c respectively. The compressive strength results of concrete cast with 0% BNT has a greater strength than that cast with any percentage of BNT. It was observed that the strength of concrete decreased with the increase in percentage replacement of cement with bentonite compared with that of the control mix at early age. The result shows that the 10% replacement of cement with bentonite at 50 days gave an ultimate strength of 20.68N/mm2. This value is very close to the value gotten from control mix at 28days.

This result validates the claim that bentonite results in poor early-stage compressive strength but gives good results in later stage.

4.4 Water Absorption Test.

Table 4.4: water absorption for 0% BNT

Age (days)	Wight of cubes before curing (kg)	Weight of cubes after curing(kg)	Water absorption	Average water absorption
7	8.4	8.7	0.3	0.25
	8.2	8.45	0.25	
	8.2	8.4	0.2	
14	8.2	8.4	0.2	0.2
	8.4	8.6	0.2	
	8.2	8.4	0.2	
28	8.2	8.4	0.2	0.27
	8.1	8.5	0.4	
	8.2	8.4	0.2	
50	8.0	8.4	0.4	0.38
	8.0	8.45	0.45	
	8.3	8.6	0.3	

Table 4.4.1 water absorption for 2%BNT

Age (days)	Wight of cubes before curing (kg)	Weight of cubes after curing(kg)	Water absorption	Average water absorption
7	8.2	8.4	0.2	0.27
	8.4	8.7	0.3	
	8.4	8.7	0.3	
14	8.2	8.4	0.2	0.28
	8.3	8.7	0.4	
	8.2	8.45	0.25	

28	7.95	8.2	0.25	0.25
	8.0	8.2	0.2	
	8.0	8.3	0.3	
50	8.2	8.5	0.3	0.3
	8.2	8.5	0.3	
	8.2	8.5	0.3	

Table 4.4.2 water absorption for 5%BNT

Age (days)	**Wight of cubes before curing (kg)**	**Weight of cubes after curing(kg)**	**Water absorption**	**Average water absorption**
7	8.2	8.4	0.2	0.2
	8.2	8.4	0.2	
	8.2	8.4	0.2	
14	8.2	8.3	0.1	0.1
	8.2	8.3	0.1	
	8.2	8.3	0.1	
28	8.2	8.6	0.4	0.33
	8.0	8.3	0.3	
	8.0	8.3	0.3	
50	8.0	8.4	0.4	0.37
	8.4	8.7	0.3	
	8.0	8.4	0.4	

Table 4.4.3 water absorption for 10%BNT

Age (days)	Wight of cubes before curing (kg)	Weight of cubes after curing(kg)	Water absorption	Average water absorption
7	8.1	8.2	0.1	0.35
	8.3	8.6	0.3	
	8.4	8.7	0.3	
14	8.1	8.3	0.2	0.13
	8.0	8.1	0.1	
	8.0	8.1	0.1	
28	7.95	8.2	0.25	0.25
	8.0	8.2	0.2	
	8.0	8.3	0.3	
50	7.95	8.4	0.45	0.48
	8.0	8.5	0.5	
	8.0	8.5	0.5	

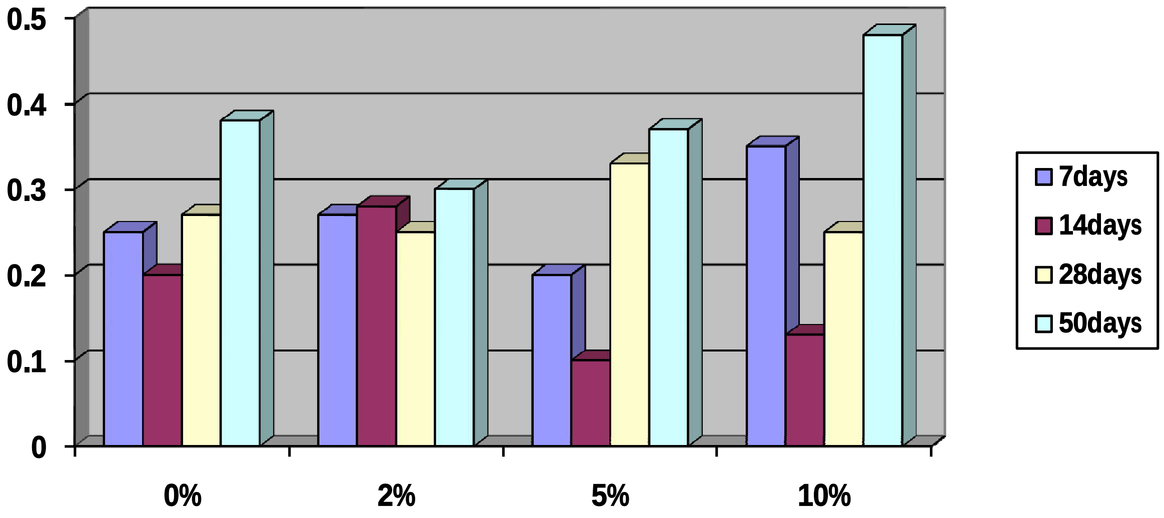

Fig 4.4: Comparison of water absorption values from 7days to 50days

From the result obtained from water absorption of concrete cubes which are represented in table 4.4 to table 4.4.3 and fig 4.4 respectively shows that the concrete cubes have the highest water absorption at 10% replacement of BNT at 50days curing age.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the results of the investigation of using BNT as a partial substitute of cement in concrete production (as pozzolanas), the following conclusions can be drawn:

1. That bentonite can be used in structural concrete as a partial replacement, by weight of cement to produce a reliable concrete.
2. Concrete containing up to 10% bentonite resulted in poor early stage but performed very well at latter stage of 50days. This is in agreement with Junaid Akbar et al. (2013)
3. The Slump test conducted indicate that the slump value increases with consistent replacement of the (BNT) from 2% to 10% for w/c ratio (0.5) with the highest slump recorded at 10% replacement of BNT.

The Sieve analysis result indicates that the percentage passing through sieve size 0.075mm and 4.75mm for SD are 99.6 and 0.0033 respectively and according to AASHTO Classification system, it is classified as A-2-4 and SC (clayey sand) according to USCS Classification system. This material constitutes a good sub-grade material for road construction. From the particle size distribution curve, $D_{30} = 0.7$ and from values of D60 and D10 above, $C_c = 1.08 < 3$.

Since the co- efficient of gradation is less than 3, it conforms to the limit given in the BS 1377: PART 2; 1990 for well- graded soils. Hence, the fine aggregate can be said to be well graded.

5.2 Recommendation.

1. The use of bentonite as partial replacement of cement in concrete up to 10% where latter stage strength is required.
2. Proper compaction of the concretes must be ensured, as compaction is observed to improve the strength of concrete

3 The use of additive to enhance the workability of the bentonite-cement concrete.

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EFFECT OF PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH PALM KERNEL SHELL ON COMPRESSIVE AND FLEXURAL STRENGTH OF CONCRETE

BY

EZEANOKWASA PASCHAL CHIDOZIE
2016224029

DEPARTMENT OF CIVIL ENGINEERING
FACULTY OF ENGINEERING.
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IN PARTIAL FUFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR IN ENGINEERING (B.ENG) DEGREE IN CIVIL ENGINEERING

PROJECT SUPERVISOR: ENGR. A.A. EZENWAMMA

FEBURARY, 2022

CERTIFICATION

This is to certify that this project topic titled “The Effect of Partial Replacement of Coarse Aggregate with Palm Kernel Shell on Compressive and Flexural Strength of Concrete was carried out by Ezeanokwasa Paschal Chidozie with registration number (NAU/2016224029) in the Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

_________________________ ___________________

Ezeanokwasa Paschal Chidozie Date

APPROVAL PAGE

This research work “The effect of Partial Replacement of Coarse Aggregate with Palm Kernel Shell on Compressive and Flexural Strength of Concrete have been assessed and approved by Department of Civil Engineering Faculty of Engineering Nnamdi Azikiwe University Awka Anambra State.

______________________ ________________

Engr. Ezenwamma Date
(Project Supervisor)

______________________ ________________

Engr. Dr. C.A. Chidolue Date
(Head of Department)

______________________ ________________

(External Examiner) Date

DEDICATION

To the individual(s) who may find this work useful.

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Finally, I will like to appreciate my entire course mate for their various admonition and encouragement during the trial times of my academic pursuit.

ABSTRACT

This study was carried out to investigate the effect of partial replacement of coarse aggregate (granite) with Palm Kernel Shell (PKS) on flexural and compressive strength of concrete. Concrete specimens were prepared with a mix ratio of 1:2:4 (Cement: Sand: Granite-PKS). Water/cement ratio of 0.55 was adopted for all relevant laboratories testing. The granite was partially replaced with PKS in increasing percentages of 4, 8, 12, 16 and 20% by weight of the dry sample. The test conducted include: Sieve analysis of Granite (GT), Sand (SD) and Palm Kernel Shell (PKS), Specific gravity of PKS, SD and GT, Slump (Workability) test of fresh concrete, Water absorption test of Granite (GT) and Palm Kernel Shell (PKS), Density test of Granite (GT), Sand (SD) and Palm Kernel Shell (PKS), Compressive and Flexural Strength test of hardened concrete cubes. Sieve analysis test conducted for both GT, SD and PKS classified the samples as GM (Gravelly Silt), SC (Clayey Sand) and GM (Gravelly Silt) according to Unified Soil Classification System and A-1-b, A-2-4 and A-1-b according to American Association of State Highway and Transport Officials (AASHTO, 1986) while the specific gravity of GT, SD and PKS was found to be 2.69, 2.61 and 2.29 respectively. The Water absorption test conducted for GT and PKS suggest a water absorption value of 1.44 and 17.07 respectively. Density test conducted indicate that GT produces the highest density in both loosed and compacted state with that of SD been relatively the same and the additive (PKS) producing the least value. The slump (workability) test of the concrete was observed to improve upon consistent addition of PKS from 4% to 20%PKS with the highest slump value recorded at 20%PKS content. The flexural Strength of the hardened concrete cubes recorded at 7, 14, 21 and 28 days of curing increased initially from 4% to 8%PKS content but beyond 8%PKS, the flexural strength decreased while the compressive strength recorded at 7, 14, 21 and 28 increased only at 4%PKS content, beyond 4%PKS content the compressive strength decreased. The observed decline in flexural and compressive strength result can be attributed to the lack of sufficient crushing strength of the additive (PKS) and hence this study strongly discourages the use of this material (PKS) beyond 4% as no obvious improvement in flexural and compressive strength of the hardened concrete was observed.

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LIST OF SYMBOL & ABBREVIATION

SD- Sand
PKS – Palm Kernel Shell
GT- Granite
G_S – Specific Gravity
AASHTO – American Association of State Highway and Transportation Officials
USCS – Unified Soil Classification System
ASTM – American Society for Testing and Material
D_{10} – Particle Size such that 10% is finer than the Size
D_{30}- Particle Size such that 30% is finer than the Size
D_{60}- Particle Size such that 60% is finer than the Size
C_U – Coefficient of Uniformity
C_C – Coefficient of Curvature
GS – Gravelly Sand
SC – Clayey Sand
OPC – Ordinary Portland cement
W/C – Water to Cement Ratio.

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CHAPTER ONE

INTRODUCTION

1.1 Background of study

Nigeria is a developing country desirous of growth, and for continuous growth, we need continuous development and one of leading factor for development is infrastructure. Civil engineering entails the analysis, design, construction and maintenance of infrastructure that supports modern society including buildings, bridges, roads, tunnels, dams, etc. This entire infrastructure involves a large amount of concrete.

Concrete is the world's most consumed man made-material (Naik, 2008). Its great versatility and relative economy in filling wide range of needs has made it a competitive building material (Sashidar and Rao, 2010). Concrete production is not only a valuable source of societal development, but it is also a significant source of employment (Naik, 2008). Production of concrete relies to a large extent on the availability of cement, sand and coarse aggregates such as granite, the costs of which have risen significantly over the past few years. Despite the rising cost of production, the demand for concrete is increasing. The negative consequences of the increasing demand for concrete include depletion of aggregate deposits; environmental degradation and ecological imbalance (Short & Kinniburg, 1978). The possibility of complete depletion of aggregates resources in the near future can therefore not be over emphasized.

Rising construction costs and the need to reduce environmental stresses to make construction sustainable, has necessitated research into the use of alternative materials, especially locally available ones which can replace conventional ones used in concrete production. The use of such re-placement materials should not only contribute to construction cost reduction and drive infrastructural development but also contribute to reduce stress on the environment and make engineering construction sustainable to help transform the building and construction sectors of national economies and contribute towards the realization of national and global poverty reduction strategies. Such materials should be cheap and readily available. The use of cheaper building materials without loss of performance is very crucial to the growth of developing countries (Zemke & Woods, 2009).

Historically, agricultural and industrial wastes have created waste management and pollution problems. However the use of agricultural and industrial wastes to complement other traditional materials in construction provides both practical and economical advantages. The wastes generally have no commercial value and being locally available transportation cost is minimal (Chandra & Berntsson, 2002). Agricultural wastes have advantages over conventional materials in low cost construction (Abdullah, 1997).The use of waste materials in construction contribute to conservation of natural resources and the protection of the environment. (Ramezanianpour, Mahdikhani & Ahmadibeni, 2009). Nimityongskul and Daladar (1995) investigated the use of coconut husk ash, corn cob ash and peanut shell ash as cement replacement in concrete production. Slim and Wakefield (1991) investigated the use of water works sludge in the manufacture of clay bricks.

The palm oil industry produces wastes such as palm kernel shells, palm oil fibres which are usually dumped in the open thereby impacting the environment negatively without any economic benefits. Palm kernel shells (PKS) are hard, carbonaceous, and organic by- products of the processing of the palm oil fruit. PKS consists of small size particles, medium size particles and large size particles in the range 0-5mm, 5-10mm and 10-15mm (Alengaram, Mahmud, Jumaat & Shiraz, 2010). The shells have no commercial value, but create disposal and waste management problems.

From the foregoing explanation, this research will therefore explore into ways of improving the compressive and flexural strength of concrete produced with partial replacement of coarse aggregate with palm kernel shell.

1.2 Statement of problem

The increasing cost of construction materials and the environmental degradation caused by the high utilization of aggregates for concrete is a global challenge in civil engineering construction. The high demand and continuous use of crushed granite for concrete in construction will overtime deplete the natural stone deposits and this will affect the environment thereby causing ecological imbalance. The palm oil industry produces wastes such as palm kernel shells, palm oil fibres which are usually dumped in the open thereby impacting the environment negatively without any economic benefits. There is need to explore and find suitable replacement material to substitute for the coarse aggregate in the production of light weight concrete. This research will therefore explore into ways of improving the compressive and flexural strength of concrete produced with partial replacement of coarse aggregate with palm kernel shell.

1.3 Aim and Objectives

The aim of the study is to evaluate the effect of partial replacement of coarse aggregate with palm kernel shell on compressive and flexural strength of concrete while the objectives include:

1. Characterize (classify) the fine aggregate (sand), coarse aggregate (granite) and additive (palm kernel shell) used for the research.
2. Determine the feasibility and efficacy of using palm kernel shell as an additive for partial replacement of coarse aggregate (granite).
3. Study the effect of palm kernel shell on the workability, flexural and compressive strength of concrete.
4. Make comparative analysis between the flexural and compressive strength of both conventional and non-conventional concrete.
5. Determine the maximum amount of palm kernel shell required for optimum improvement of flexural and compressive strength of the concrete.
6. Make relevant recommendation based on the findings obtained.

1.4 Scope of study

The study is restricted to the evaluating the effect of partial replacement of coarse aggregate with palm kernel shell on the flexural and compressive strength of concrete and the laboratory test to be conducted include: Sieve analysis and Specific gravity of fine, coarse aggregate and additive (palm kernel shell), Water absorption of coarse aggregate and additive (PKS), Bulk density test of fine, coarse aggregate and additive (palm kernel shell), Workability test of the fresh concrete and lastly to investigate the effect of partial substitution of coarse aggregate with palm kernel shell, Flexural and Compressive strength test of the hardened concrete cube will be conducted.

1.5 Significance of study

This research will be carried out to assess the efficacy of using palm kernel shell as a partial substitute for coarse aggregates in concrete and the findings obtained from the research will be useful in the following ways:

1. It will guarantee massive infrastructural development through the relative economy achieved in the utilization of construction material.
2. Ensure environmental sustainability through the use of environmentally friendly materials for concrete production.
3. Reduction of environmental load posed by unauthorized dumping of agricultural waste (palm kernel shell).
4. Ensure rational use of natural resources.
5. Guarantee the availability of construction materials through the use of renewable resources (palm kernel shell).

CHAPTER TWO

LITERATURE REVIEW

2.1 Preamble

This chapter reviews the relevant literature on the topic of study. It present the work of other researchers in the field of science and engineering as they relate to this study which focuses on palm kernel shell (PKS), cement, granite and concrete but most essentially, the effect of partial replacement of granite with palm kernel shell on flexural and compressive strength of concrete.

2.2 Concrete

Concrete is the most commonly used material employed for construction purpose in the world today (Meftah, et al 2013), the expensive cost of concrete constituents such as cement, fine and coarse aggregate has necessitated the need to search for alternative construction materials (Meftah, et al 2013: Nguyen, et al 2013). The general importance of concrete application in construction projects and civil works cannot be overemphasized. The overwhelming demand for concrete in construction adopting normal weight aggregates (NWA), such as gravel and sand has led to tremendous depletion in naturally occurring aggregates causing numerous damage to the environment which are irreparable (Nguyen, et al 2013).

It is a composite material that consist essentially of a binding material such as a mixture of Portland cement and water within which are embedded particles or fragments of aggregate usually a combination of fine and coarse aggregate (Mc Graw-Hill, 2003). Gambir, (2004), concrete is a synthetic construction material made by mixing cement, fine aggregate, coarse aggregate and water in the proportions. Each of these components contributes to the strength of concrete. Concrete is by far the most versatile and most widely used construction material (Aderinola, et al. 2020). It can be engineered to satisfy a wide range of performance specification, unlike other building material such as natural stone or steel which generally have to be used as they are.

2.2.1 Constituents of Concrete.

(Mc Graw-Hill, 2003) stated that the ingredient used for concrete production include cement, fine aggregate (sand), coarse aggregate (granite).

I. Water

(Shatty, 2000) states that water is an important ingredient of concrete as it actively participate in chemical reaction with cement. Since it help to form the strength giving cement gel. (Nakhil, et al. 2011) stated that water is an essential ingredient as part of mixing water is utilized in the hydration of cement and the balanced water is required for impacting workability to concrete. Thus the quality and quantity of water is required to be given adequate consideration in the production of concrete. (Nakhil, et al. 2011), Also state that water plays a vital role in the strength of concrete as it helps in the following areas:

a) It wet the surface of aggregate as it helps to develop cohesion thereby enabling the cement paste to adhere quickly and satisfactorily to the wet surface of aggregate than to the dry surface.
b) To prepare a plastic mixture of the various ingredient and to impact workability to concrete so as to facilitate placing in the desired position.
c) Water is also needed for hydration of the cementing material to set and harden during the period of curing.

I.I Influence of Water Quality on Concrete

(Nakhil, et al. 2011), conducted a research on the impact of water quality on strength properties of concrete using portable water, ground water and sewage water and it was deduced that portable water satisfy the requirement of water to be used for construction work as there was significant resulting increase in the flexural, split tensile and compressive strength of the concrete compared to other source of water. (Tahir, et al. 2020), stated that the quality of water has a significant effect on the strength properties of concrete as treated water produces concrete with comparatively higher strength than groundwater and saline water.

I.II Influence of Water-Cement ratio on Concrete

(Shatty, 2000) stated that the water-cement ratio of concrete must lie within practical limit (0.55-0.6) as this determine the strength of concrete. According to (Shatty, 2000) lower cement – water ratio could be used when the concrete is vibrated to achieve higher strength where as higher water-cement ratio is required when the concrete is hand compacted. In other word, the effect of water-cement ratio on strength and durability properties of concrete depends on the type of compaction. But however, regardless of the type of compaction employed during the production of concrete the water-cement ratio falls within the practical limit (0.55-0.6) as any deviation could result to fall in the strength of concrete due to introduction of air voids.

II. Cement

Cement is one of the essential ingredient of concrete as the compressive strength of concrete largely depends on the quality and quantity of cement as cement is the strength giver that binds the fine aggregate (usually sand or other substitute) and coarse aggregate (gravel, crushed stone) together to form a rigid mass that is capable of sustaining loads. (Chanadan, 2019). Cement grade or cement strength class correspond to the minimum 28 days compressive strength of concrete. Generally, there are three cement grades: grade 33, grade 43 and grade 53 which have a compressive strength of 32.5Mpa, 42.5Mpa and 52.5Mpa respectively. (Chanadan, 2019) stated that in terms of quality of assurance of cement, any cement with a compressive strength of 32.5Mpa would be adjudged as meeting the strength requirement of cement grade 32.5Mpa. During the course of this research work Ordinary Portland Cement (OPC) will be used for the production of concrete. Ordinary Portland Cement (OPC) is cement containing 95%-100% clinker and gypsum and 0%-5% minor additional constituents (Chanadan, 2019).

II.I Chemical Composition of Ordinary Portland Cement (OPC)

The raw materials used in the manufacture of Portland cement consist mainly of lime (Cao), silica (SiO2), alumina (Al2O3) and iron oxide (Fe2O3). The four compounds are usually regarded as the major constituents of cement. They are described in abbreviated form by cement chemists as follows: CaO = C; SiO2 = S; Al2O3 = A; and Fe2O3 = F. Likewise, H2O in hydrated cement is denoted by H, and SO3 by S. In addition to the main compounds listed above, there exist minor compounds, such as MgO, TiO2, Mn2O3, K2O and Na2O; they usually amount to not more than a few per cent of the mass of cement. Two of the minor compounds are of particular interest: the oxides of sodium and potassium, Na2O and K2O, known as the alkalis. They have been found to react with some aggregates, the products of the reaction causing disintegration of the concrete, and have also been observed to affect the rate of the gain of strength of cement (Neville, 2005). The relative proportions of these oxide compositions are responsible for influencing the various properties of cement; in addition to rate of cooling and fineness of grinding. Table 2.0 shows the approximate oxide composition limits of ordinary Portland cement.

Table 2.0 Oxide Composition Limit of Ordinary Portland Cement (OPC) (Shetty, 2005).

Oxide	**Approximate Percentages**
CaO	60-67
SiO2	17-25
AL2O3	3.0-8.0
Fe2O3	0.5-6.0
MgO	0.1-4.0
Alkalis(K2O, N2O)	0.4-1.3
SO3	1.3-3.0

The oxides present in the raw materials when subjected to high clinkering temperature combine with each other to form complex compounds. The identification of the major compounds is largely based on R.H. Bogue's work and hence it is called ―Bogue's Compounds. The four compounds usually regarded as major compounds are tricalcium silicate (C3S), dicalcium silicate (C2S), tricalcium aluminate (C3A) and tetracalciumalumino ferrite (C4AF). Shetty, (2005).The Bogue's formula used in calculating the percentage of the various compounds is given as follows: C3S = 4.07 (CaO) – 7.60 (SiO2) – 6.72 (Al2O3) – 1.43 (Fe2O3) – 2.85 (SO3) C2S = 2.87 (SiO2) – 0.754 (3CaO.SiO2)C3A = 2.65 (Al2O3) – 1.69 (Fe2O3) C4AF= 3.04 (Fe2O3).

II.II Properties of Ordinary Portland Cement

a. Fineness of cement

As hydration take place at the surface of the cement, it is the surface area of the cement particles which provide the material available for hydration. The rate of hydration is controlled by fineness of the cement. For a rapid rate of hydration, a higher fineness is necessary. (Anna, K. 1994) Investigated the effect of fineness of cement and eventually came up with the following observation:

i. Higher fineness require higher grinding (High cost implication)
ii. Finer cement deteriorate faster upon exposure to atmosphere
iii. Finer cement are very sensitive to alkali-aggregate reaction
iv. Finer cement require more gypsum for proper hydration

v. Finer cement requires more water.

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence fastens the development of strength. Fineness of cement is determined by permeability. For example in the blaine air permeability method, a known volume of air is passed through cement. The time is recorded and the specific surface is calculated by a formula. Fineness is expressed in terms of specific surface of the cement (Cm^2/gr). For OPC specific surface area is 2600-3000 Cm^2/gr. This test is conducted as per BS EN196-6:1995.

b. Setting Time of Cement

Setting time refers to a change from liquid state to solid state. During setting time, cement paste acquire some strength (Gartener, et al. 1989). The water content has a marked effect on time of setting. In acceptance test for cement, the water content is regulated by bringing the paste to a standard condition of wetness and this is referred to as "normal consistency". Normal consistency of OPC ranges from 20-30% by weight of concrete. Vicat apparatus is used to determine normal consistency. Normal consistency is that condition for which the penetration of a standard weighed plunger into the paste is 10mm in 30sec. In practice, the terms initial set and final set are used to describe arbitrary chosen time of setting. Initial set indicates the beginning of a noticeable stiffening and final set may be regarded as the start of hardening (or complete loss of plasticity). It is the also the period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat'smould 5 mm to 7 mm from the bottom of the mould. Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression. The setting time test is carried out using the Vicat apparatus as per BS-EN 196 part3 (1995). The results of the test should comply with the requirements of BS-EN 197 part1 (2000), which recommend a minimum of 60 minutes and a maximum of 10 hours as the initial and final setting times of ordinary Portland cement respectively. (Gartener, et al 1989) summarized the factors affecting setting time as:

i. Temperature and Humidity.
ii. Amount of water

iii. Chemical composition of cement
iv. Fineness of cement (the finer the cement, the faster the setting)

Marthong, (2012), Investigated that the addition of saw dust ash in OPC grade 42.5 had increased the initial and final setting times. This was attributed to the low rate of hydration in the paste containing the saw dust ash.

c. Soundness of Cement.

Soundness is referred to as the volume stability of cement paste. The cement paste should not undergo large changes in volume after it has set. Free CaO and MgO may result in unsound cement (Chanadan, G. 2019). Upon hydration, C and M (calcium and magnesium) will form CH and MH with volume increase thus cracking. (Gartener, et al. 1983), Since unsoundness is not apparent untill several months or years, it is necessary to provide an accelerated method for its determination which include:

i. Lechatelier Method where only free CaO can be determined.
ii. Autoclave Method where both free CaO and MgO can be determined.

In the soundness test a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is sped up and can be detected. Soundness means the ability to resist volume expansion. For ordinary Portland cement, BS-EN 197 part1 (2000) has specified a maximum expansion of 10mm. The work of Chowdhury et al, (2015) indicated that the soundness of cement was improved with the addition of saw dust ash as partial replacement. In the research, cement was replaced by the ash within the range of 5% to 30% and the soundness was found to increase with an increase in the ash content.

d. **Strength of Cement and it’s effect on Concrete.**

Strength test are not carried out on neat cement paste because it is very difficult to form this paste due to cohesive property of cement. Strength test are carried out on cement mortar prepared by standard gradation (1 part cement + 3 part sand + ½ part water). The strength of cement is tested through compression, direct tension or flexure tests. According to BS-EN 196 part1 (1995), prisms of size 40mmx40mmx160mm are cast of a cement sand mortar produced using 1:3 mix ratio. The test prisms are tested for compressive strength at 2days and 28 days.

According to BS 5826, cement mortar is classified into M4, M6, and M12 with compressive strengths of 4N/mm2, 6N/mm2, and 12N/mm2 respectively at 28 days. BS EN 998 part 2 (2003) had also provided similar compressive strength.

(Chandan, G. 2019) Investigated on the effect of grade of cement on compressive strength of concrete where it was reported that the compressive strength is largely dependent on the grade of cement as cement grade 52.5 produces comparatively higher compressive strength than cement grade 42.5 and 32.5 respectively. Similar observation was also confirmed by (Gideon, et al. 2015).

e. Hydration of Ordinay Portland Cement (OPC).

It is the chemical reaction of cement with water. As the water comes into contact with cement particles, hydration reactions start immediately at the surface of the particles. (Gartener, et al. 1989). Although hydrate such as C-H are formed, process of hydration is a complex one and results in reorganization of the constituents of original compound to form new hydrated compounds. (Gartener, et al. 1989) state that at any stage of hydration, the hardened cement paste (HCP) consist of:

i. Hydrate of various compounds referred to collectively as Gel.
ii. Crystals of calcium hydroxide (CH)
iii. Some minor hydrate compound
iv. Unhydrated cement
v. Residue of water filled spaces-pores.

(Jenings, et al. 1983) opined that upon hydration, C_3S, C_2S and CH are formed which become an integral part of the hydration products. CH does not contribute very much to the strength of Portland cement. According to (Jenning, et al. 1983) C_3S having a faster rate of reaction accompanied by greater heat of hydration develops early strength of the paste. On the other hand, C_2S hydrates and hardens slowly so results in less heat generation and develops most of the ultimate strength. (Gartener, et al. 1989) summarized hydration process as:

i. Immediately after mixing with water
ii. Reaction occurs around particles referred to as early stiffening.
iii. Accompanied by formation of skeletal structure referred to as first hardening
iv. Gel infilling known as later hardening.

III. Fine Aggregate

Fine aggregate plays an important role as it combines with cement in the presence of water increasing the workability and uniformity of concrete (Balamuwgan and Perumal, 2013). Shatty, (2000). Stated that fine aggregate are important constituents as it gives body to the concrete and also help to reduce shrinkage. Mindness and Young, (1987), Fine aggregate aid in the hydration of cement as it react with cement in the presence of water to form paste. In other word, hydration of cement is largely controlled by the fineness of the aggregate. (Anna, 1994) stated that fine aggregate have the possibility of improving particle parking as they act as fillers both in lean and rich mixes with crushed aggregate.

IV. Coarse Aggregate

Coarse aggregate occupies over 75% of the concrete volume acting as economic filler material. (Ezeldin and Actcin, 1991) compared concrete with the same mix proportion containing four different coarse aggregate types. They concluded that in high strength concrete, higher strength coarse aggregate typically yield higher compressive strength while in normal strength –concrete coarse aggregate has little effect on compressive strength. Some research (Strange and Bryant, 1979) and (Nallathambi, et al. 1984) has shown that there is an increase in fracture toughness with an increase in the sizes of coarse aggregate.

2.3 Palm Kernel Shell (PKS).

Palm Kernel Shell was partially a waste in the 1990s and early 2000 as more than 350,000 tons were available for sale. The PKS had been a little known then for its potential usage on a large scale especially in concrete work (Mohammad, 2007). Beyond 2000, research into utilization of Palm Kernel Shell as light weight concrete and other uses had received a big boost. Palm kernel shells (PKS) are organic waste materials obtained from crude palm oil producing factories in Asia and Africa (Alengaram, et al, 2010).

During the crude palm oil process the fruit's flesh is melted through a steaming treatment. The residual nuts are further mechanically crushed to extract the seeds or kernels. The Palm Kernel Shells (PKS) is a virgin biomass with a high calorific value, typically about 3,800

Kcal/kg (ASTM, 1978). Oil Palm trees grow in the coastal belt in Nigeria which varies in depth from 100 to 150 miles and a riverine belt which follows the valleys of the Niger and Benue for a distance of about 450 miles from the sea. The main palm oil producing states include Ogun, Ondo, Oyo, Edo, Cross River, Anambra, Enugu, Imo, Abia, Ekiti, Akwa-Ibom, Delta and Rivers.

Palm kernel shells in the past had been used solely as fuelling material at home and for industries. The quest for alternative civil engineering construction material which is economical and light in weight has been a major drive in carrying out this work. Palm kernel shell possesses hard characteristics as coarse aggregate and there have been attempts to use it as a coarse aggregate to replace conventional coarse aggregates traditionally used for concrete production (Mohd et al., 2008). Ata et al (2006) compared the mechanical properties of palm kernel shell concrete with that of coconut shell concrete and reported the economy of using palm kernel shell as lightweight aggregate. Generally, palm kernel shell consists of 60 – 90% of particles in the range of 5 – 12.7mm (Okafor, 1988). The specific gravity of palm kernel shell varies between 1.17 and 1.37, while the maximum thickness of the shell was found to be about 4mm (Okpala, 1990).

2.3.1 Physical Properties of Palm Kernel Shell Concrete.

Okafor, (1988) and Okpala, (1990), reported that palm kernel shell consists of 60 to 90percent particles in the range of 5 to 12.7mm, specific gravity between 1.17 and 1.37, maximum thickness of the shell was found to be 4mm and density to vary in the range of 1,700 to 2,050kg/m^3.They also reported a 28days cube compressive strength in the range of 15 to 25MPa. In the same study Okafor, (1988) conducted a study using palm kernel shell as aggregate replacement in concrete and discovered that similar to normal weight concrete (NWC), water to cement (w/c) ratio affects the mechanical properties of palm kernel shell concrete. He reported that the 28 days compressive strength of palm kernel shell concrete varied depending on the mix ratio employed. Also Ayanbadefo, (1990) in his research on the investigation into the use of palm kernel shell as light weight aggregate for concrete reported that the Aggregate Impact Value (AIV) and the Aggregate Crushing Value (ACV), were approximately 46percent and 58percent lower respectively compared to granite aggregates, which shows that palm kernel shell is a good shock absorbing material.

Also Alengaram et al., (2010) investigated the physical and mechanical properties of different sizes of palm kernel shells as lightweight aggregates (LWA) and their influence on mechanical properties of palm kernel shell concrete reported that the 28day compressive strengths were in the range of 21 to 26MPa.They further showed that palm kernel shell consists of about 65 to 70percent of medium size particles in the range of 5 to 10mm. The other two sizes, namely, small (0-5mm) and large (10-15mm) sizes were found to influence the mechanical properties of palm kernel shell concrete. The concrete mix that was made with medium size palm kernel shell only produced lower compressive strength of about 11 percent compared to the mix that contained all sizes of palm kernel shell. Acheampong et al., (2013) investigated the Comparative Study of the Physical Properties of Palm kernel shells Concrete and Normal Weight Concrete using different cement types in Nigeria and reported that the density of the palm kernel shell concrete was about 22 percent lower than that of the normal weight concrete for both cement types.

2.3.2 Density of Palm Kernel Shell (PKS) Concrete.

The density of palm kernel shell ranges from 1700 to 2050kg/m3 and it depends on factors such as type of sand and palm kernel shell contents (Mohd et al., 2008). Generally, when the density of concrete is lower than 2000kg/m3, it is categorized as light weight concrete. Thus, the palm kernel shell concrete can be produced within this target density of 2000kg/m3, hence palm kernel shell concrete is a light weight concrete. According to (Mohd et al., 2008), the 28 days cube compressive strength obtained was 15 –25MPa while the structural behavior of palm kernel shell is very limited.

On density of concrete and percentage replacement of palm kernel shell in concrete, Alengaran et al., 2010; Olutoge et al., 2010, 1995 and Okpala, (1990), investigated among other things the density of palm kernel shell aggregate as well as its concrete and discovered that when palm kernel shell is completely used as coarse aggregate, the density of the palm kernel shell concrete is less by over 20percent with reference to normal weight concrete. Olutoge et al., (1995), found the density of palm kernel shell concrete to be 740kg/m^3. They concluded that the materials have properties which resembled those of lightweight concrete materials. Generally, when the density of concrete is lower than 2000kg/m^3, it is categorized as lightweight concrete (LWC).

Neville (2000) also reported that the use of palm kernel shell as a material of construction could have other advantages in concrete aside from serving as lightweight concrete. He further stated that one of the major advantages is the reduction in concrete density, which consequently reduces the total dead load of the structure. He also stated that when lightweight concrete is employed in the construction process, the formwork is subjected to lower pressure than would be the case with normal or heavy weight concrete.

2.3.3 Bond Characteristics of Palm Kernel Shell Concrete (PKSC).

Some research had been done in assessing the bond characteristics of the palm kernel shell in concrete matrix like works of Raheem et al., (2008) and Jumaat et al., (2009). According to Raheem et al., (2008) and Jumaat et al., (2009), the poor bond between palm kernel shell aggregate and the concrete matrix produced a poorly compacted concrete because of the smooth and convex nature of the shell.

However, higher sand content has been reported to improve significantly the bond strength of palm kernel shell concrete (Babafemi and Olawuyi, 2011). Previously, researchers like Okafor , (1988), Mannan and Ganapathy, (2002) and Jumaat et al., (2009) have shown that a poor bond between palm kernel shell and the cement matrix resulted in bond failure. This contributed to lower mechanical properties in palm kernel shell concrete. They reported that bond failure may be attributed to the smooth and convex surface of palm kernel shell. Jumaat et al., (2009) reported that the ordinary failure in tension occurs as a result of breakdown of bond between the matrix and the surface of the aggregate or by fracture of the matrix itself, and not as a result of fracture of the aggregate. Since gravel stone have rough surface compared to palm kernel shell, it tends to have better bonding with the cement paste (Jumaat et al., 2009). The behaviour of palm kernel shell concrete in a marine environment had been previously reported by Mannan and Ganapathy (2001) and they revealed that the compressive strength of palm kernel shell concrete was 28.1MPa at an age of 28days.They also observed that the bond property of palm kernel shell concrete is comparable to other types of lightweight concrete.

2.3.4 Durability of Palm Kernel Shell Concrete (PKSC).

Durability properties of PKSC such as creep (Ali, 1984) and shrinkage (Mannan and Ganapathy, 2002) were also compared with normal weight concrete (NWC). Achieving the minimum concrete grade requirement as well as specify areas where palm kernel shell concrete (PKSC) can be used will promote the application of palm kernel shell in many civil works thereby eradicating the biological and environmental hazards caused as a result of improper disposal of the palm kernel shells and reduce cost of construction. Palm kernel shells could be employed for construction purposes in rural villages where they are easily accessible and places where natural occurring aggregates are expensive.

2.4 Palm Kernel Shell (PKS) as a sustainable building material in Nigeria

PKS as a Sustainable Building Material in Nigeria as a quest for implementing affordable housing system for both the rural and urban population of Nigeria and other developing countries, various proposals focusing on cutting down conventional building material costs have been put forward. One of the suggestions in the forefront has been the sourcing, development and use of alternative, non-conventional local construction materials including the possibility of using some agricultural and industrial wastes and residues (e.g. palm kernel shells) as construction materials (Tukiman and Mohd, 2009). The quality and cost effectiveness of construction materials employed in housing developments are among the major factors that determines the optimal delivery of housing projects (Akutu, 1983). Therefore, materials to be used for building construction must provide objective evidence of quality and cost effectiveness in terms of functional requirements and low income economy respectively. In view of this, the search for low-cost material that is socially acceptable and economically available, at an acceptable quantity within the reach of an ordinary man becomes a subject of continuous interest. The belief that the African region is full of raw materials suitable for local uses encourages this, yet the construction sector is not making optimal use of them (chandran, 2019).

2.5 Effect of Mineral Admixture on Palm Kernel Shell Concrete (PKSC).

Several researches in the past have shown that the cube compressive and flexural strengths could be improved with the addition of mineral admixtures like silica fume and fly ash to mention a few. Among studies done in this area include the works of Neville (1995 and 1996); Alengaram et al., 2008; Teo et al., 2006; Alengaran et al., 2010; Robert et al., 2003 and Alengaram et al., 2008).

Neville, (1995) had reported that Silica fume (SF) has the ability to localize at the surface of the aggregates to enhance the bond between an aggregate and the cement matrix. This addition of silica fume strengthens the zone of weakness being the zone between the aggregate and the cement paste interface. The weaker bond between aggregate-matrix contributes to the lower tensile strength in palm kernel shell concrete. In Normal weight concrete (NWC), the rough surface of aggregates increases the bond and thereby increasing tensile strength. According to Neville, (1996), Silica fume (SF) is always employed in the production of palm kernel shell concrete of grade 30 and above mainly to improve the bond between the smooth convex surfaces of palm kernel shell and cement matrix. He further reported that Silica fume (SF) particles are 100 times smaller than cement particles and the extremely very fine Silica fume (SF) particles have the ability to be located in the very close proximity of the aggregate particles. Alengaram et al., (2008) and Teo et al., (2006) respectively investigated the flexural behaviour of palm kernel shell concrete with and without mineral admixture and reported that for structural concrete using palm kernel shell as lightweight aggregate, the compressive strength was between 25 to 28.1MPa at 28days curing. They also concluded that lightweight concrete from palm kernel shell has dry density of 1950kg/m^3 and that the performance of beams made from palm kernel shell concrete of dimension (3000mm ×250mm × 150mm) was superior with respect to ductility. Alengaran et al., (2010) also observed that when mineral admixtures of silica fume (SF) and fly ash (FA) were added to a concrete mix with palm kernel shell aggregate, the compressive strength at 28days was improved to 37N/mm^2. Similarly, Robert et al., (2003) reported that the extremely fine Silica fume (SF) particles would produce calcium silicate and aluminate hydrates in Concrete on reacting with liberated calcium hydroxide.

This chemical reaction increases strength and reduces permeability by increasing the density of the concrete matrix. Also Alengaram et al., (2008), from his research paper on the influence of sand content and silica fume on mechanical properties of palm kernel shell concrete observed improvement of palm kernel shell concrete by the use of Silica fume (SF). The authors reported that one of the ways to improve the bond is to check the influence of sand content as mechanical properties, in which is governed by density of concrete. The fresh densities of palm kernel shell ranged between 1852 and 1940kg/m^3. It was observed that oven dry densities were about 220 to 260kg/m^3 lower than water cured densities. The highest density of 1971kg/m^3 was reported for mix containing sand/cement (s/c) ratio of 1.6. Alengaram et al., (2008) also observed that an increase in sand content beyond s/c ratio of 1.6 might have resulted in higher density than the limit for lightweight concrete (LWC) of 2000kg/m^3 and hence mixes containing s/c ratio higher than 1.6 was not considered. The authors reported 10 to 15percent increase in strength for mixes containing silica fume. It was further reported that the silica fume plays a major role in early strength development of palm kernel shell concrete.

2.5.1 Effect of proportion and aggregate size on palm kernel shell concrete.

Nuhu-Koko (1990), Akpe (1997), Olusola and Babafemi, (2013) and Abang, (1982) have studied the effects of proportion and aggregate sizes on palm kernel shell concrete. Aggregates have an overwhelming influence on the properties of concrete considering the percentage occupied in the mix. According to Nuhu-Koko (1990), Akpe (1997), Olusola and Babafemi (2013), the compressive strength of concrete varies between 0.3N/mm^2 and 22.97N/mm^2 depending on the proportion of the palm kernel shell in the mix. Olusola and Babafemi (2013) also showed that both compressive and splitting tensile strengths increased with increase in aggregate sizes. Both strengths however decreased with increase in replacement levels of granite with palm kernel shell. Optimum replacement level of granite with palm kernel shell was 25percent with compressive and tensile strengths of 22.97N/mm^2 and 1.89N/mm^2 respectively at maximum coarse aggregate size of 20mm. However, at 50percent palm kernel shell content, which results in lightweight concrete, compressive strength, was 18.13N/mm^2 which is above the minimum value of 17MPa for lightweight concrete. Abang (1982) reported that a higher proportion of Palm kernel shell in a mix lowers the workability and compressive strength of palm kernel shell concrete. He also observed that the strength of the shell also plays a significant role in the strength of the concrete.

2.5.2 Effect of Palm Kernel Shell Sizes and Mix Ratio on Concrete.

Yusuf and Jimoh (2011) worked on the appropriateness of the various nominal mixes of the ‘palm kernel shell concrete’ as rigid pavement. They evaluated the mixes accordingly at both fresh and matured ages with corresponding costs. They reported that the Nigerian PKS satisfies the density criterion for normal concrete and lightweight concrete in all respects while the palm kernel shell concrete at nominal mixes of 1:1.5:3 and 1:1:2 satisfied the specifications for rigid pavement.

Oyejobi, et al (2012) worked on the effect of palm kernel shell sizes and mix ratio on concrete. Concrete mixes of 1:1½:3, 1:2:4, 1:3:6 and 1:4:8 were used to produce cubes, beams and cylinders which were cured for 7, 14 and 28 days before testing. PKSC had density that was less than 2000 kg/m3 for a lightweight concrete. The results showed that concrete mix of 1:1½:3 with compressive strength of 20.1N/mm2 at 28 days hydration period met the British Standard recommended minimum strength of 15N/mm2 for structural lightweight concrete while other concrete mixes did not but they can also be employed as plain concrete.

Results of tests on modulus of rupture and splitting tensile strength exhibited similar trend to that of compressive strength test. The nominal mix 1:1½:3 gave the highest values of modulus of rupture and splitting tensile strength.

2.5.3 Effect of Partial Replacement Coarse aggregate with Palm Kernel Shell (PKS) on Workability of Concrete.

Mohamed et al. (2018), investigated the proportioning of mixture for oil palm kernel shell lightweight concrete with batch of 1:1.6:0.96 and 1:1.53:0.99 for C:S:OPKS ratio with cement content of 450 kg/m3 which yielded minimum slump of 20 mm, density within the range of 1800 and 1900 kg/m3 and minimum compressive strength of 15 N/mm2.

Saman and Omidreza (2011) reported the influence of Palm kernel shell on workability and compressive strength of high strength concrete. They noted that the general strength of palm kernel shell concrete samples produced high strength concrete with compressive strength reaching up to 52.2N/mm^2 at 28days.They also noted that concrete made with nominal mixes of 1:3:6 and 1:4:8 generally gave poor results. Similarly, Emiero and Oyedepo (2012) investigated the strength and workability of concrete using palm kernel shell (PKS) and palm kernel fiber (PKF) as a coarse aggregate. Concrete batching was by volume and two mix ratios of 1:1.5:3 and 1:2:4 were used. They reported that for Lightweight concrete obtained using Palm kernel shell and Palm kernel fiber respectively as partial replacement for coarse aggregate the concrete mix ratio PKS: PKF of 50:50 for 1:1.5:3 and 1:2:4 had compressive strength of 12.29N/mm^2 and 10.38N/mm^2 after 28days, which confirms light weight concrete. It was also observed that the rate of absorption for water increase from 7days to 28days was about 9.2 percent for the combination of PKS and PKF for mix 1:1.5:3 while mix 1:2:4 was 13.0 percent.

2.5.4 Effect of Partial Replacement Coarse aggregate with Palm Kernel Shell (PKS) on Flexural and Compressive Strength of Concrete.

Ndoke (2006) in his work observed the performance of palm kernel shells as partial replacement for coarse aggregate in asphalt cement. According to Teo et al (2006), for structural concrete using oil palm shell (OPS) as light weight aggregate, the compressive strength of OPS concrete was 28.1MPa at 28days curing which is approximately 65% higher than the minimum required strength of 17MPa for structural light weight concrete recommended by American Standard of Testing Materials (ASTM 1330).

Mohammad et al. (2016) replaced nominal concrete constituents with agricultural solid wastes of oil palm shell (OPS) and oil palm fuel ash (OPFA) at 10–15% in a bid to produce a sustainable OPS lightweight concrete of enhance mechanical properties. Increase in percentage addition of POFA led to subsequent decrease in flexural and split tensile strengths of OPSC but gave optimum sustainability performance at 10%. Elnaz et al. (2016) developed an economical lightweight pervious concrete by replacing gravel sized 6.3–9.5 mm with palm kernel shell (PKS) sized 4.75–6.3 mm and 6.3–9.5 mm. In the same manner PKS was used to replace limestone from 25 to 75% to reduce cost. Results showed maximum compressive of12 N/mm2 and higher permeability values ranging from 4 to 6 mm/s which can be applied in parking lots and roads of light traffic.

Okechukwu et al. (2017), conducted a study on assessment of palm kernel shell as a composite aggregate in concrete. Mix design of 1:2:4 and a water-cement ratio of 0.6 were used to produce concrete specimen cubes of size 150 mm3. A total of 60 cubes were made and wholly submerged in water to cure for 28 days at intervals of seven days i.e. seven, 14, 21 and 28 days after which their densities and compressive strengths were determined. Granite was replaced by palm kernel shell in the mix at 25% interval resulting in three replicates of specimen cubes at each curing age. Compressive strength and density decreased continuously as palm kernel shell was added to the mix for all the Curing ages tested. The 28 day compressive strength of the palm kernel shell concrete ranged from 12.71 to 16.63 N mm^2, whereas the density ranged from 1562 to 2042 kg m^3.

Festus et al (2012), conducted an investigation of the strength properties of palm kernel shell concrete. The chemical properties of the ash are examined whereas physical and mechanical properties of varying percentage of PKSA cement concrete and 100% cement concrete of mix

1:2:4 and 0.5 water-cement ratios are examined and compared. A total of 72 concrete cubes of size 150 × 150 × 150 mm³ with different volume percentages of PKSA to Portland cement in the order 0:100, 10:90 and 30:70 and mix ratio of 1:2:4 were cast and their physical and mechanical properties were tested at 7, 14, 21 and 28 days time. Although the compressive strength of PKSA concrete did not exceed that of OPC, compressive strength tests showed that 10% of the PKSA in replacement for cement was 22.8 N/mm2 at 28 days; which was quite satisfactory with no compromise in compressive strength requirements for concrete mix ratios 1:2:4.

Oyedepo et al. (2015) evaluated the performance of both coconut and palm kernel shells ash (CSA and PKSA) as cement replacements in concrete, adopting mix proportion of 1:2:4 and w/c of 0.63. Maximum compressive strengths of 15.4 N/mm2 and 17.26 N/mm2 was achieved at 20% cement replacement with PKSA and CSA while 10% cement substitution with CSA gave a compressive strength of 20.58 N/mm2 at 28 days.

Sachin et al (2017) conducted an experiment on partial replacement of coarse aggregate with palm kernel shell in concrete. The ratio of these materials are 1: 1.5: 3 by volume batch and the dimension of the cube is 150mm x 150mm x 150mm and the size of coarse aggregate which is used are passed by 16 mm sieve and retained on 12.5mm sieve. Then the partial replacement of coarse aggregate is done by 10%, 13%, 15%, 20%, and 25% and the testing of the cube is done on 7days, 14days, and 28days. This experiment gives the idea about the possible amount of weight reduction of concrete without heavily affecting the strength of concrete.

Based on the backdrop of previous researches conducted, this study will evaluate the effect of partial replacement of coarse aggregate with palm kernel shell on compressive and flexural strength of concrete and the granite will be admixed with the additive (palm kernel shell) from 4%PKS starting from 0%PKS to 20%PKS thereby establishing six different specimens.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials, Sourcing and Preservation.

The materials required for this research work are fine aggregate (river sand) designated as SD. Coarse aggregate (granite) designated as GT, additive (palm kernel shell) designated as PKS, ordinary Portland cement and water. The mode of sourcing and preservation of these materials are discussed below:

1 Cement

The ordinary Portland cement designated as OPC used for this experiment is dangote cement. This cement was purchased at Onitsha market in Anambra State. Upon purchase, the cement was conveyed to school laboratory where it was kept in a cool dry place preparatory for various laboratory testing. The cement sample satisfy the requirement for use as one of the major component of concrete in that, it was not caked or baked through visual inspection and quick setting time.

2 Water

The water sample used for this experiment was collected from at Amansea River in Awka Anambra State. The sample passed all the necessary requirement for use as ingredient of concrete based on the fact that it is colorless, devoid of suspended solid particles, contains infinitesimal trace of dissolved solid particles with no trace of turbidity after being subjected to laboratory testing. The water was collected in three gallons (25 litre each) and was conveyed to the school laboratory.

3 Palm Kernel Shell Ash (PKS).

The palm kernel shell designated as PKS was obtained from palm kernel production site at Ogbukpa, Nsukka in Enugu State Nigeria. The palm kernel shell sizes ranges between 5mm to 16mm. The shells were flushed with hot water to remove dust and other impurities that could be detrimental to concrete. It was collected in two empty cement bags and was conveyed to a laboratory, but before use, they were sun-dried and packed in plastic sheets to prevent contact with water. The coarse aggregate (crushed granite) will be completely admixed with palm kernel shell in a stepped increase starting from 0%-4%-8%-12%-16% and 20% by dry weight of palm kernel shell so as to establish six different specimens.

Plate 3.0 Palm Kernel Shell Sample to be used for research.

4. Coarse Aggregate (Crushed Granite).

The granite samples designated as GT was procured from a road construction company (popularly known as RCC) at 9th mile in Enugu State. The granite sample passed all the necessary physical test in that, it has high crushing strength, it is relatively large in size (within range of 4.75mm to 20mm) and is a representative of granite (chippings) in color. The granite was collected in one and half cement bag and was conveyed to the school laboratory via public transport. This granite sample will be partly replaced with palm kernel shell (PKS).

5.Fine Aggregate (Sand).

Natural river sand used in producing the concrete was collected from at Amansea River in Awka Anambra State. The sand sample was collected in two cement bags with the aid of shovel. The sample passed the necessary requirement for use as ingredient of concrete based on the fact that it is gritty with particle sizes visible to the naked eyes. The sand sample after collection was conveyed to the school laboratory for various testing.

3.2 Batching

Being that the process of measuring the quantities of each material i.e. cement, fine and coarse aggregate and water in their relative proportion before they are mixed is known as batching. And there are two methods of this batching; by weight and by volume. This research adopted batching by weight, which involves the application of mathematical concept known as ratio to find out the requirement weight. Weight was used for the measurement.

3.2.1 Mix Proportion of Concrete Specimens

The proportioning by weight was used in this research. The cement-aggregate ratio used in this work was 1:2:4. Palm kernel shell (PKS) were used to replace granite at dosage levels of 4%, 8%, 12%, 16% and 20% replacement by weight of granite. The mix proportion was calculated below:

No of cubes per batch = 12

(i.e three cubes each for ages 7, 14, 21 and 28 days test).

Note: Batch implies control mix (0% PKS Replacement, 4% PKS Replacement, 8% PKS Replacement, 12% PKS Replacement, 16%Replacement and 20% PKS Replacement).

Size of each cube = 150mmx150mmx150mm

Volume of cube = $150^3 = 3.375 \times 10^{-3} m^3$

Volume of 12 cubes = $12 \times 6 \times 3.375 \times 10^{-3} m^3 = 0.243 m^3$

To cater for wastage, it was factored by 1.3

Volume of the batch = $0.243 \times 1.3 = 0.3159 m^3$

The ratio used in this research is 1:2:4 = Cement: Sand: Granite

Cement = (1/7)

Volume of Cement = $\frac{1}{7} \times 0.31596 m^3 = 0.045 m^3$

Standard Weight of Cement = 2400kg/m^3

Therefore:

Weight of Cement in one batch = 2400x 0.045 = 108kg

Volume of Sand = $\frac{2}{7}$x 0.3159m^3 = 0.0903m^3

Weight of Sand = 2400x 0.0903m^3 = 216.72kg ≈217kg

Volume of Coarse aggregate = $\frac{4}{7}$x 0.31596m^3 = 0.1805m^3

Weight of Coarse aggregate = 2400x 0.1805m^3 = 433.2kg $\approx 434kg$

The water –cement ratio adopted in the course of the research was 0.55 and this was used to calculate the amount or weight of water required per batch.

Weight of water = 0.55x weight of binder (cement) = 0.55x 108kg = 59.4kg

Table 3.0 Mix Design of Concrete

Constituents Materials	**Control 0%PKS**	**4% PKS**	**8% PKS**	**12% PKS**	**16% PKS**	**20% PKS**
Cement (kg)	**108**	**108**	**108**	**108**	**108**	**108**
PKS (kg)	**0**	**17.36**	**34.72**	**52.08**	**69.44**	**86.8**
Fine Aggregate (kg)	**217**	**217**	**217**	**217**	**217**	**217**
Coarse Aggregate (kg)	**434**	**416.64**	**399.28**	**381.92**	**364.56**	**347.2**
Water-Cement ratio	**59.4**	**59.4**	**59.4**	**59.4**	**59.4**	**59.4**

3.3 Methods of Study

In this project, different test were carried out, test was carried out on different percentages of replacement of palm kernel shell with Sand. Below are the detailed descriptions of the experiments.

3.3.1 Sieve Analysis

Sieve analysis is a procedure used to assess the particle size distribution of a granular material (sand, gravel). The size distribution is often of critical importance to the behaviour of the material during use. Sieve analysis can performed on any type of non-organic or organic granular material including sand, crushed rock, clay, granite, feldspar and a wide range of manufactured powders, grains and seed down to minimum size depending on the exact method. The standard grain size analysis test determines the relative proportion of different grain sizes as they are distributed among certain size ranges.

The grain size analysis is widely used in classification of soils. The data obtained from the grain distribution curve is used in the design of filters for earth dams and to determine the suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability test are more generally used. Soil gradation is very important to geotechnical engineering; it is an indication of other engineering properties such as shear strength, compressibility and hydraulic conductivity. In a design, the gradation of the in-situ- soil help in the selection of filler material for the construction of highway embankment and it also controls the design and ground water drainage of site. A poorly graded soil (one with predominantly one-sized particle) will have better drainage property than the well graded soil (soil with varieties of particle sizes) because of the relatively higher magnitude of void present. A well graded can be easily compacted more than a poorly graded soil. However most Engineering project may have gradation requirement that must be satisfied before the soil is to be used is accepted for construction work. When options for ground remediation technique are to be considered the soil gradation is a controlling factor.

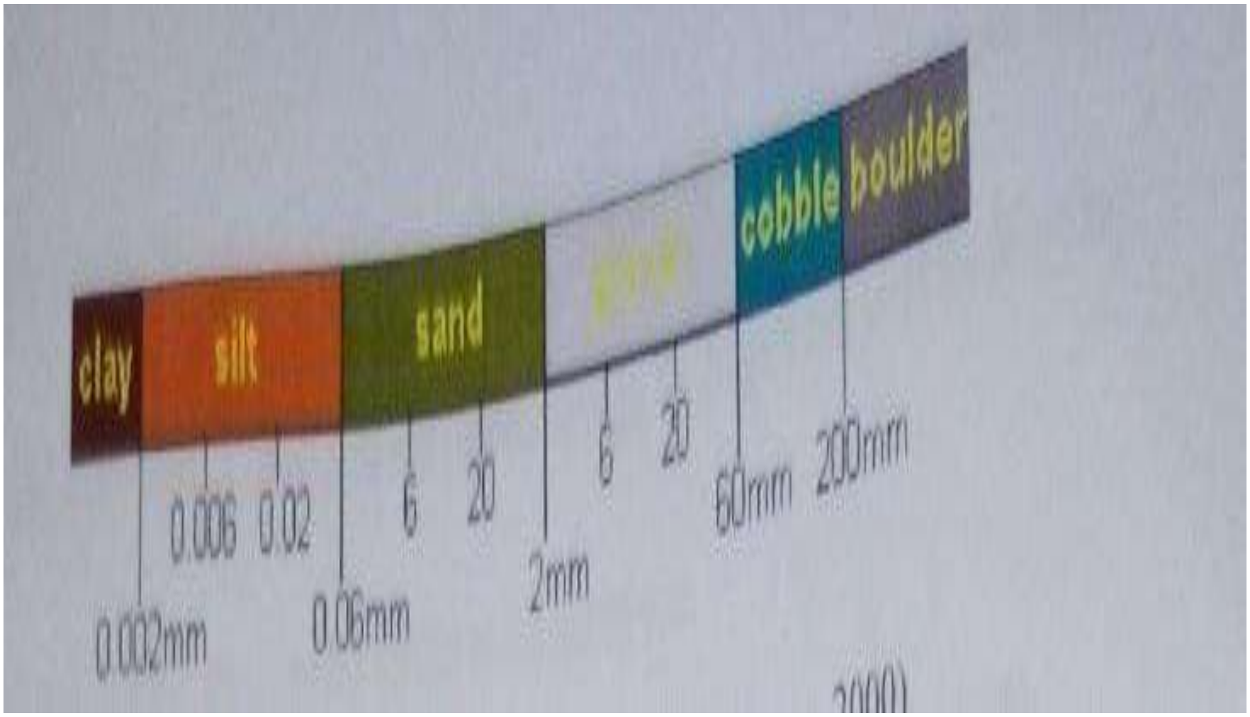


Plate 3.1 Ranges for grain Sizes of different Soil type (Courtesy of Atkinson, 2000).

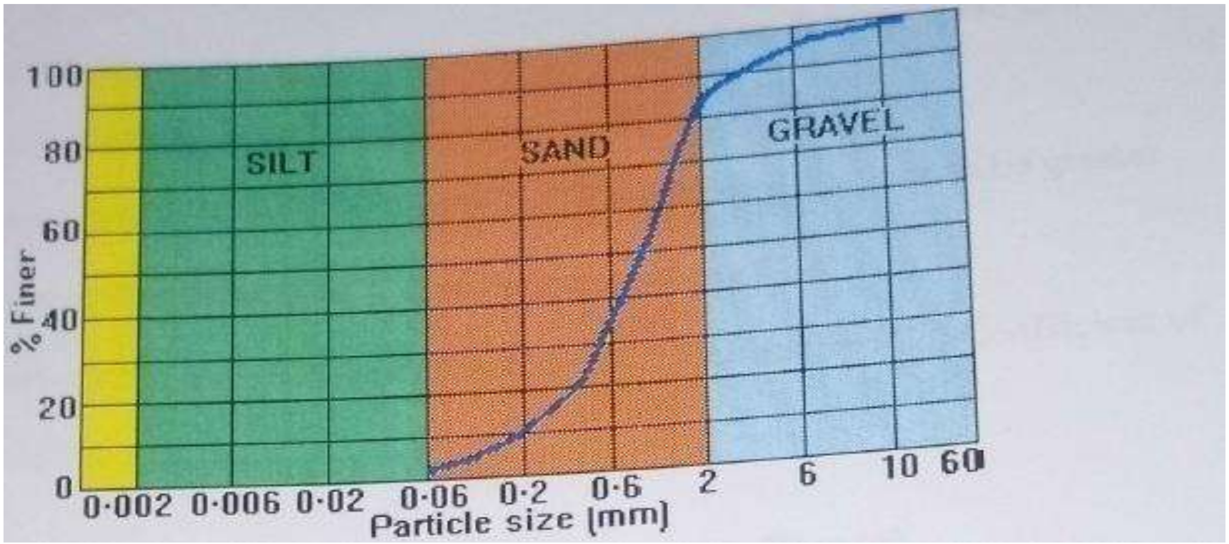


Plate 3.2 Grading Curve Ranges for Different Soil Types (Courtesy of Atkinson, 2000).

Soil posses a number of physical characteristics which can be used as aid to identify it sizes in the field. A handful of soil rubbed through the finger can yield the following:

1. Sand and other coarser particle are visible to the naked eye.
2. Silt particle becomes dusty and are easily brushed off.

3. Clay particle are greasy and sticky when wet and hard when dry and have to be scrapped or washed off hand and boot

For a soil to be well graded the value of coefficient of uniformity (Cu) has to be greater than 4 and 6 for gravel and sand respectively, while the Coefficient of Curvature (C_v) should be in the range of 1 to 3.

The apparatus needed for this experiment is listed below:

1. Stack of sieves including pan and cover.
2. Mechanical sieve shaker.
3. Weighing balance of 0.01g sensitivity.
4. Hand brush
5. Mortar and pestle (Used for crushing if the sample is conglomerated or lumped)
6. Thermostatically controlled Oven (With temperature of about $80^{O}C$-$110^{O}C$).
7. Masking tape for identification of sample.
8. Exercise book and pen for recording of result.
9. The calculation for attaining Coefficient of uniformity and Coefficient of curvature are outlined below.

Percentage retained (%) =$\frac{mass\ of\ soil\ retained\ in\ the\ sieve(g)}{total\ mass\ of\ soil\ sample(g)} \times 100$

Cumulative percentage retained = $\sum Percentage\ retained$ (%)

Cumulative Percentage Finer (%) = 100-Cummulative percentage retained.

Coefficient of Curvature =$\frac{D60}{D10}$

Coefficient of Uniformity =$\frac{(D30)2}{D10 \times D60}$

Where

D10= particle size such that 10% of the soil is finer than the size

D30= particle size such that 30% of the soil is finer than the size.

D60= particle size such that 60% of the soil is finer than the size**.**

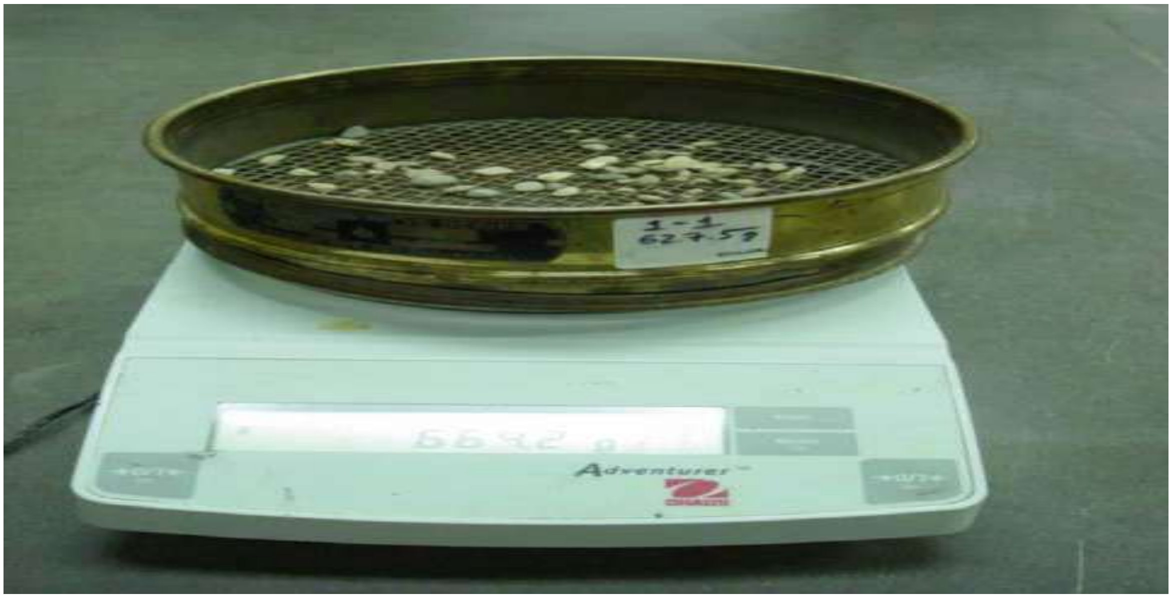


Plate 3.3 Apparatus for Particle Size Distribution Test (Sieve Analysis).

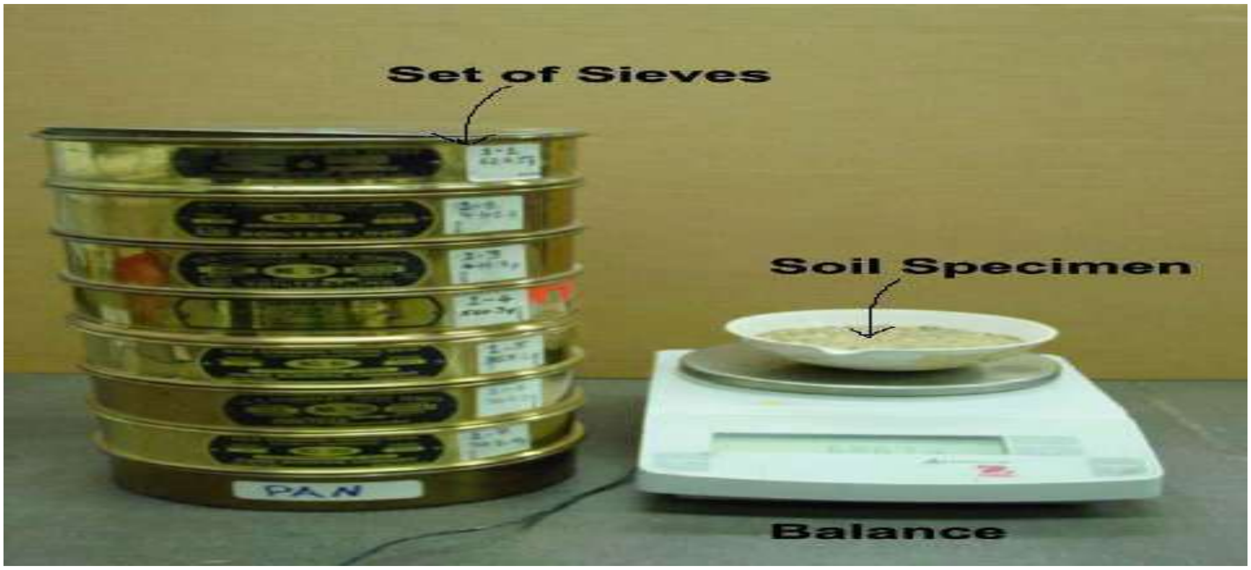


Plate 3.4 Apparatus for Particle Size Distribution Test (Sieve Analysis).

TEST PROCEDURE

1. Clean properly the stack of sieves to be used for the experiment using hand brush.
2. Weigh about 500g of air-dried soil sample on a weighing balance.
3. Pour the weighed soil sample into 75um sieve and wash under a steady supply of water until clear water start coming out from the sieve after passing through the soil sample.

4. After washing pour the washed soil sample into a pre-weighed plate and dry it inside the thermostatically controlled oven at a controlled temperature of 80-110^{O}C for 16-24hrs.
5. Remove the sample from the oven and determine it weight (net weight) by deducting the weight of plate from the weight of plate and soil.
6. Arrange the stacks of sieve in the ascending order, place in a mechanical sieve shaker, and thereafter pour the sample and connect the shaker for about 10-15 minute.
7. Disconnect the sieve shaker and determine the mass retained on each of the sieve sizes.
8. Determine the percentage retained, Cumulative percentage retained and Cumulative percentage finer.
9. Plot the graph of sieve Cumulative percentage finer against sieve sizes.
10. Determine D10, D30 and D60 from the plotted graph.
11. Determine the Coefficient of Curvature and Coefficient of Uniformity and classify the soil using the American Association of State Highway and Transportation Official (AASHTO) and Unified Soil Classification System (USCS) respectively.

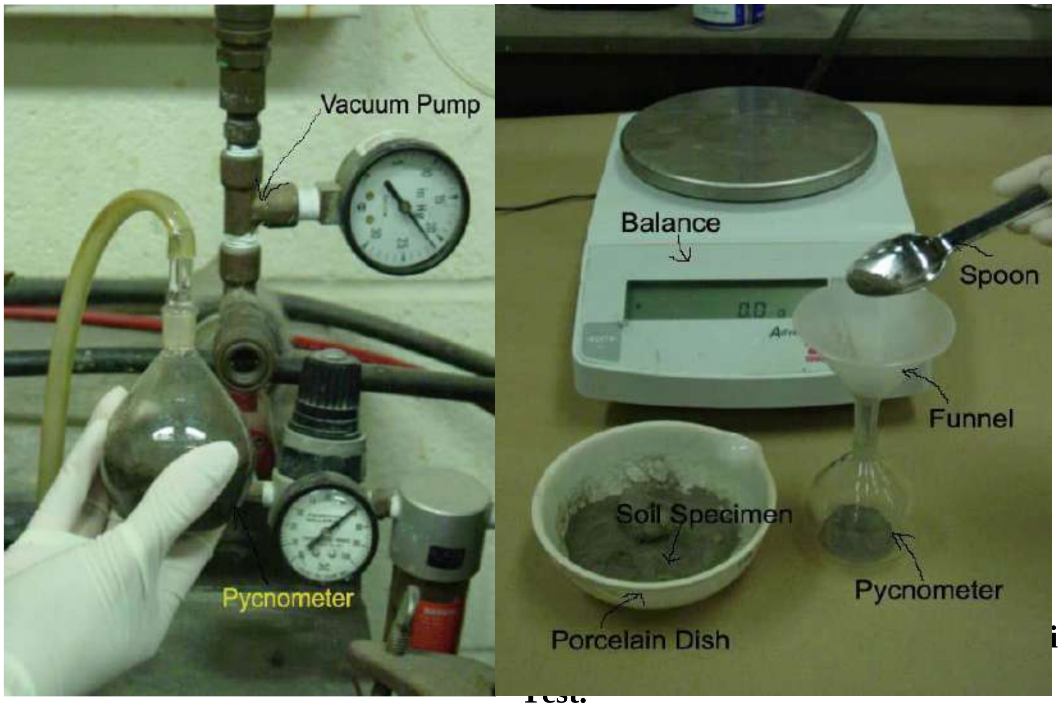
3.3.2 Specific Gravity for Fine Aggregate

Specific gravity is the ratio of mass of unit volume of soil at a stated temperature to mass of equal volume of gas-free distilled water at the same temperature (Krishna, 2002). Also as defined by (Braja, 2006), Specific gravity can be defined as the ratio of unit weight of a material to unit weight of water. The specific gravity of soil solids is often needed for various calculations in soil mechanics. It can be determined accurately in the soil laboratory.

The apparatus employed for this experiment includes:

1. Density bottle of 50ml capacity and a stopper.
2. Desiccator containing anhydrous silica gel.
3. Thermostatically controlled oven with temperature of about 80-110^{O}C.
4. Weighing balance of 0.01g sensitivity.
5. Mantle heater.
6. Plastic wash bottle.
7. Distilled water.
8. Funnel
9. Thin glass rod for stirring.

10. 425um Sieve.
11. Dry piece of cloth for cleaning.
12. Masking tape for identification of sample.
13. Exercise book and pen for recording of result.



ific Gravity Test.

3.3.3 Specific Gravity Test for Coarse Aggregate (Granite).

The specific gravity of aggregate is defined as the ratio of aggregate to the weight of equal volume of water. The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Aggregate having low specific gravity is generally weaker than those with high specific gravity. This property helps in general identification of aggregate.

APPARATUS USED.

1. Wire mesh Bucket or perforated container of convenient sizes with thin wire hangers for suspending it from a balance.
2. Pycnometer of 1000ml.

3. Set up consisting of container for filling water and suspending the wire basket in it and airtight container of capacity similar to that of a bucket, a shallow tray, two dry absorbent clothes.

TEST PROCEDURE

1. About 2 kg of aggregate sample is taken, washed to remove fines and then placed in the wire basket. The wire basket is then immersed in water, which is at a temperature of 22^0C to 32^0C.

2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket 2mm above the base of the tank and allowing it to drop, 25 times at a rate of about one drop per second.

3. The basket, with aggregate are kept completely immersed in water for a period of 24 ± 0.5 hour.

4. The basket and aggregate are weighed while suspended in water, which is at a temperature of 220Cto 320C.

5. The basket and aggregates are removed from water and dried with dry absorbent cloth.

6. The surface dried aggregates are also weighed.

7. The aggregate is placed in a shallow tray and heated to about 110^0C in the oven for 24 hours. Later, it is cooled in an airtight container and weighed.

3.3.4 Compression Test of Concrete Cubes

The test method covers determination of compressive strength of cubic concrete specimens. It consists of applying a compressive axial load to molded cubes at a rate which is within a prescribed range until failure occurs.

The Apparatus Used includes:

1. **Testing Machine -** The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The permissible error shall be not greater than ± 2 percent of the maximum load.
2. **Cube Moulds -** The mould shall be of 150 mm size conforming to IS: 10086-1982.
3. Weights and weighing device
4. Tools and containers for mixing,
5. Tamper (square in cross section)

TEST PROCEDURE

1. **Sampling of Materials -** Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.

2. **Proportioning -** The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work.

3. **Weighing -** The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

4. **Mixing Concrete -** The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.

5. **Mould -** Test specimens cubical in shape shall be 15 × 15 × 15 cm. If the largest nominal size of the aggregate does not exceed 2 cm, 10 cm cubes may be used as an alternative. Cylindrical test specimens shall have a length equal to twice the diameter.

6. **Compacting -** The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance.

7. **Curing -** The test specimens shall be stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27°± 2°C for 24 hours ± ½ hour from the time of addition of water to the dry ingredients.

8. **Placing the Specimen in the Testing Machine -** The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression plates.

9. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom

10. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine.

11. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained.

12. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

The compressive strength of concrete cube is computed as follows:

Compressive Strength (N/mm^2) = $\frac{Applied\ load\ (N)}{Area\ of\ Cube\ (mm \times mm)}$

Where applied load (N) = Force

Now conversion of applied load from Ton force to KN or N.

1 Ton force = 10kN or 10,000N.

For 220kN = 220× 1000 = 220,000N

Area of cube = 150mm×150mm = 22,500mm^2

Compressive Strength = $\frac{220{,}000N}{22{,}500mm2}$ = 9.78N/mm^2

Plate 3.6 Compression Testing Machine.

Plate 3.7 Weighing process to determine densities of concrete samples

3.3.5 Slump Test (Workability Test)

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch.

The apparatus employed for conducting Slump test include:

1. Metallic Mould in form of frustum of a cone (Internal dimension are 20cm for bottom diameter, 10cm for top diameter and 30cm for height).
2. A steel tamping rod (16mm diameter)
3. Trowel
4. Measuring Cylinder
5. Porcelin evaporating dish.

Plate 3.8 Apparatus used for Slump Test

TEST PROCEDURE

1. Clean the internal surface of the mould thoroughly (this is done in order to prevent superfluous moisture and adherence of old set concrete).
2. Place the mould on the evaporating dish or alternatively on any smooth, horizontal, rigid and non-absorbent surface.
3. Measure and mix properly the various component of the concrete depending on the concrete grade.
4. In a vertical direction. Divide the concrete into four layers such that each layer is one-quarter the height of the mould.
5. Place each layer into the mould and tamp for 25 times using the tamping rod taking care to distribute the stroke evenly over the cross section.
6. After tamping each layer consecutively, use a trowel and tamping rod to struck off level the rodded concrete at the top layer of the mould.
7. Remove the mould from the concrete by raising it slowly and carefully in a vertical direction. Immediately the concrete will subside and the subsidence is referred as SLUMP of the concrete.

Measure the difference in height between the height of the mould and the average value of the subsidence this is referred to as slump value of concrete

3.3.6 Bulk and Compacted Densities Test.

The purpose of this test is to determine the unit weight or bulk density and voids of both fine and coarse aggregates.

Apparatus employed.

1. Weighing balance sensitive to 0.5% of weight of material.
2. Cylindrical metal measure of 3 litre capacity for fine aggregate and of 15 litre capacity for coarse aggregate up to 40mm size.
3. Tamping rod of 16mm diameter and 60cm long.

TEST PROCEDURE FOR COMPACTED BULK DENSITY.

1. Measure the volume of the cylindrical metal measure by pouring water into the metal measure and record the volume “V” in litre.

2. Fill the cylindrical metal measure about one-third full with thoroughly mixed aggregate and tamp it 25 times using tamping bar.

3. Add another layer of one-third volume of aggregate in the metal measure and give another 25 strokes of tamping bar.

4. Finally fill aggregate in the metal measure to over-flowing and tamp it 25 times.

5. Remove the surplus aggregate using the tamping rod as a straightedge.

6. Determine the weight of the aggregate in the measure and record that weight “W” in kg.

CALCULATION FOR COMPACTED BULK DENSITY

Compacted unit weight or bulk density = W/V

Where,

W = Weight of compacted aggregate in cylindrical metal measure, kg

V = Volume of cylindrical metal measure, litre

CALCULATION OF VOIDS

The percentage of voids is calculated as follows

Percentage of voids = $[(G - \Upsilon)/G]*100$

Where

G = Specific gravity of the aggregate

Υ = Bulk density in kg/litre

TEST PROCEDURE FOR LOOSED BULK DENSITY

1. Measure the volume of the cylindrical metal measure by pouring water into the metal measure and record the volume “V” in litre.

2. Fill the cylindrical measure to overflowing by means of a shovel or scoop, the aggregate being discharged from a height not exceeding 5 cm above the top of the measure

3. Level the top surface of the aggregate in the metal measure, with a straightedge or tamping bar.

4. Determine the weight of the aggregate in the measure and record the weight “W” in kg.

CALCULATION FOR LOOSE BULK DENSITY

Loose unit weight or bulk density = W/V

Where,

W = Weight of loose aggregate in cylindrical metal measure, kg

V = Volume of cylindrical metal measure, litre

CALCULATION OF VOIDS

The percentage of voids is calculated as follows

Percentage of voids = [(G – ϒ)/G]*100

Where,

G = Specific gravity of the aggregate ϒ = Bulk density in kg/litre

3.3.9 Water Absorption on Aggregate Test.

Water absorption test gives an idea on the internal structure of aggregate. Aggregate having more absorption are more porous in nature and are generally considered unsuitable, unless found to be acceptable based on strength, impact and hardness test.

APPARATUS REQUIRED

1. Wire mesh bucket of not more than 6.3mm mesh or a perforated container of convenient sizes with thin wire hangers for suspending it from the balance.
2. Set up of water absorption which consists of container for filling water and suspending the wire basket in it and an airtight container of capacity similar to that of the basket, a shallow tray and two dry absorbent clothes.

TEST PROCEDURE

1. About 2 kg of aggregate sample is taken, washed to remove fines and then placed in the wire basket. The wire basket is then immersed in water, which is at a temperature of 22^0C to 32^0C.

2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket 25mm above the base of the tank and allowing it to drop, 25 times at a rate of about one drop per second.

3. The basket, with aggregate are kept completely immersed in water for a period of 24 ± 0.5 hour.

4. The basket and aggregate are weighed while suspended in water, which is at a temperature of 22^0C to 32^0C.

5. The basket and aggregates are removed from water and dried with dry absorbent cloth.

6. The surface dried aggregates are also weighed.

7. The aggregate is placed in a shallow tray and heated to 100 to 110^0C in the oven for 24 ± 0.5 hours.

Later, it is cooled in an airtight container and weighed.

Calculation for water absorption

1. Weight of saturated aggregates in air: = W1
2. Weight of oven dry aggregates in air: = W2

Water Absorption (%) = $\frac{W1-W2}{W2}$×100

3.3.8 Flexural Strength Test

Age at Test - Tests shall be made at recognized ages of the test specimens, the most usual being 7 and 28 days. Where it may be necessary to obtain the early strengths, tests may be made at the ages of 24 hours ±½ hour and 72 hours ± 2 hours. The ages shall be calculated from the time of the addition of water to the dry ingredients.

Number of Specimens - At least three specimens, preferably from different batches, shall be made for testing at each selected age.

APPARATUS :

Testing Machine - The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The permissible error shall be not greater than ± 2 percent of the maximum load.

Beam Moulds - The beam moulds shall conform to IS: 10086-1982. The standard size shall be 15 × 15 × 70 cm. Alternatively, if the largest nominal size of the aggregate does not exceed 19 mm, specimens 10 × 10 × 50 cm may be used.

Weights and weighing device, Tools and containers for mixing, Tamper (square in cross section)

TEST PROCEDURE

1. Sampling of Materials - Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.

2. Proportioning - The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work.

3. Weighing - The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

4. Mixing Concrete - The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.

5. Mould - The standard size shall be 15 × 15 × 70 cm. Alternatively, if the largest nominal size of the aggregate does not exceed 19 mm, specimens 10 × 10 × 50 cm may be used.

6. Compacting - The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance.

7. Curing - The test specimens shall be stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27° ± 2°C for 24 hours ± ½ hour from the time of addition of water to the dry ingredients.

8. Placing the Specimen in the Testing Machine - The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers.

The specimen shall then be placed in the machine in such a manner that the load shall be applied to the uppermost surface as cast in the mould, along two lines spaced 20.0 or 13.3 cm apart.

10. The axis of the specimen shall be carefully aligned with the axis of the loading device. No packing shall be used between the bearing surfaces of the specimen and the rollers.

11. The load shall be applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 7 kg/sq cm/min, that is, at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

12. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted.

CHAPTER FOUR

RESULT AND DISCUSSION

During the course of the research certain result was obtained which was useful in classifying the properties of the aggregates (GT and SD) and the additive (PKS) these results are presented in the Table 4.1 below.

Table 4.1 Physical Properties of the Material used for the research

Properties	**GT**	**SD**	**PKS**
Specific Gravity	**2.69**	**2.61**	**2.29**
Water absorption	**1.44**	**-**	**17.07**
Loosed density (kg/m^3)	**1566.7**	**1466.67**	**556.67**
density Compacted (kg/m^3)	**1700**	**1466.67**	**756.67**
Coefficient of Uniformity Cu	**2**	**2.76**	**1.2**
Coefficient of Curvature Cc	**1.39**	**0.3**	**0.83**
Gradation	**GP**	**SP**	**GP**
Percentage Passing Sieve Size 4.75mm	**0.16**	**_**	**2.34**
Percentage Passing Sieve Size 0.075mm	**_**	**0.91**	**_**
AASHTO Classification System	**A-1-b**	**A-2-4**	**A-1-b**
USCS Classification System	**GM**	**SC**	**GM**

Table 4.2 Slump Test Value for GT + PKS Concrete at 0.55w/c ratio.

Percentage Replacement of PKS (%)	**Slump Value at 0.55w/c ratio (mm)**	**Slump Type**
0	**65**	**Shear slump**
4	**75**	**Shear slump**
8	**87**	**Shear slump**
12	**95**	**Shear slump**
16	**102**	**Shear slump**
20	**110**	**Shear slump**

Table 4.3 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 100% GT + 0%PKS at 0.55w/c ratio.

Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
A1	8.65	7	1:2:4	505.2	22.5	22.3
A2	9.28			499	22.2	
A3	9.39			501.1	22.3	
B1	8.66	14	1:2:4	504	22.4	22.7
B2	9.38			512	22.8	
B3	9.68			515	22.9	
C1	9.04	21	1:2:4	748	33.2	33.2
C2	9.26			745	33.1	
C3	8.70			752	33.4	
D1	9.58	28	1:2:4	767	34.1	35.1
D2	9.86			780	34.7	
D3	9.74			824	36.6	

Table 4.3.1 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 96% GT + 4%PKS at 0.55w/c ratio.

Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
E1	8.88	7	1:2:4	506.4	22.5	22.4
E2	8.68			502.1	22.3	
E3	8.58			501.6	22.3	
F1	8.94	14	1:2:4	508.5	22.6	22.5
F2	9.11			504.6	22.4	
F3	9.18			503.4	22.4	
G1	9.28	21	1:2:4	752.6	33.4	33.5
G2	9.22			750.8	33.4	
G3	8.92			755.4	33.6	
H1	9.45	28	1:2:4	795.4	35.4	35.4
H2	9.55			800.2	35.6	
H3	9.69			792.7	35.2	

Table 4.3.2 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 92% GT + 8%PKS at 0.55w/c ratio.

Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
I1	8.94	7	1:2:4	397.5	17.7	18.2
I2	8.86			418	18.6	
I3	9.02			411.1	18.3	
J1	9.26	14	1:2:4	422	18.8	18.7
J2	8.64			421.5	18.7	
J3	9.36			418	18.6	
K1	9.84	21	1:2:4	593	26.4	25.4
K2	9.38			574.5	25.5	
K3	8.62			545	24.2	
L1	9.61	28	1:2:4	600.5	26.6	26.4
L2	9.35			594.2	26.4	
L3	9.30			587.4	26.1	

Table 4.3.3 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 88% GT + 12%PKS at 0.55w/c ratio.

Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
M1	8.41	7	1:2:4	329	14.6	14.3
M2	9.18			320.5	14.2	
M3	8.56			318	14.1	
N1	9.11	14	1:2:4	377	16.8	15.7
N2	9.34			355	15.8	
N3	8.66			327	14.5	
O1	9.11	21	1:2:4	479.5	21.3	20.8
O2	9.52			458.5	20.4	
O3	8.40			464.8	20.7	
P1	9.07	28	1:2:4	479.7	21.3	21.6
P2	9.36			486.5	21.6	
P3	9.18			495	22	

Table 4.3.4 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 84% GT + 16%PKS at 0.55w/c ratio.

Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
Q1	8.75	7	1:2:4	277	12.3	12.2
Q2	8.68			285	12.7	
Q3	9.12			259	11.5	
R1	9.44	14	1:2:4	312.5	13.9	13.8
R2	9.28			307.5	13.7	
R3	8.74			308	13.7	
S1	9.06	21	1:2:4	390.5	17.3	17.4
S2	9.32			413.1	18.3	
S3	8.99			378	16.8	
T1	9.08	28	1:2:4	412	18.3	18.2
T2	9.28			413.5	18.3	
T3	9.20			405.5	18.0	

Table 4.3.5 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 80% GT + 20%PKS at 0.55w/c ratio.

Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
U1	8.69	7	1:2:4	272	12.1	11.9
U2	9.21			279	12.4	
U3	8.94			255	11.3	
V1	9.28	14	1:2:4	304	13.5	13.4
V2	9.68			301	13.3	
V3	8.52			298.7	13.3	
W1	9.64	21	1:2:4	391.5	17.4	17.5
W2	9.54			414.1	18.4	
W3	9.22			378	16.8	
X1	9.66	28	1:2:4	410.6	18.2	18.2
X2	9.55			409.6	18.2	
X3	9.38			408.7	18.2	

Table 4.4 Flexural Strength Test Result for Concrete Cubes grade 1:2:4 for 100%GT + 0%PKS at 0.55w/c ratio.

Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm^2)	(Flexural Strength) (N/mm^2)	Average Flexural Strength (N/mm^2)	Curing Age of Specimen (Days)
A1	9.04	257.8	22,500	11.46	11.41	7
A2	8.52	260.8	22,500	11.59		7
A3	8.64	251.7	22,500	11.19		7
B1	9.26	264.9	22,500	11.77	12.07	14
B2	8.92	278.8	22,500	12.39		14
B3	9.35	271.1	22,500	12.05		14
C1	9.12	280.9	22,500	12.48	12.60	21
C2	9.64	287.5	22,500	12.78		21
C3	8.94	282.2	22,500	12.54		21
D1	9.42	288.5	22,500	12.82	12.90	28
D2	9.18	290.4	22,500	12.91		28
D3	9.37	291.7	22,500	12.96		28

Table 4.4.1 Flexural Test Result for Concrete Cubes grade 1:2:4 for 96%GT + 4%PKS at 0.55w/c ratio.

Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm^2)	(Flexural Strength) (N/mm^2)	Average Flexural Strength (N/mm^2)	Curing Age of Specimen (Days)
E1	9.24	264.5	22,500	11.76	11.80	7
E2	8.64	268.9	22,500	11.95		7
E3	9.05	263.2	22,500	11.70		7
F1	9.28	274.2	22,500	12.19	12.31	14
F2	9.14	280.4	22,500	12.46		14
F3	9.42	276.5	22,500	12.29		14
G1	9.22	289.5	22,500	12.87	12.97	21
G2	9.45	290.1	22,500	12.89		21
G3	9.37	295.8	22,500	13.15		21
H1	9.45	302.5	22,500	13.44	13.43	28
H2	9.36	305.4	22,500	13.57		28
H3	9.18	298.8	22,500	13.28		28

Table 4.4.2 Flexural Test Result for Concrete Cubes grade 1:2:4 for 92%GT + 8%PKS at 0.55w/c ratio.

Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm^2)	(Flexural Strength) (N/mm^2)	Average Flexural Strength (N/mm^2)	Curing Age of Specimen (Days)
I1	9.42	270.5	22,500	12.02	11.93	7
I2	9.52	269.1	22,500	11.96		7
I3	9.16	266	22,500	11.82		7
J1	9.29	278.2	22,500	12.36	12.55	14
J2	9.24	286.4	22,500	12.73		14
J3	9.35	282.8	22,500	12.57		14
K1	9.32	294.5	22,500	13.09	13.20	21
K2	9.40	297	22,500	13.2		21
K3	9.35	299.3	22,500	13.30		21
L1	9.51	310.5	22,500	13.80	13.66	28
L2	9.22	306.4	22,500	13.62		28
L3	9.35	304.9	22,500	13.55		28

Table 4.4.3 Flexural Test Result for Concrete Cubes grade 1:2:4 for 88%GT + 12%PKS at 0.55w/c ratio.

Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm^2)	(Flexural Strength) (N/mm^2)	Average Flexural Strength (N/mm^2)	Curing Age of Specimen (Days)
M1	9.42	265.4	22,500	11.80	11.74	7
M2	9.52	264.8	22,500	11.77		7
M3	9.16	262.2	22,500	11.65		7
N1	9.29	275.2	22,500	12.23	12.43	14
N2	9.24	283.8	22,500	12.61		14
N3	9.35	280.2	22,500	12.45		14
O1	9.32	290	22,500	12.89	12.88	21
O2	9.40	292.1	22,500	12.98		21
O3	9.35	287.6	22,500	12.78		21
P1	9.51	304.4	22,500	13.53	13.38	28
P2	9.22	300	22,500	13.33		28
P3	9.35	298.6	22,500	13.27		28

Table 4.4.4 Flexural Test Result for Concrete Cubes grade 1:2:4 for 84%GT + 16%PKS at 0.55w/c ratio.

Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm^2)	(Flexural Strength) (N/mm^2)	Average Flexural Strength (N/mm^2)	Curing Age of Specimen (Days)
Q1	9.48	260.7	22,500	11.59	11.48	7
Q2	9.42	258.6	22,500	11.49		7
Q3	9.22	255.8	22,500	11.37		7
R1	9.34	270	22,500	12.00	12.12	14
R2	9.28	275.8	22,500	12.26		14
R3	9.38	272.3	22,500	12.10		14
S1	9.34	286.5	22,500	12.73	12.57	21
S2	9.51	282.2	22,500	12.54		21
S3	9.06	280.0	22,500	12.44		21
T1	9.45	290.6	22,500	12.92	12.92	28
T2	9.31	289.4	22,500	12.86		28
T3	9.20	292.1	22,500	12.98		28

Table 4.4.5 Flexural Test Result for Concrete Cubes grade 1:2:4 for 80%GT + 20%PKS at 0.55w/c ratio.

Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm^2)	(Flexural Strength) (N/mm^2)	Average Flexural Strength (N/mm^2)	Curing Age of Specimen (Days)
U1	9.48	255.2	22,500	11.34	11.18	7
U2	9.42	250.4	22,500	11.13		7
U3	9.22	248.8	22,500	11.06		7
V1	9.30	264.2	22,500	11.74	11.85	14
V2	9.25	270.2	22,500	12.01		14
V3	9.32	265.6	22,500	11.80		14
W1	9.34	281.8	22,500	12.52	12.33	21
W2	9.51	276.3	22,500	12.28		21
W3	9.06	274	22,500	12.18		21
X1	9.45	285.4	22,500	12.68	12.65	28
X2	9.36	282.5	22,500	12.56		28
X3	9.28	285.8	22,500	12.70		28

ANALYSIS OF TEST RESULTS

4.2.1 Particle Size Distribution (Sieve Analysis).

Figure 4.1 is the semi logarithmic plot of the particle size distribution of the GT, SD and PKS. Result recorded shows that for GT, the percentage passing through 4.75mm is 0.16 and according to AASHTO, it is classified as A-1-b and the constituent material constitutes an excellent sub-grade material. According to USCS, it is classified as GM (Gravelly mixed with silt sized particles i.e Silty gravel). For SD, the percentage passing through sieve size 0.075mm is 0.91 and according to AASHTO Classification system, it is classified as A-2-4 and SC (clayey sand) according to USCS Classification system. This material constitutes a good sub-grade material for road construction. While the percentage passing sieve size 4.75mm for the additive (PKS) is 2.34 and according to AASHTO, it is categorized as A-1-b and GM (gravel mixed with silt). It can be deduced from the findings that the coarse aggregate (GT) is of larger size compared to the additive (PKS) since lower percentages is passes through sieve size 4.75mm. The gradation of GT, SD and PKS obtained from their respective shape parameters (Cu and Cc) shows that they are poorly graded.

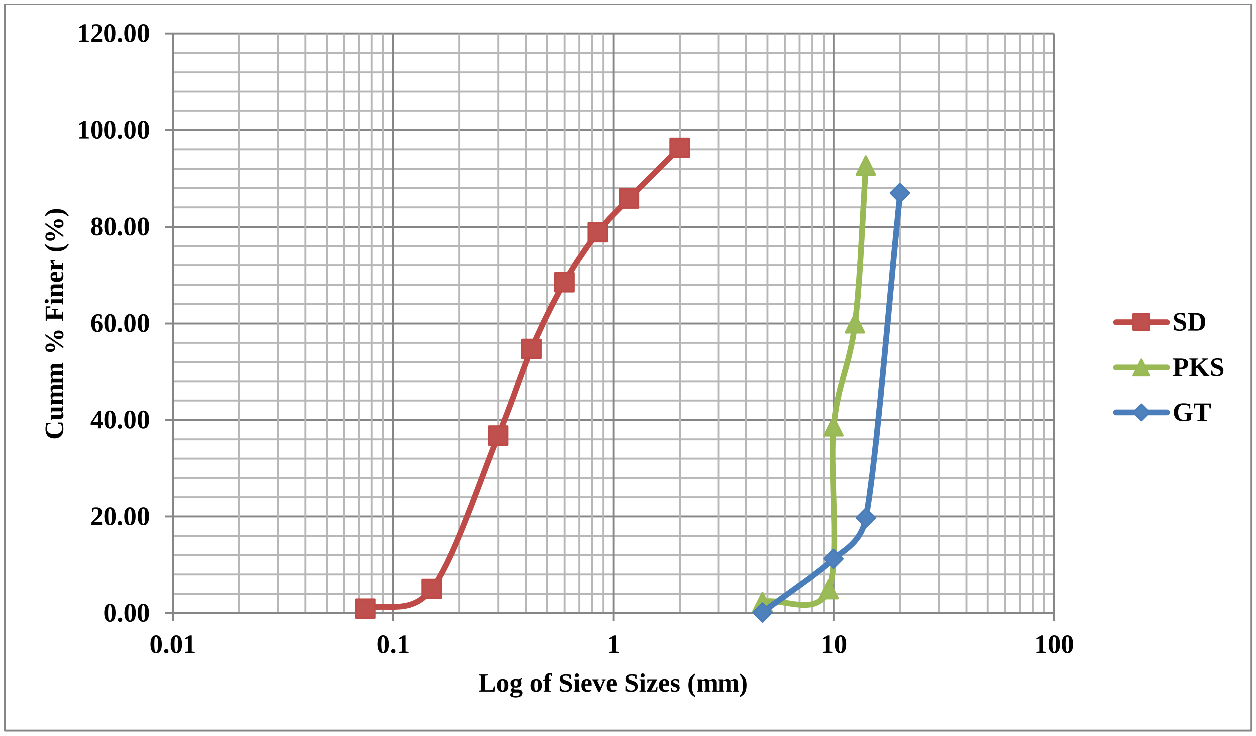


Figure 4.1 Particle Size Distribution Curve for aggregate (SD and GT) and additive (PKS).

4.2.2 Specific Gravity Test.

The specific gravity of the soil is defined as the ratio of weight of the soil to the rate of equal volume of water; it is used to obtain the unit weight of construction materials in the presence of water. Specific gravity test were conducted in accordance to ASTM D854-14 specification. For the aggregate designated as SD and GT and the additive (palm kernel shell) designated as PKS, the average apparent specific gravity computed are 2.61, 2.69 and 2.27 respectively. The range of specific gravity from 2.58 to 2.62 obtained for SD and GT satisfies ASTM D854-14 requirement which states that the specific gravity of aggregates should be between 2.55 to 2.9 and therefore justifies the use of the aggregates for this work. The Federal Ministry of work Standard Specification for roads and bridges (1997) states that a good sub-grade material should have specific gravity value ranging from 2.5 to 2.75. The values obtained also suggest that GT and SD satisfy this requirement. From the specific gravity test result, it can also be inferred that the additive (PKS) with a lower specific gravity value (2.29) have a low unit weight in the presence of water and this can be attributed to the degree of voids present in the additive.

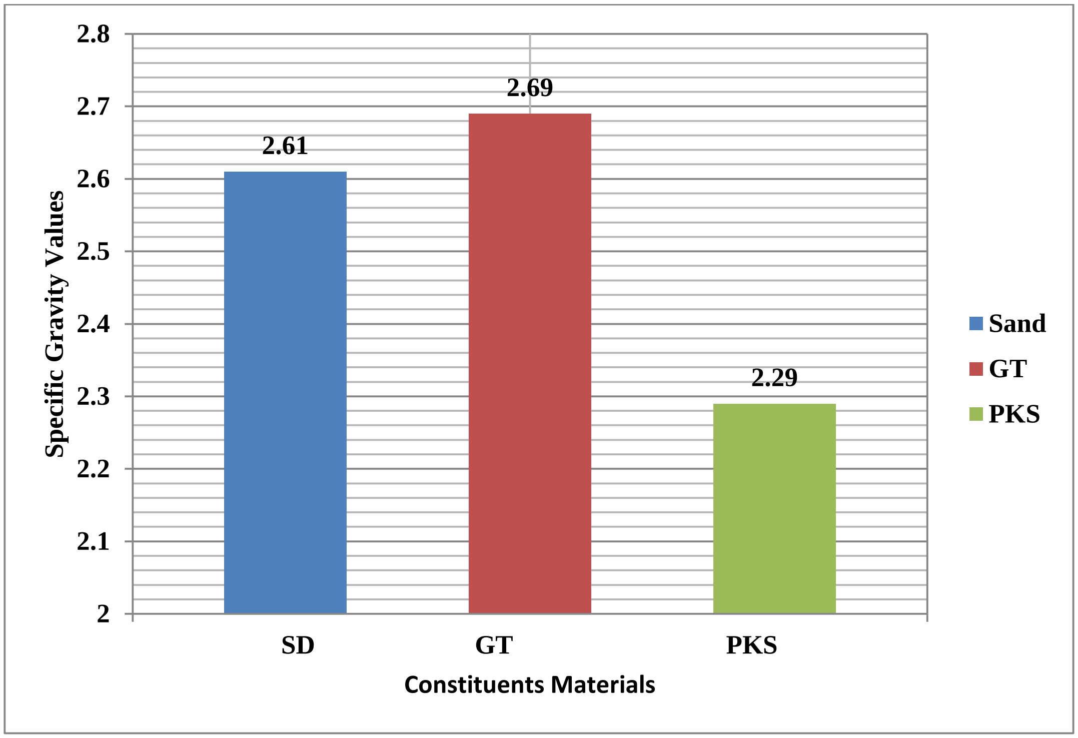


Figure 4.2 Specific Gravity Chart for Aggregate (SD and GT) and Additive (PKS).

4.2.3 Water Absorption Test.

Water absorption is defined as the transport of liquids in porous solids caused by surface tension acting in the capillaries (Basheer, 2001). It is conducted to ascertain the amount of voids present in a material as materials with large voids have high water absorption capacity. From the findings obtained, the water absorption capacity of GT and PKS are 1.44 and 17.07 respectively. This result is evident to the internal structure of both GT and PKS as the additive (PKS) contains higher voids than GT which makes it unsuitable for constructional purposes. This result is in correlation/ association with previous researches conducted by (Azuna, 2019), (Amu, 2008) and (Ndoke, 2006) where the absorption capacity of PKS was assessed.

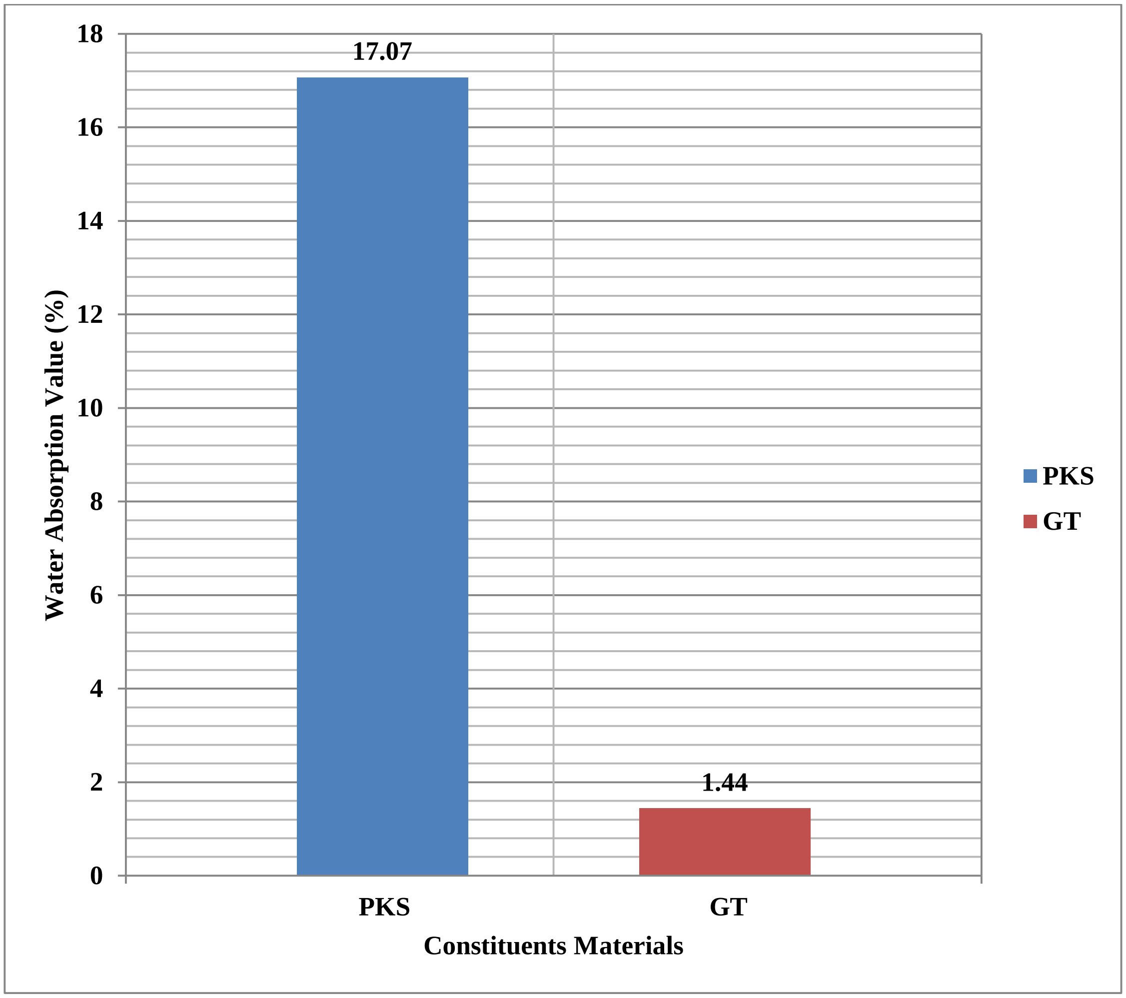


Figure 4.3 Water absorption Chart for Coarse aggregate (GT) and Additive (PKS).

4.2.4 Density of Aggregate Test.

Table 4.1 shows the average loosed and compacted density of GT, SD and PKS. Result recorded show that GT with a loosed density of 1566.67 and compacted density of 1700 produces the highest density in both loosed and compacted state. While SD produces comparatively the same density (1466.67) in both loosed and compacted state. The additive (PKS) with loosed and compacted density of 556.67 and 756.67 respectively produces the least density in both loosed and compacted state. This result is an indication of the fact that consistent addition of PKS in replacement of GT will ultimately produces concrete with light weight referred to as light weight concrete. This finding is consistent with previous researches conducted by (Azuna, 2019) and (Alengaram, 2010).

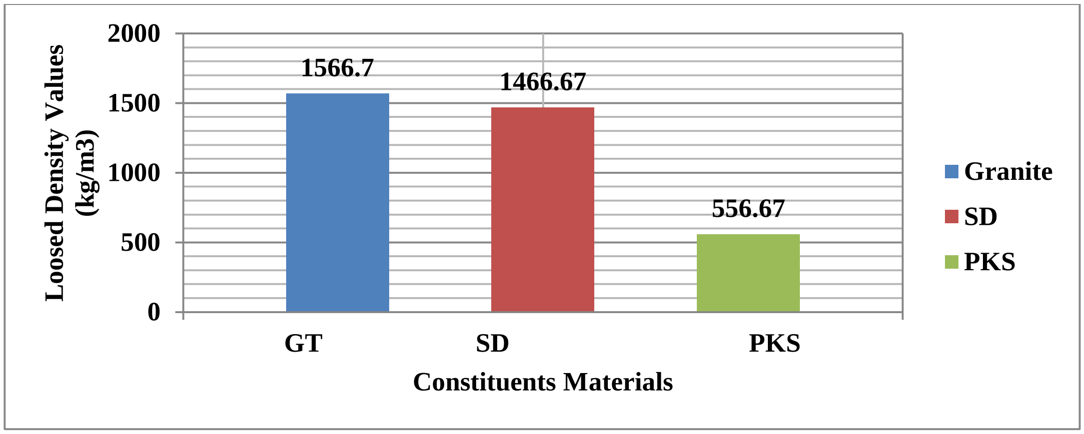


Figure 4.4 Loosed Density Chart for Aggregate (GT and SD) and Additive (PKS).

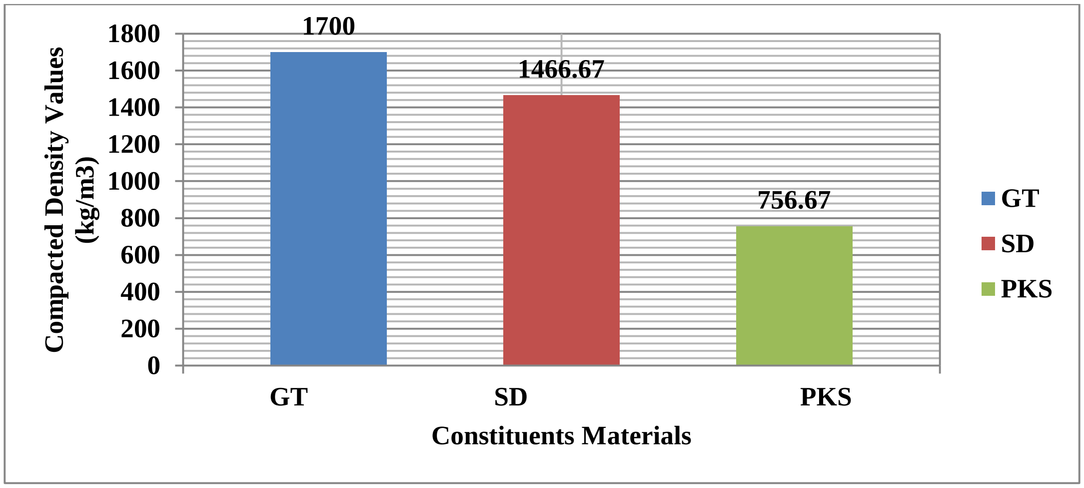


Figure 4.4.1 Loosed Density Chart for Aggregate (GT and SD) and Additive (PKS).

4.2.5 Slump (Workability Test).

Table 4.2 presents the slump test result of SD-PKS concrete. Slump test was carried out to check the effect of PKS on the workability of fresh concrete. The test was carried out in accordance with the requirements of BSEN, (1995). From the result recorded, it was observed that the slump value increases with consistent addition of the additive (PKS) from 4% to 20% at w/c ratio of 0.55 with the highest slump recorded at 20% partial replacement of GT. This result suggests that increase in PKS up to 20% increases the workability of the concrete. The slump type formed by the fresh GT + PKS concrete are classified as shear slump since the slump value exceed 40mm. This finding is in agreement with previous research conducted on the effect of complete replacement of coarse agreement with PKS on concrete by (Azuna, 2019) but lack correlation with the works of Mannan and Ganapathy (2001) where relatively low slump value was recorded.

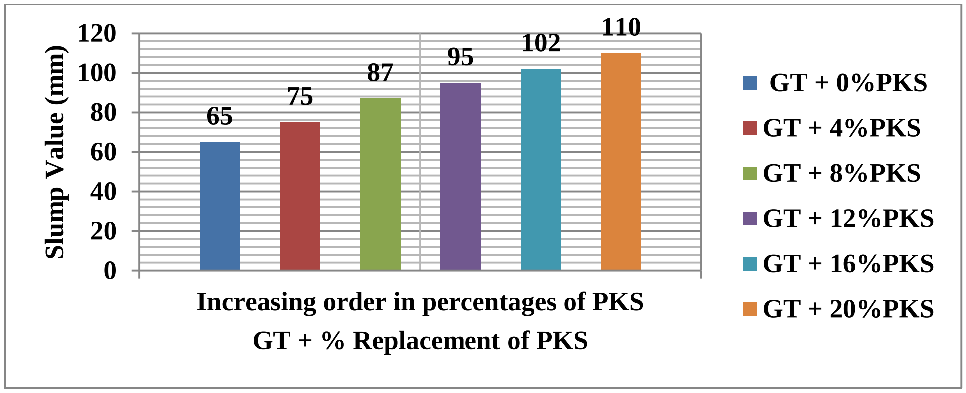


Figure 4.5 Slump Value Chart for GT + PKS Concrete.

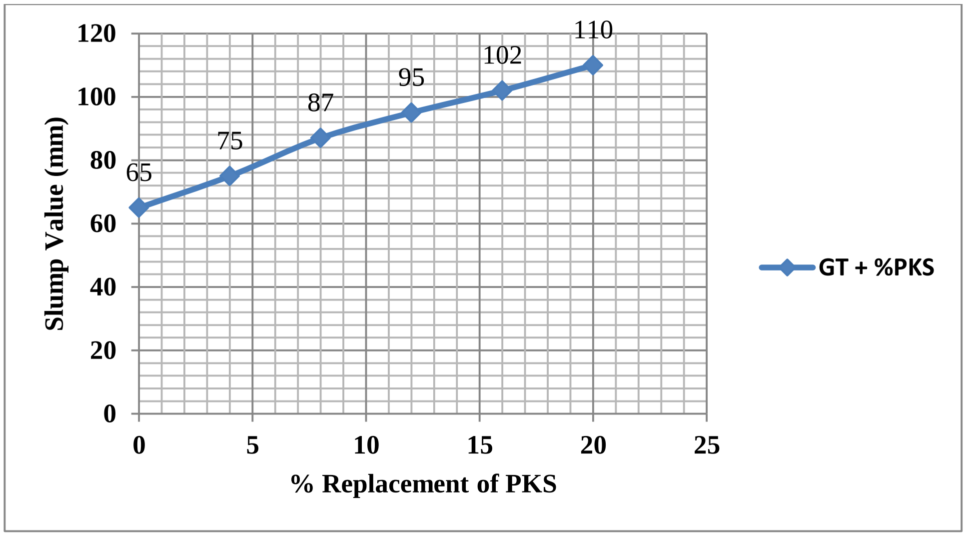


Figure 4.5.1 Slump Value Graph for GT + PKS Concrete.

4.2.6 Compressive Strength Test.

The results obtained from the compressive test performed on the hardened concrete cubes are presented in Table 4.3 to 4.3.6 and Fig 4.6a-d respectively. Results presented in Table 4.3 to 4.3.6, shows that the compressive strength of concrete increases with curing age. This result is consistent with the findings obtained by (Azuna, 2019) where the effect of Partial replacement of Coarse aggregate (GT) with PKS on the compressive strength of concrete was evaluated. Also, according to (Neville, 2012), Concrete contains over 60% of the 7 days at the 28 days curing age. The result obtained agrees with these findings. Fig 4.6c-d shows that the graph and chart of compressive strength against Percentage replacement of PKS content. From the graph, it was observed that the compressive strength of the hardened concrete increased marginally from 28.3kN/m3 to 28.5kN/m3 from 0% to 4% addition of PKS at w/c ratio of 0.55. Beyond this point, the compressive strength decreased. The decline in compressive strength of GT + PKS concrete can be attributed to the crushing strength of the additive (PKS) as GT have higher crushing strength than PKS thereby producing concrete with higher compressive strength. This finding is against previous research conducted like the works of (Azuna, 2019) where the compressive strength was found to increase with consistent addition of PKS and Okechukwu et al (2017) where the compressive strength was found to decrease with consistent addition of PKS. However, the finding is in agreement with the works of (Jonathan, et al, 2015 where the compressive strength increased initially and subsequently decreased.

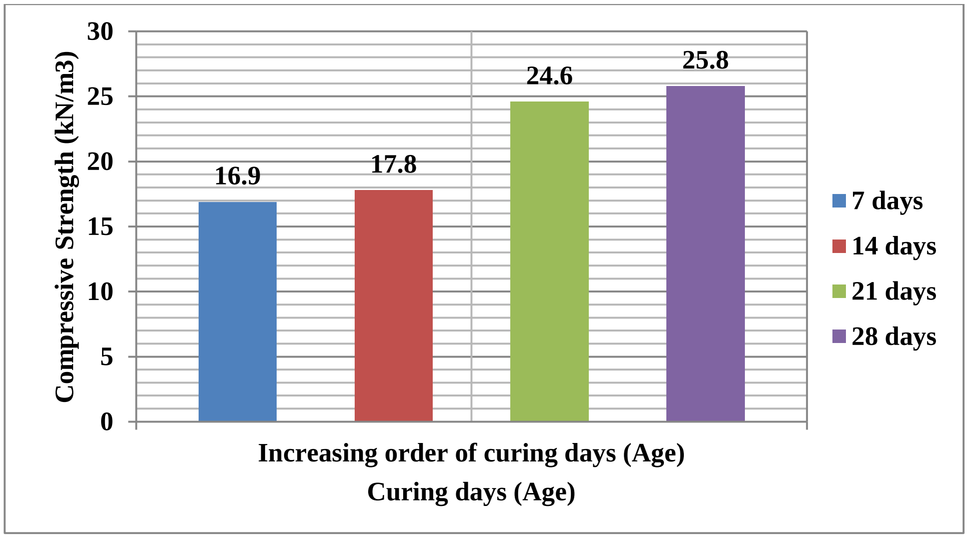


Figure 4.6a Chart Showing the Compressive Strength against Curing days for GT + PKS Concrete.

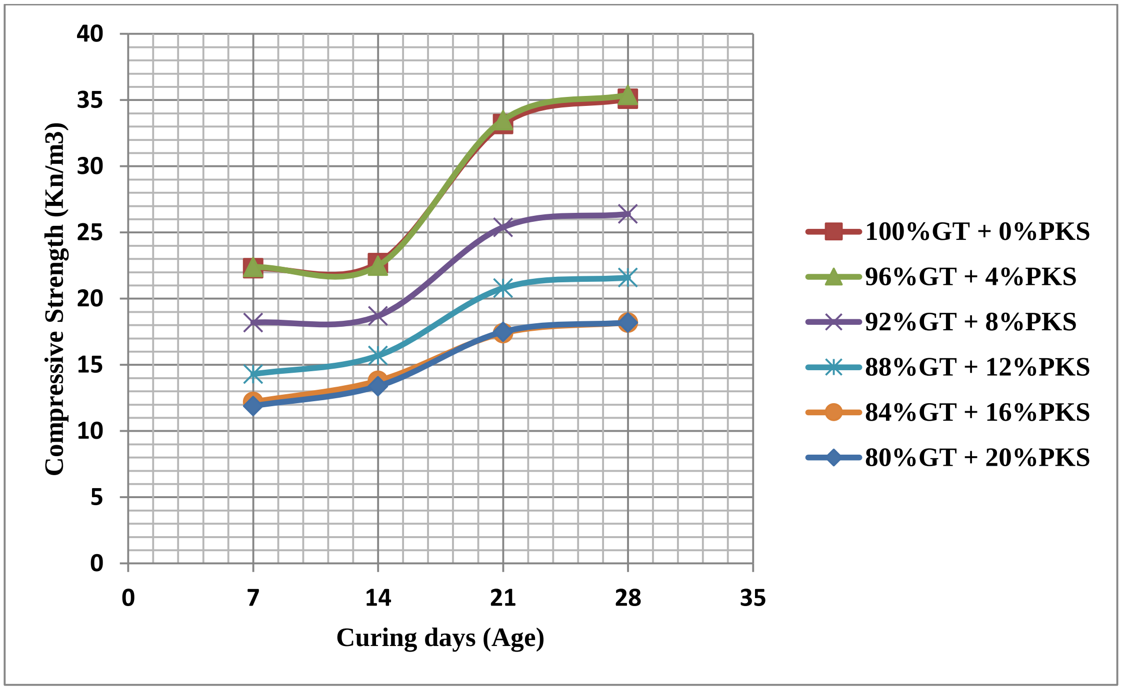


Figure 4.6b Graph Showing the Compressive Strength Value against Curing days for GT + PKS Concrete.

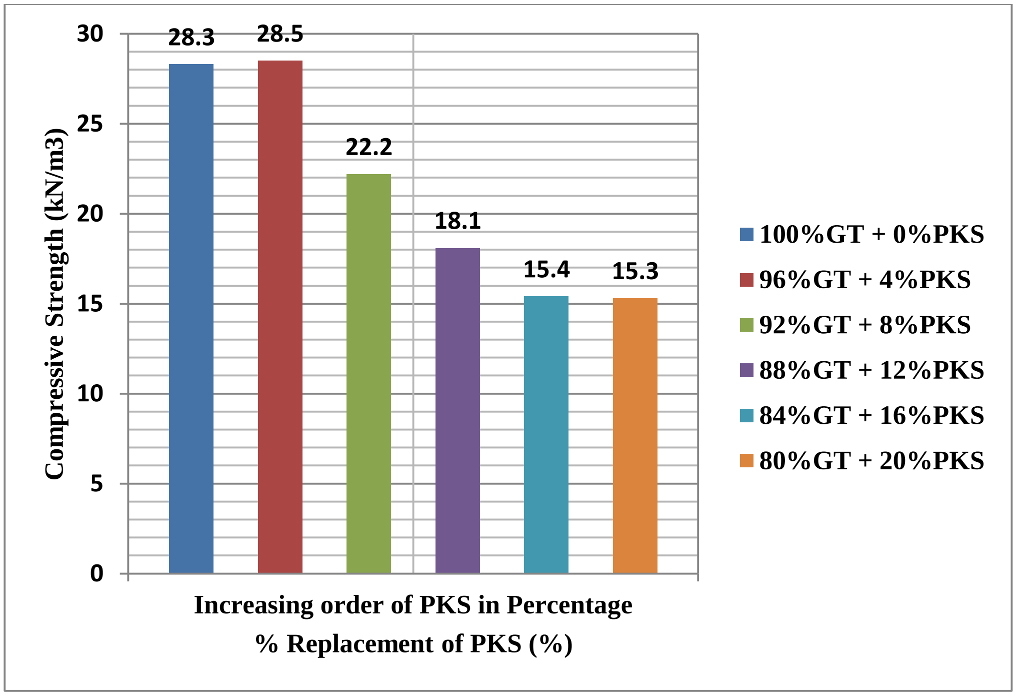


Figure 4.6c Chart Showing the Compressive Strength Value against % Replacement of PKS for GT + PKS Concrete.

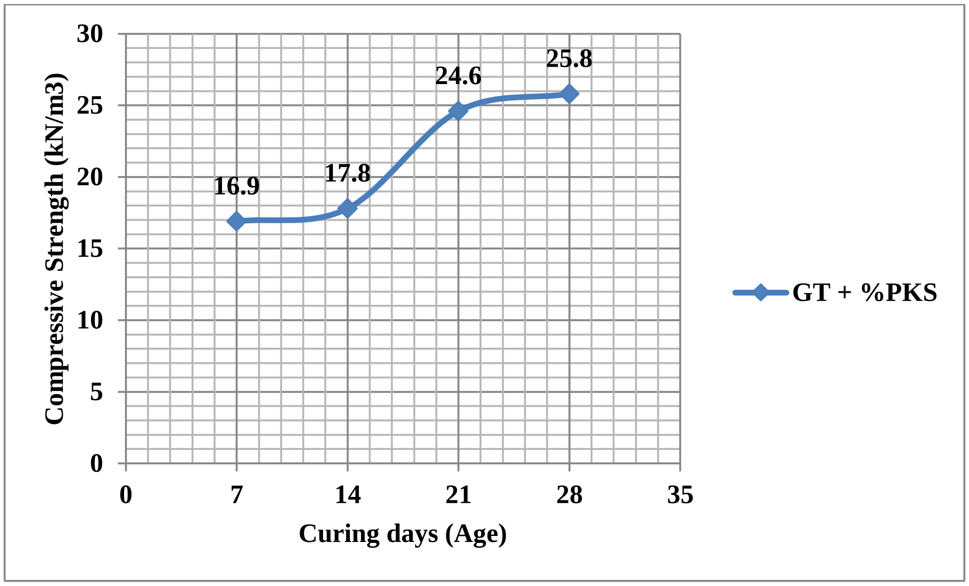


Figure 4.6d Graph Showing the Compressive Strength Value against % Replacement of PKS for GT + PKS Concrete.

4.1.7 Flexural Strength Test.

The flexural strength test was conducted at 7, 14, 21 and 28days as shown in Table 4.4-4.4.5 respectively. From the findings, it was observed that there was an increase in the flexural strength of the hardened concrete from 0%PKS to 8%PKS content. Beyond 8%PKS content, the flexural strength decreased. The subsequent consistent decline in the flexural strength of the hardened concrete can be attributed to the relatively low crushing strength of the additive (PKS) which became evident with higher value it replacement. This result is in agreement with the works of (Umamgeshwari and Ramadasan, 2020). However, the flexural strength was found to increase with curing age for all percentages of PKS as shown in Figure 4.7a-b.

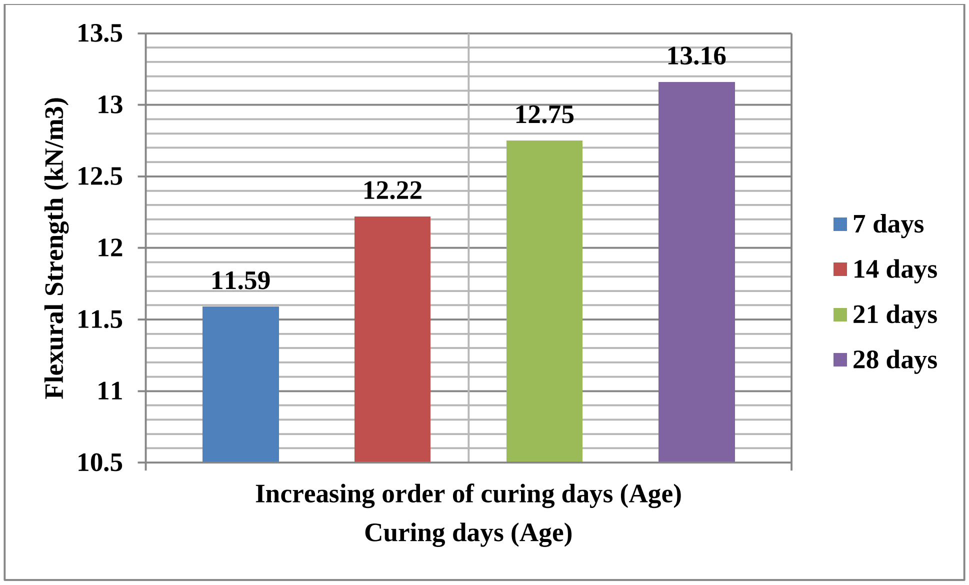


Figure 4.7a Chart Showing the Flexural Strength Value against Curing days for GT + PKS Concrete.

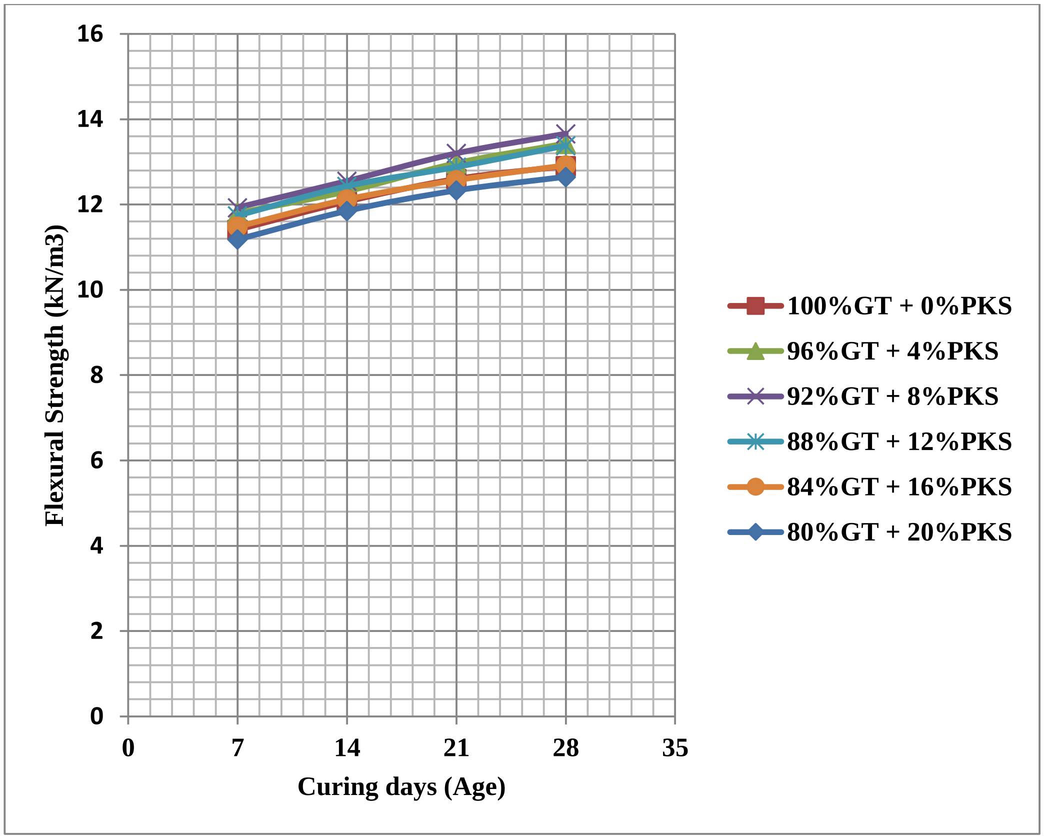


Figure 4.7b Graph Showing the Flexural Strength Value against Curing days for GT + PKS Concrete.

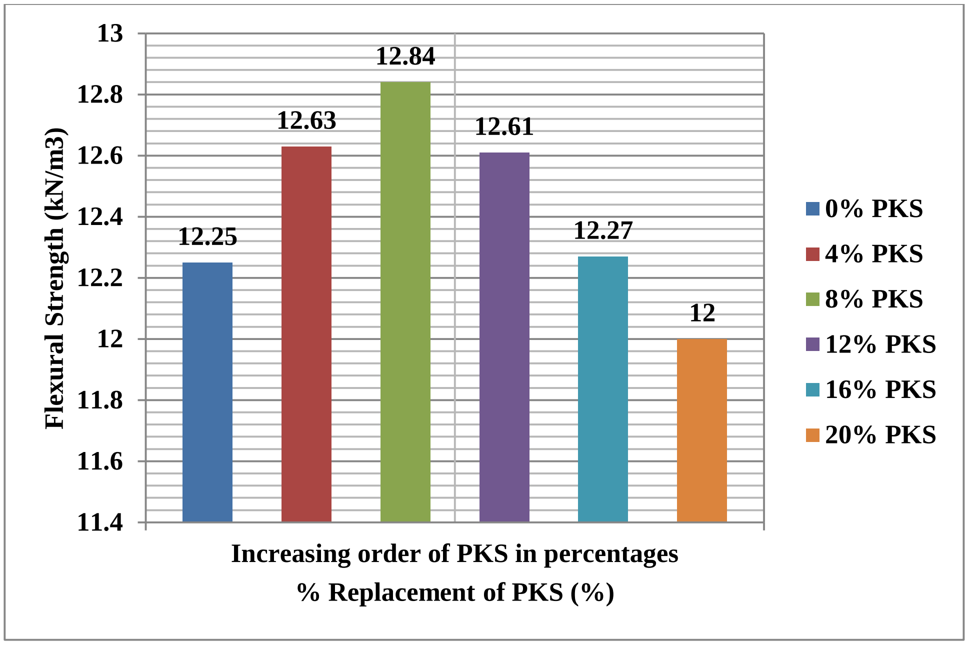


Figure 4.7c Chart Showing the Flexural Strength Value against % Replacement of PKS for GT + PKS Concrete.

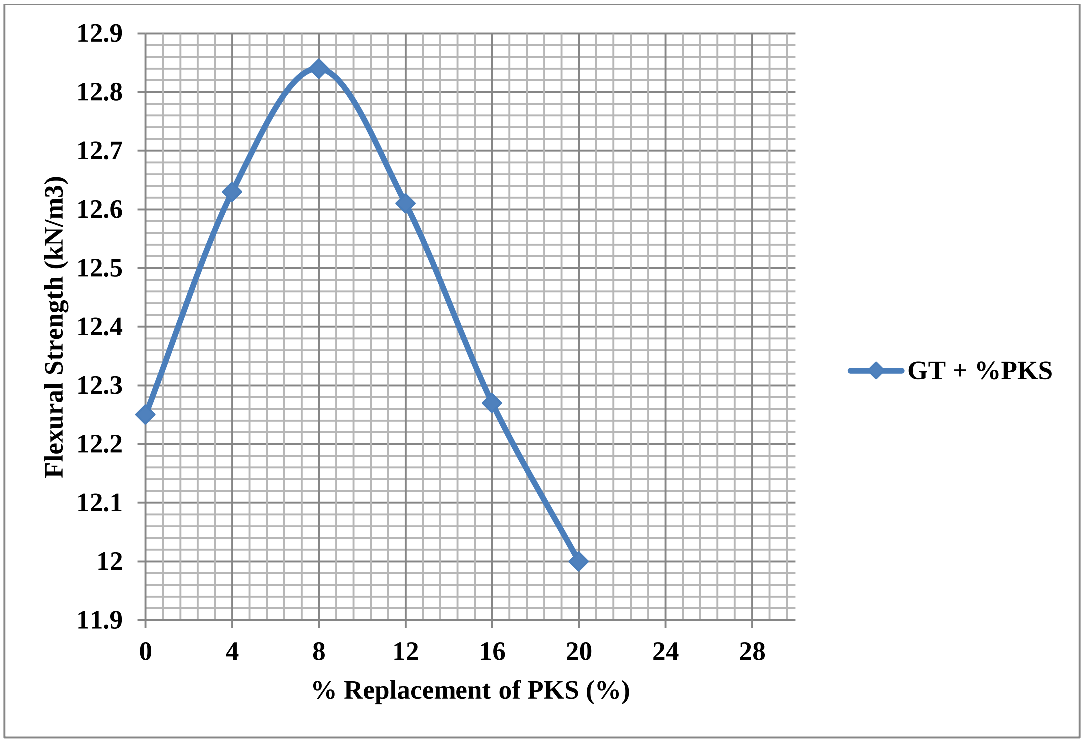


Figure 4.7d Graph Showing the Flexural Strength Value against % Replacement of PKS for GT + PKS Concrete.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

1. The Sieve analysis results shows that for GT, the percentage passing through 4.75mm is 0.16 and according to AASHTO, it is classified as A-1-b and the constituent material constitutes an excellent sub-grade material. According to USCS, it is classified as GM (Gravelly mixed with silt sized particles i.e Silty gravel). For SD, the percentage passing through sieve size 0.075mm is 0.91 and according to AASHTO Classification system, it is classified as A-2-4 and SC (clayey sand) according to USCS Classification system. This material constitutes a good sub-grade material for road construction. While the percentage passing sieve size 4.75mm for the additive (PKS) is 2.34 and according to AASHTO, it is categorized as A-1-b and GM (gravel mixed with silt The gradation of GT, SD and PKS obtained from their respective shape parameters (Cu and Cc) shows that they are poorly graded.
2. The specific gravity were conducted in accordance to ASTM D854-14 specification. For the aggregate designated as SD and GT and the additive (palm kernel shell) designated as PKS, the average apparent specific gravity computed are 2.61, 2.69 and 2.27 respectively. The range of specific gravity from 2.58 to 2.62 obtained for SD and GT satisfies ASTM D854-14 requirement which states that the specific gravity of aggregates should be between 2.55 to 2.9 and therefore justifies the use of the aggregates for this work.
3. The water absorption test conducted, indicate that the water absorption capacity of GT and PKS are 1.44 and 17.07 respectively. This result is evident to the internal structure of both GT and PKS as the additive (PKS) contains higher voids than GT which makes it unsuitable for constructional purposes.
4. Result recorded from density test of aggregate and additive show that GT with a loosed density of 1566.67 and compacted density of 1700 produces the highest density in both loosed and compacted state. While SD produces comparatively the same density (1466.67) in both loosed and compacted state. The additive (PKS) with loosed and compacted density of 556.67 and 756.67 respectively produces the least density in both loosed and compacted state.

5. The slump test result recorded indicate that the slump value increases with consistent addition of the additive (PKS) from 4% to 20% at w/c ratio of 0.55 with the highest slump recorded at 20% partial replacement of GT. This result suggests that increase in PKS up to 20% increases the workability of the concrete. The slump type formed by the fresh GT + PKS concrete are classified as shear slump since the slump value exceed 40mm.
6. The results obtained from the compressive test performed on the hardened concrete cubes shows that the compressive strength of concrete increases with curing age. From the result of compressive strength against percentage replacement of PKS content, it was observed that the compressive strength of the hardened concrete increased marginally from 28.3kN/m3 to 28.5kN/m3 from 0% to 4% addition of PKS at w/c ratio of 0.55 beyond this point, the compressive strength decreased.
7. The flexural strength test was conducted at 7, 14, 21 and 28days respectively suggest that there was an increase in the flexural strength of the hardened concrete from 0%PKS to 8%PKS content. Beyond 8%PKS content, the flexural strength decreased.
8. The additive (PKS) is therefore adjudged as feasible but ineffective as no improvement in the compressive strength of the concrete was observed.
9. Based on the finding obtained from compressive and flexural strength test from 0% to 20% addition of PKS at w/c of 0.55.This study therefore, discourage the use of this material as partial substitute for coarse aggregate in concrete beyond 4% as no substantial improvement in the concrete compressive and flexural strength was recorded.

5.2 Recommendation.

1 This study discourages the use of Palm kernel shell (PKS) as partial substitute for coarse aggregate in concrete beyond 4% since no obvious improvement in compressive and flexural strength was observed.

2 The recommendation 1 should be subject to further research so as to ascertain whether other material can be added to PKS in other to improve the compressive and flexural strength of concrete.

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APPENDIX A

SPECIFIC GRAVITY RESULT

Table A1. Specific Gravity Result for Sand.

Determinants	**Trial 1**	**Trial 2**	**Trial 3**
Wt of density bottle, W_1 (g).	**24.07**	**25.54**	**25.20**
Wt of bottle + dry soil, W_2 (g).	**34.06**	**35.52**	**35.20**
Wt of bottle + soil + water, W_3 (g).	**78.86**	**83.11**	**81.47**
Wt of bottle + water, W_4 (g).	**72.71**	**76.93**	**75.30**

The Specific gravity of the sample is calculated as follows:

Specific Gravity for Sand.

$$\text{Trial 1 } (G_{S1}) = \frac{(W2-W1)}{(W2-W1)-(W3-W4)} = \frac{(34.06-24.07)}{(34.06-24.07)-(78.86-72.71)} = 2.60$$

$$\text{Trial 2 } (G_{S2}) = \frac{(W2-W1)}{(W2-W1)-(W3-W4)} = \frac{(35.52-25.54)}{(35.52-25.54)-(83.11-76.93)} = 2.62$$

$$\text{Trial 3 } (G_{S3}) = \frac{(W2-W1)}{(W2-W1)-\ (W3-W4)} = \frac{(35.20-25.20)}{(35.20-25.20)(81.47-75.30)} =2.61$$

$$\text{Specific Gravity} = \frac{(GS1+GS2+GS3)}{3} = \frac{(2.60+2.62+2.61)}{3} = 2.61$$

Table A2. Specific Gravity Result for PKS

Determinants	**Trial 1**	**Trial 2**	**Trial 3**
Wt of Saturated aggregate and basket in water W_1 (g).	**342.7**	**311.60**	**288.17**
Wt of basket in Water W_2 (g).	**152.20**	**145.61**	**139.32**
Wt of Saturated aggregate in air W_3 (g).	**367.88**	**342.11**	**315.76**
Wt of Oven-dried aggregate in air W_4 (g).	**320.77**	**298.24**	**279.17**

The Specific gravity of the sample is calculated as follows:

Apparent Specific Gravity for PKS.

$$\text{Trial 1 } (G_{S1}) = \frac{W4}{(W4-(W1-W2)} = \frac{320.77}{(320.77-(342.7-152.20)} = 2.46$$

$$\text{Trial 2 } (G_{S2}) = \frac{W4}{(W4-(W1-W2)} = \frac{298.24}{(298.24-(311.60-145.61)} = 2.26$$

$$\text{Trial 3 } (G_{S3}) = \frac{W4}{(W4-(W1-W2)} = \frac{279.17}{(279.17-(288.17-139.32)} = 2.14$$

$$\text{Apparent Specific Gravity} = \frac{(GS1+GS2+GS3)}{3} = \frac{(6.86)}{3} = 2.29$$

Table A3. Specific Gravity Result for Crushed Granite.

Determinants	**Trial 1**	**Trial 2**	**Trial 3**
Wt of Saturated aggregate and basket in water W_1 (g).	**458.72**	**495.7**	**508.8**
Wt of basket in Water W_2 (g).	**190.48**	**183.59**	**184.35**
Wt of Saturated aggregate in air W_3 (g).	**438.62**	**442.24**	**440.82**
Wt of Oven-dried aggregate in air W_4 (g).	**432.80**	**434.28**	**434.86**

The Specific gravity of the sample is calculated as follows:

Apparent Specific Gravity for Crushed Granite.

Trial 1 (G_{S1}) $= \frac{W4}{(W4-(W1-W2)} = \frac{495.7}{(495.7-(495.7-183.5)} = 2.70$

Trial 2 (G_{S2}) $= \frac{(W4}{(W4-(W1-W2)} = \frac{434.28}{(434.28-(460.60-192.84)} = 2.61$

Trial 3 (G_{S3}) $= \frac{W4}{(W4-(W1-W2)} = \frac{508.8}{(508.8-(508.8-184.35)} = 2.76$

Apparent Specific Gravity $= \frac{(GS1+GS2+GS3)}{3} = \frac{(8.07)}{3} = 2.69$

APPENDIX B

BULK DENSITY TEST

Table B1 Loose and Compacted Bulk Density of coarse aggregate (GT).

Sample	W (kg)	WL (kg)	Wc (kg)	Loose density (kg/m^3)	Density Compacted (kg/m^3)
1	4.0	5.4	5.5	1400.00	1500.00
2	4.0	5.6	5.7	1600.00	1700.00
3	4.0	5.7	5.9	1700.00	1900.00
Average				1566.67	1700.00

Table B2 Loose and Compacted Bulk Density of Fine Aggregate (SD)

Sample	W (kg)	WL (kg)	Wc (kg)	Loose density (kg/m^3)	Density Compacted (kg/m^3)
1	4.0	5.2	5.6	1200.00	1600.00
2	4.0	4.8	5.3	1300.00	1300.00
3	4.0	4.9	5.5	1900.00	1500.00
Average				1466.67	1466.67

Table B3 Loosed and Compacted Bulk Density of Additive (PKS).

Sample	W (kg)	WL (kg)	Wc (kg)	Loose density (kg/m^3)	Density Compacted (kg/m^3)
1	4.0	4.6	4.75	600.00	750.00
2	4.0	4.55	4.77	550.00	770.00
3	4.0	4.52	4.75	520.00	750.00
Average				556.67	756.67

APPENDIX C

WATER ABSORPTION TEST

Water absorption = $\frac{W1-W2}{W2}$×100

Where W1 = Weight of Saturated aggregate in air

W2 = Weight of oven-dried aggregate in air

For PKS

W1 = 19.2g

W2 = 16.4g

The Water absorption of PKS is calculated as $\frac{19.2-16.4}{16.4}$×100 = 17.07

For GT

W1 = 19.05g

W2 = 18.78

The Water absorption of GT is calculated as $\frac{19.05-18.78}{18.78}$×100 = 1.44

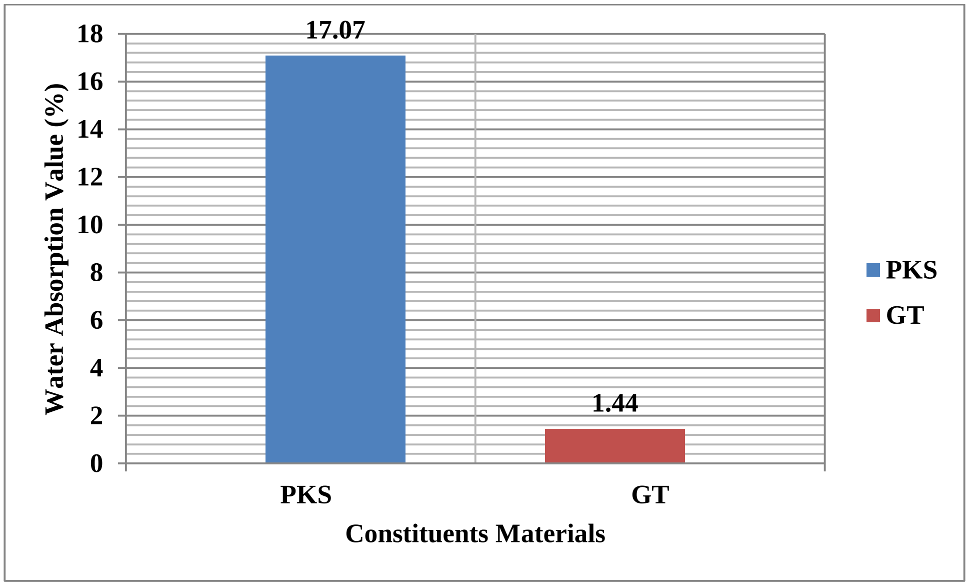


Figure C1 Water absorption Chart for PKS and GT.

APPENDIX D

SLUMP TEST

Table D1 Slump Test Value for GT + PKS Concrete at 0.55w/c.

Percentage Replacement of PKS	Slump Value at 0.55w/c ratio (mm)	Slump Type
0	65	Shear slump
4	75	Shear slump
8	87	Shear slump
12	95	Shear slump
16	102	Shear slump
20	110	Shear Slump

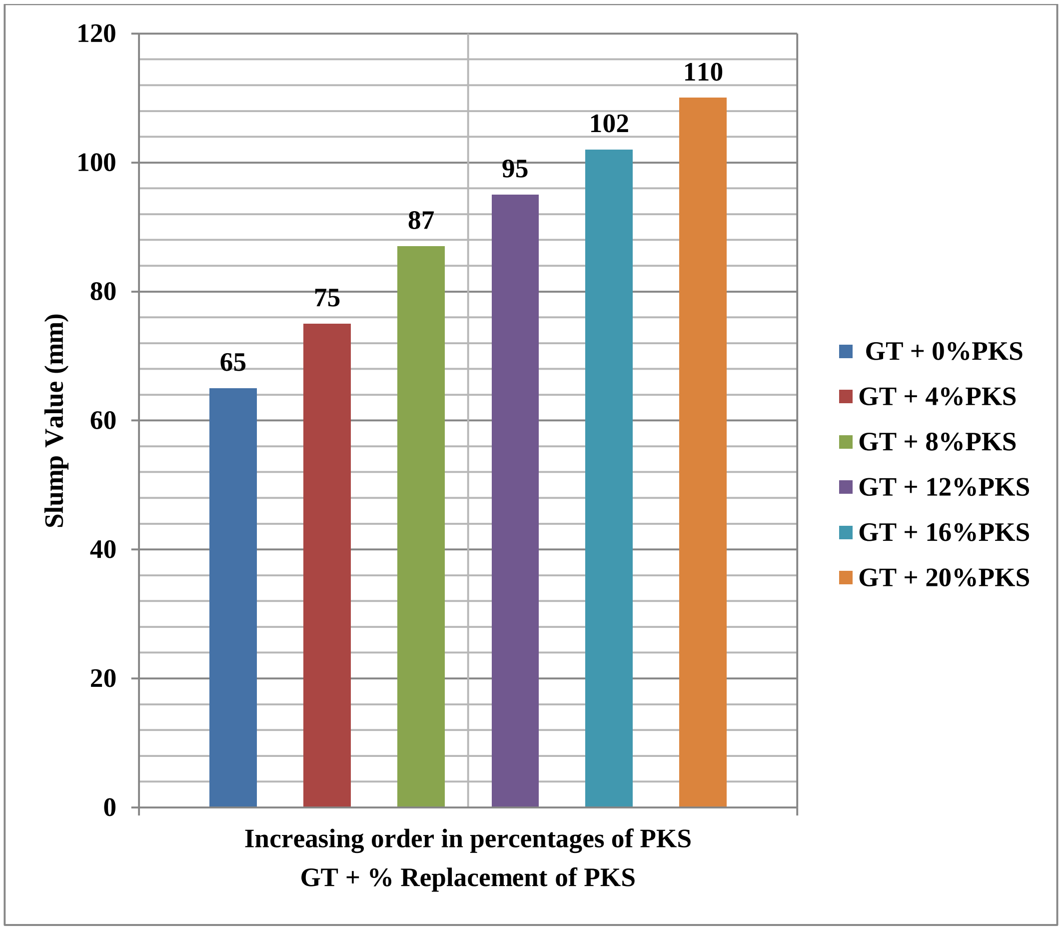


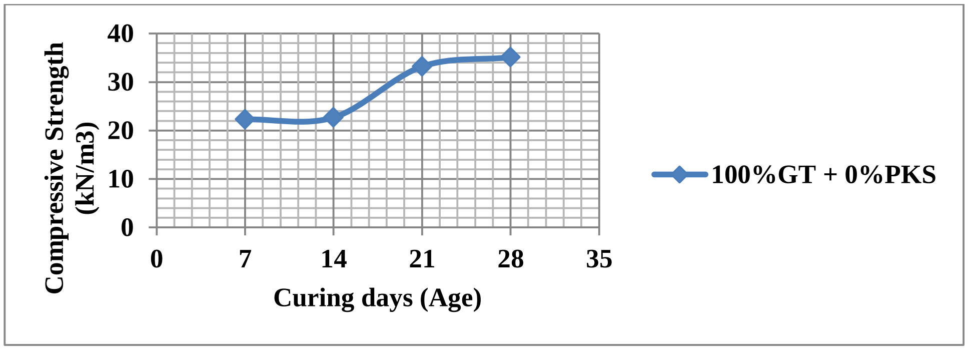
Figure D1 Slump Value Chart for PKS and GT.

APPENDIX E

COMPRESSIVE STRENGTH TEST

Table E1 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 100% GT + 0%PKS at 0.55w/c ratio.

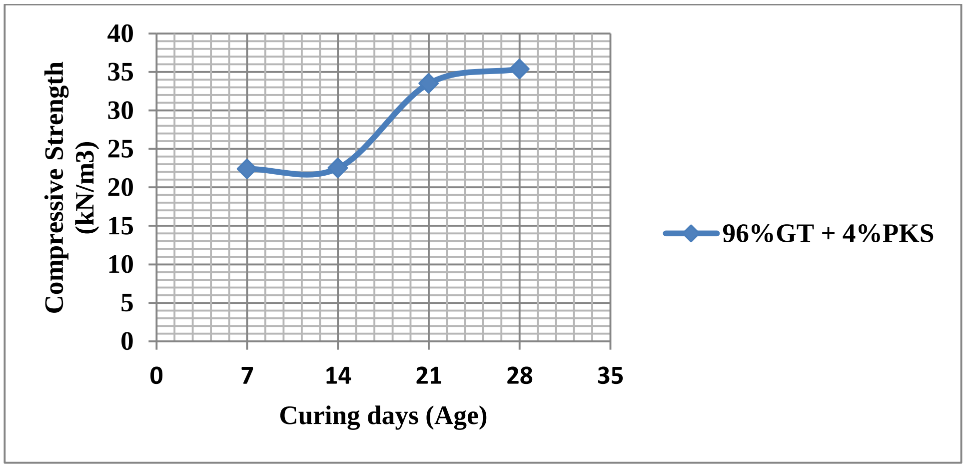
Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
A1	8.65	7	1:2:4	505.2	22.5	22.3
A2	9.28			499	22.2	
A3	9.39			501.1	22.3	
B1	8.66	14	1:2:4	504	22.4	22.7
B2	9.38			512	22.8	
B3	9.68			515	22.9	
C1	9.04	21	1:2:4	748	33.2	33.2
C2	9.26			745	33.1	
C3	8.70			752	33.4	
D1	9.58	28	1:2:4	767	34.1	35.1
D2	9.86			780	34.7	
D3	9.74			824	36.6	



E1 Graph of Comp Strength against Curing days for 100%GT + 0%PKS.

Table E2 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 96% GT + 4%PKS at 0.55w/c ratio.

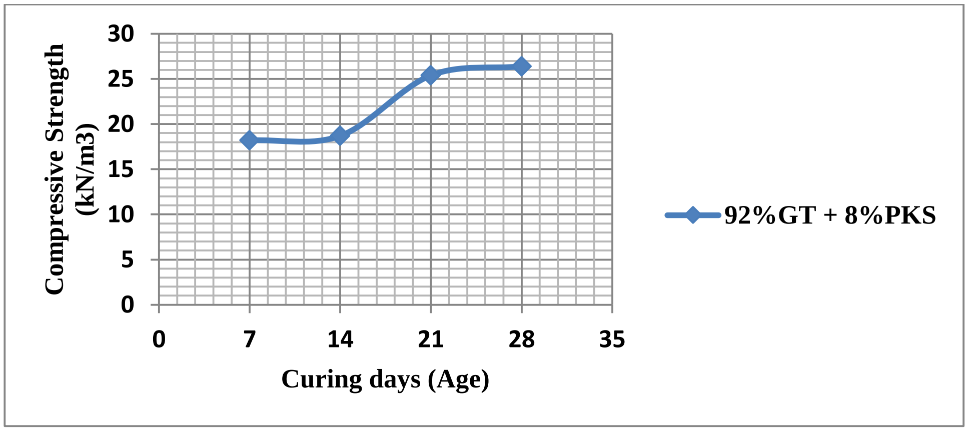
Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
E1	8.88	7	1:2:4	506.4	22.5	22.4
E2	8.68			502.1	22.3	
E3	8.58			501.6	22.3	
F1	8.94	14	1:2:4	508.5	22.6	22.5
F2	9.11			504.6	22.4	
F3	9.18			503.4	22.4	
G1	9.28	21	1:2:4	752.6	33.4	33.5
G2	9.22			750.8	33.4	
G3	8.92			755.4	33.6	
H1	9.45	28	1:2:4	795.4	35.4	35.4
H2	9.55			800.2	35.6	
H3	9.69			792.7	35.2	



E2 Graph of Comp Strength against Curing days for 96%GT + 4%PKS.

Table E3 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 92% GT + 8%PKS at 0.55w/c ratio.

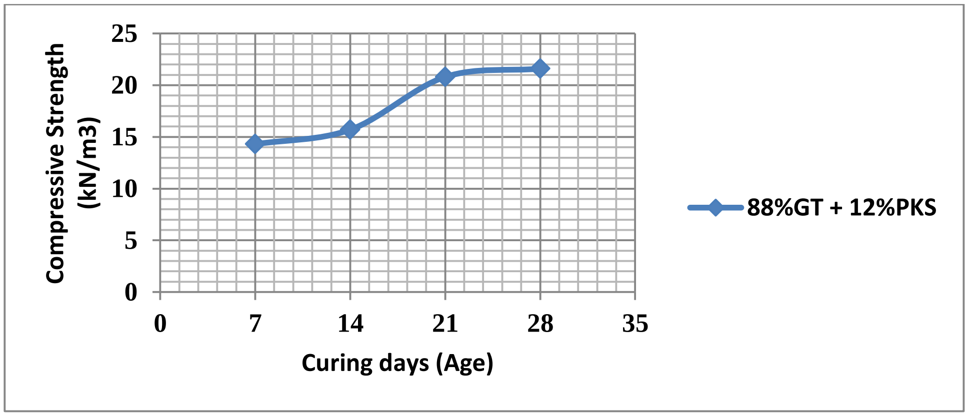
Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
I1	**8.94**	**7**	**1:2:4**	**397.5**	**17.7**	**18.2**
I2	**8.86**			**418**	**18.6**	
I3	**9.02**			**411.1**	**18.3**	
J1	**9.26**	**14**	**1:2:4**	**422**	**18.8**	**18.7**
J2	**8.64**			**421.5**	**18.7**	
J3	**9.36**			**418**	**18.6**	
K1	**9.84**	**21**	**1:2:4**	**593**	**26.4**	**25.4**
K2	**9.38**			**574.5**	**25.5**	
K3	**8.62**			**545**	**24.2**	
L1	**9.61**	**28**	**1:2:4**	**600.5**	**26.6**	**26.4**
L2	**9.35**			**594.2**	**26.4**	
L3	**9.30**			**587.4**	**26.1**	



E3 Graph of Comp Strength against Curing days for 92%GT + 8%PKS.

Table E4 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 88% GT + 12%PKS at 0.55w/c ratio.

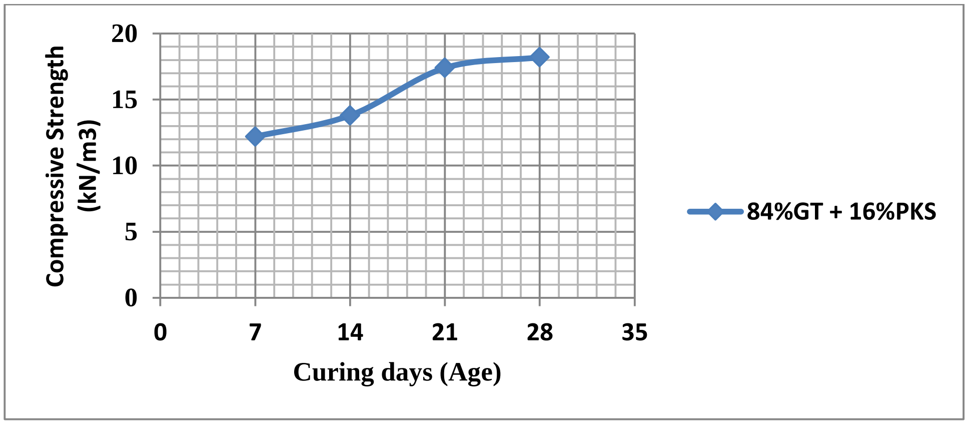
Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
M1	8.41	7	1:2:4	329	14.6	14.3
M2	9.18			320.5	14.2	
M3	8.56			318	14.1	
N1	9.11	14	1:2:4	377	16.8	15.7
N2	9.34			355	15.8	
N3	8.66			327	14.5	
O1	9.11	21	1:2:4	479.5	21.3	20.8
O2	9.52			458.5	20.4	
O3	8.40			464.8	20.7	
P1	9.07	28	1:2:4	479.7	21.3	21.6
P2	9.36			486.5	21.6	
P3	9.18			495	22	



E4 Graph of Comp Strength against Curing days for 88%GT + 12%PKS.

Table E5 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 84% GT + 16%PKS at 0.55w/c ratio.

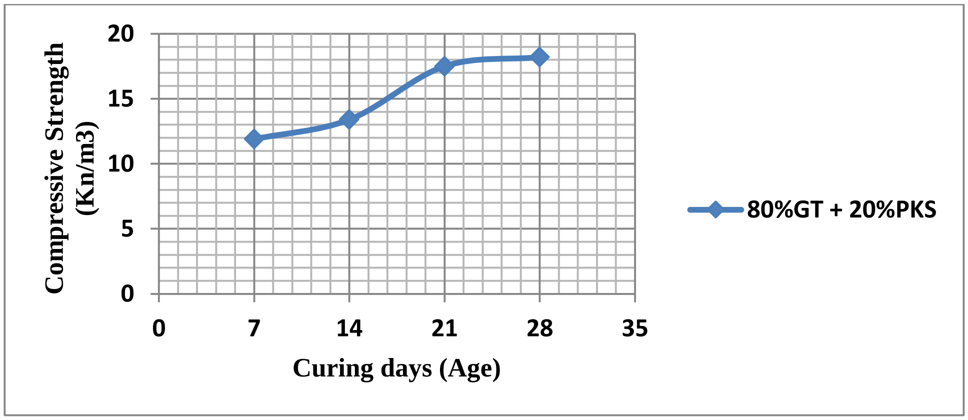
Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
Q1	8.75	7	1:2:4	277	12.3	12.2
Q2	8.68			285	12.7	
Q3	9.12			259	11.5	
R1	9.44	14	1:2:4	312.5	13.9	13.8
R2	9.28			307.5	13.7	
R3	8.74			308	13.7	
S1	9.06	21	1:2:4	390.5	17.3	17.4
S2	9.32			413.1	18.3	
S3	8.99			378	16.8	
T1	9.08	28	1:2:4	412	18.3	18.2
T2	9.28			413.5	18.3	
T3	9.20			405.5	18.0	



E5 Graph of Comp Strength against Curing days for 84%GT + 16%PKS.

Table E6 Compressive Strength Test Result for Concrete Cubes grade 1:2:4 for 80% GT + 20%PKS at 0.55w/c ratio.

Cube No	Weight (kg)	Age (days)	Mix by Volume	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
U1	8.69	7	1:2:4	272	12.1	11.9
U2	9.21			279	12.4	
U3	8.94			255	11.3	
V1	9.28	14	1:2:4	304	13.5	13.4
V2	9.68			301	13.3	
V3	8.52			298.7	13.3	
W1	9.64	21	1:2:4	391.5	17.4	17.5
W2	9.54			414.1	18.4	
W3	9.22			378	16.8	
X1	9.66	28	1:2:4	410.6	18.2	18.2
X2	9.55			409.6	18.2	
X3	9.38			408.7	18.2	



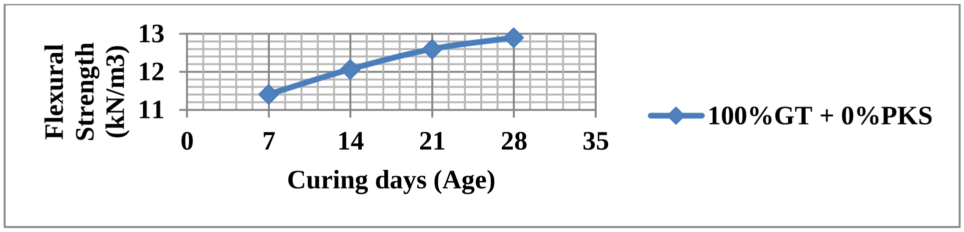
E6 Graph of Comp Strength against Curing days for 80%GT + 20%PKS.

APPENDIX F

FLEXURAL STRENGTH TEST

Table F1 Flexural Strength Test Result for Concrete Cubes grade 1:2:4 for 100%GT + 0%PKS at 0.55w/c ratio.

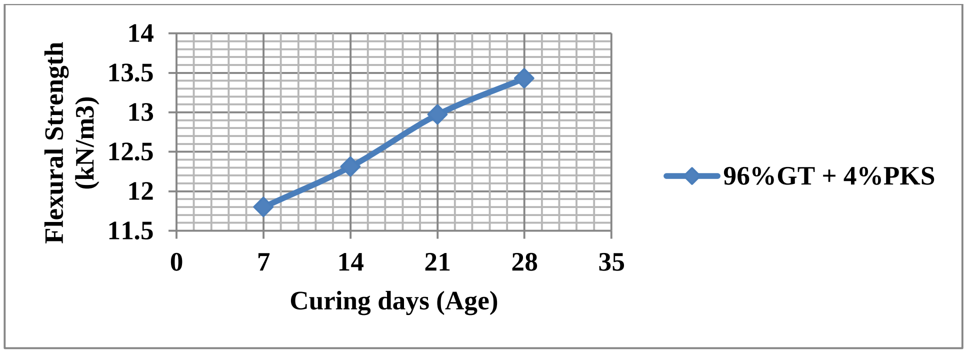
Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm^2)	(Flexural Strength) (N/mm^2)	Average Flexural Strength (N/mm^2)	Curing Age of Specimen (Days)
A1	9.04	257.8	22,500	11.46	11.41	7
A2	8.52	260.8	22,500	11.59		7
A3	8.64	251.7	22,500	11.19		7
B1	9.26	264.9	22,500	11.77	12.07	14
B2	8.92	278.8	22,500	12.39		14
B3	9.35	271.1	22,500	12.05		14
C1	9.12	280.9	22,500	12.48	12.60	21
C2	9.64	287.5	22,500	12.78		21
C3	8.94	282.2	22,500	12.54		21
D1	9.42	288.5	22,500	12.82	12.90	28
D2	9.18	290.4	22,500	12.91		28
D3	9.37	291.7	22,500	12.96		28



F1 Graph of Flexural Strength against Curing days for 100%GT + 0%PKS.

Table F2 Flexural Test Result for Concrete Cubes grade 1:2:4 for 96%GT + 4%PKS at 0.55w/c ratio.

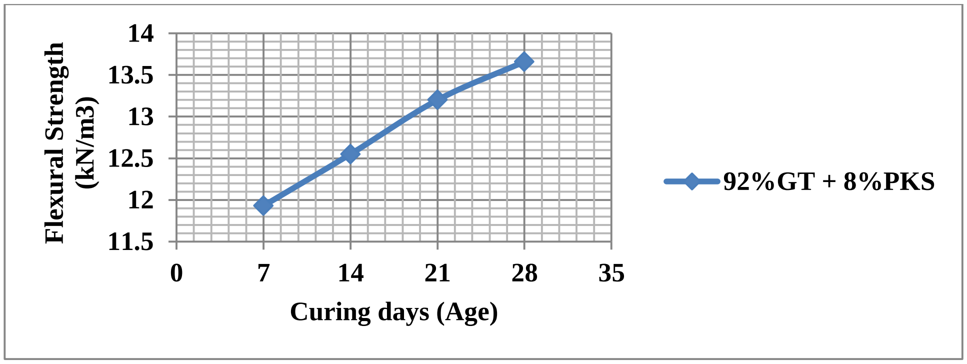
Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm^2)	(Flexural Strength) (N/mm^2)	Average Flexural Strength (N/mm^2)	Curing Age of Specimen (Days)
E1	9.24	264.5	22,500	11.76	11.80	7
E2	8.64	268.9	22,500	11.95		7
E3	9.05	263.2	22,500	11.70		7
F1	9.28	274.2	22,500	12.19	12.31	14
F2	9.14	280.4	22,500	12.46		14
F3	9.42	276.5	22,500	12.29		14
G1	9.22	289.5	22,500	12.87	12.97	21
G2	9.45	290.1	22,500	12.89		21
G3	9.37	295.8	22,500	13.15		21
H1	9.45	302.5	22,500	13.44	13.43	28
H2	9.36	305.4	22,500	13.57		28
H3	9.18	298.8	22,500	13.28		28



F2 Graph of Flexural Strength against Curing days for 96%GT + 4%PKS

Table F3 Flexural Test Result for Concrete Cubes grade 1:2:4 for 92%GT + 8%PKS at 0.55w/c ratio.

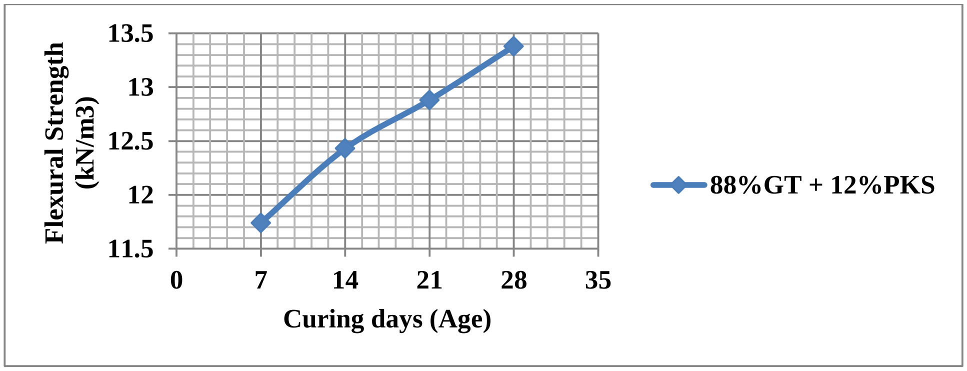
Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm^2)	(Flexural Strength) (N/mm^2)	Average Flexural Strength (N/mm^2)	Curing Age of Specimen (Days)
I1	9.42	270.5	22,500	12.02	11.93	7
I2	9.52	269.1	22,500	11.96		7
I3	9.16	266	22,500	11.82		7
J1	9.29	278.2	22,500	12.36	12.55	14
J2	9.24	286.4	22,500	12.73		14
J3	9.35	282.8	22,500	12.57		14
K1	9.32	294.5	22,500	13.09	13.20	21
K2	9.40	297	22,500	13.2		21
K3	9.35	299.3	22,500	13.30		21
L1	9.51	310.5	22,500	13.80	13.66	28
L2	9.22	306.4	22,500	13.62		28
L3	9.35	304.9	22,500	13.55		28



F3 Graph of Flexural Strength against Curing days for 92%GT + 8%PKS

Table F4 Flexural Test Result for Concrete Cubes grade 1:2:4 for 88%GT + 12%PKS at 0.55w/c ratio.

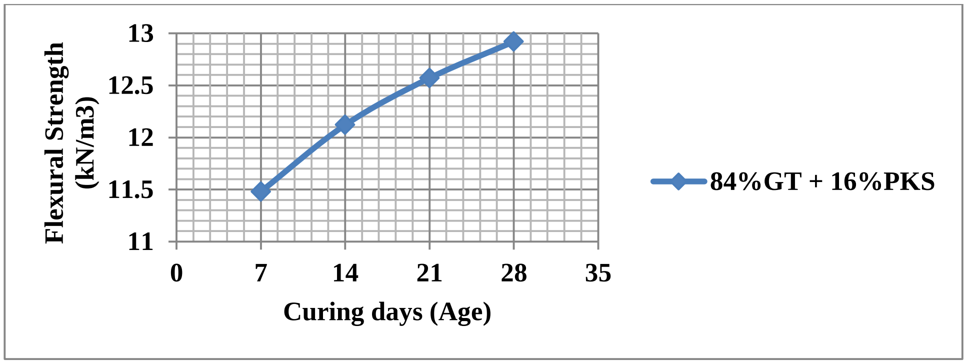
Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm^2)	(Flexural Strength) (N/mm^2)	Average Flexural Strength (N/mm^2)	Curing Age of Specimen (Days)
M1	9.42	265.4	22,500	11.80	11.74	7
M2	9.52	264.8	22,500	11.77		7
M3	9.16	262.2	22,500	11.65		7
N1	9.29	275.2	22,500	12.23	12.43	14
N2	9.24	283.8	22,500	12.61		14
N3	9.35	280.2	22,500	12.45		14
O1	9.32	290	22,500	12.89	12.88	21
O2	9.40	292.1	22,500	12.98		21
O3	9.35	287.6	22,500	12.78		21
P1	9.51	304.4	22,500	13.53	13.38	28
P2	9.22	300	22,500	13.33		28
P3	9.35	298.6	22,500	13.27		28



F4 Graph of Flexural Strength against Curing days for 88%GT + 12%PKS

Table F5 Flexural Test Result for Concrete Cubes grade 1:2:4 for 84%GT + 16%PKS at 0.55w/c ratio.

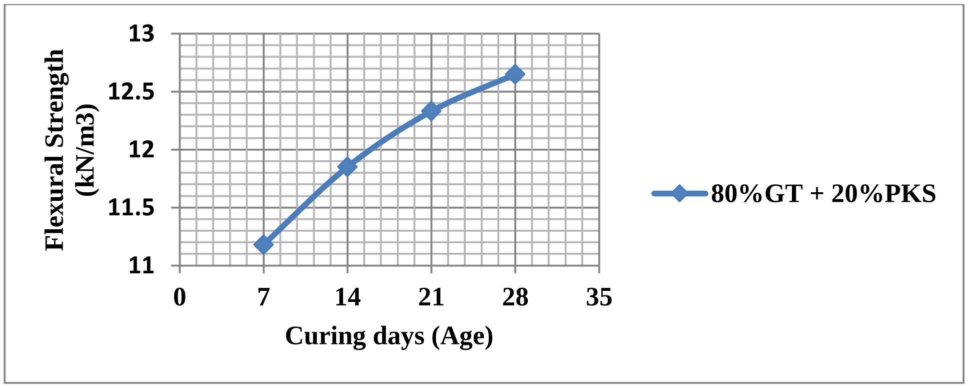
Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm^2)	(Flexural Strength) (N/mm^2)	Average Flexural Strength (N/mm^2)	Curing Age of Specimen (Days)
Q1	9.48	260.7	22,500	11.59	11.48	7
Q2	9.42	258.6	22,500	11.49		7
Q3	9.22	255.8	22,500	11.37		7
R1	9.34	270	22,500	12.00	12.12	14
R2	9.28	275.8	22,500	12.26		14
R3	9.38	272.3	22,500	12.10		14
S1	9.34	286.5	22,500	12.73	12.57	21
S2	9.51	282.2	22,500	12.54		21
S3	9.06	280.0	22,500	12.44		21
T1	9.45	290.6	22,500	12.92	12.92	28
T2	9.31	289.4	22,500	12.86		28
T3	9.20	292.1	22,500	12.98		28



F5 Graph of Flexural Strength against Curing days for 84%GT + 16%PKS

Table F6 Flexural Test Result for Concrete Cubes grade 1:2:4 for 80%GT + 20%PKS at 0.55w/c ratio.

Cube No	Weight (Kg)	Maximum Load (KN)	Area of Cube (mm²)	(Flexural Strength) (N/mm²)	Average Flexural Strength (N/mm²)	Curing Age of Specimen (Days)
U1	9.48	255.2	22,500	11.34	11.18	7
U2	9.42	250.4	22,500	11.13		7
U3	9.22	248.8	22,500	11.06		7
V1	9.30	264.2	22,500	11.74	11.85	14
V2	9.25	270.2	22,500	12.01		14
V3	9.32	265.6	22,500	11.80		14
W1	9.34	281.8	22,500	12.52	12.33	21
W2	9.51	276.3	22,500	12.28		21
W3	9.06	274	22,500	12.18		21
X1	9.45	285.4	22,500	12.68	12.65	28
X2	9.36	282.5	22,500	12.56		28
X3	9.28	285.8	22,500	12.70		28



F6 Graph of Flexural Strength against Curing days for 80%GT + 20%PKS.

APPENDIX G

SIEVE ANALYSIS TEST

Table G1 Sieve Analysis Result for Sand

Sieve Sizes (mm)	Mass Retained (kg)	% Mass Retained (%)	Cumulative % Retained (%)	Cumulative % Finer (%)
2	10.99	3.66	3.66	96.34
1.18	31.45	10.48	14.14	85.86
0.85	20.91	6.97	21.11	78.89
0.6	31.03	10.34	31.46	68.54
0.425	41.45	13.82	45.27	54.73
0.3	53.94	17.98	63.25	36.75
0.15	95.12	31.71	94.96	5.04
0.075	12.39	4.13	99.09	0.91
Tray	2.78	0.93	100.02	
Total	300.06			

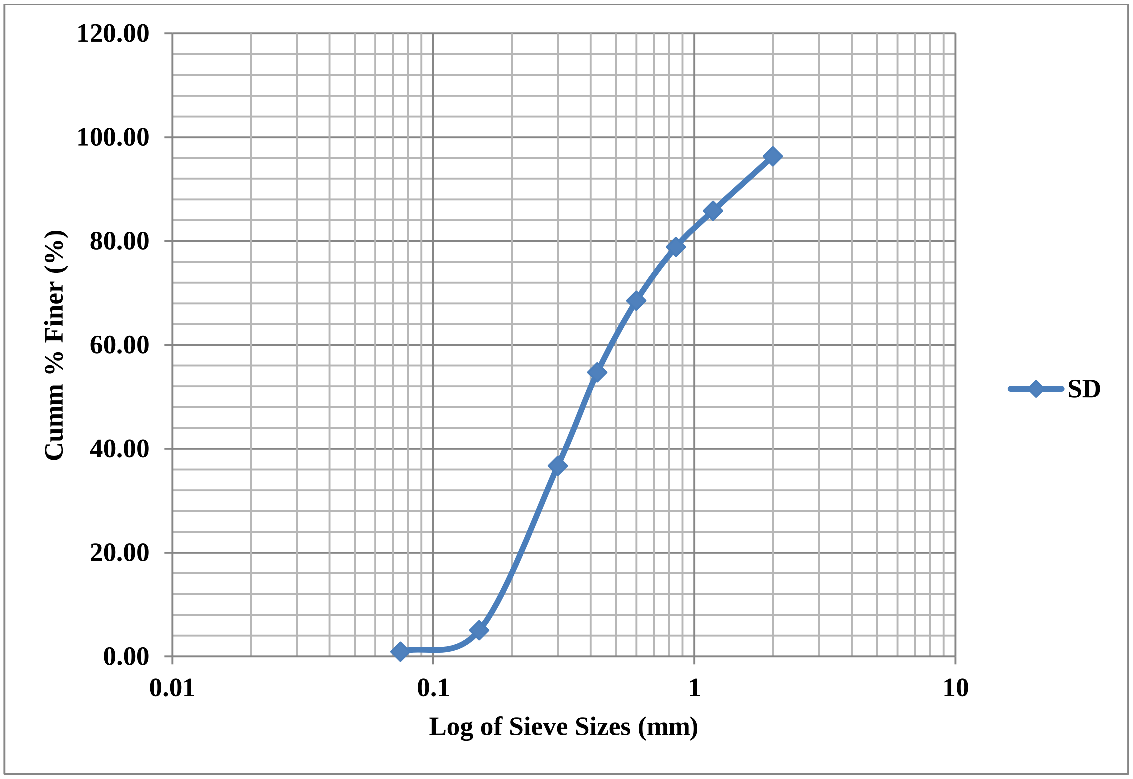


Figure F1 Particle Size Distribution Curve for Sand.

Table G2 Sieve Analysis Result for PKS

Sieve Sizes (mm)	Mass Retained (kg)	% Mass Retained (%)	Cumulative % Retained (%)	Cumulative % Finer (%)
14	22	7.33	7.33	92.67
12.5	98	32.67	40.00	60.00
10	64	21.33	61.33	38.67
9.5	101	33.67	95.00	5.00
4.75	8	2.67	97.66	2.34
Tray	7	2.33	100.00	0.00
Total	300			

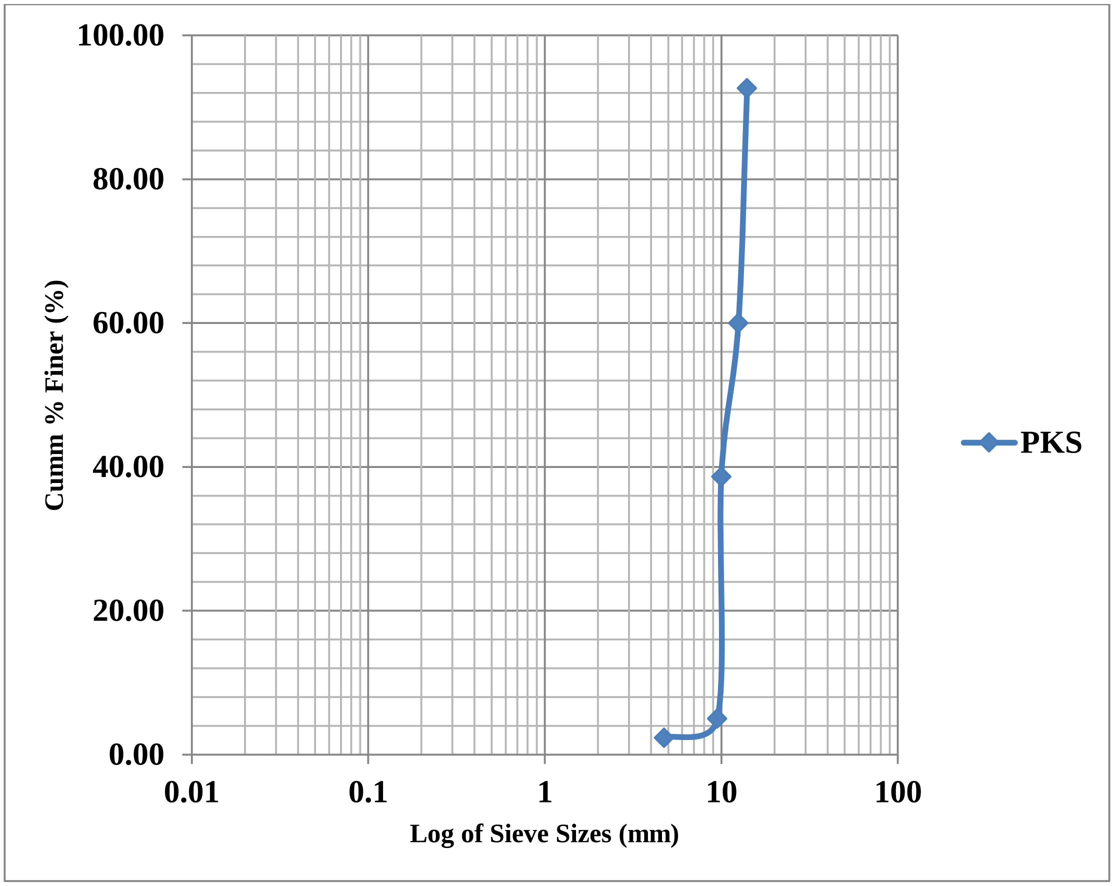


Figure F2 Particle Size Distribution Curve for PKS.

Table G3 Sieve Analysis Result for GT

Sieve Sizes (mm)	Mass Retained (kg)	% Mass Retained (%)	Cumulative % Retained (%)	Cumulative % Finer (%)
20	103.97	13.00	13	87.00
14	538.15	67.27	80.27	19.73
10	67.61	8.45	88.72	11.28
4.75	88.95	11.12	99.84	0.16
Tray	1.33	0.17	100.00	0.00
Total	800.01			

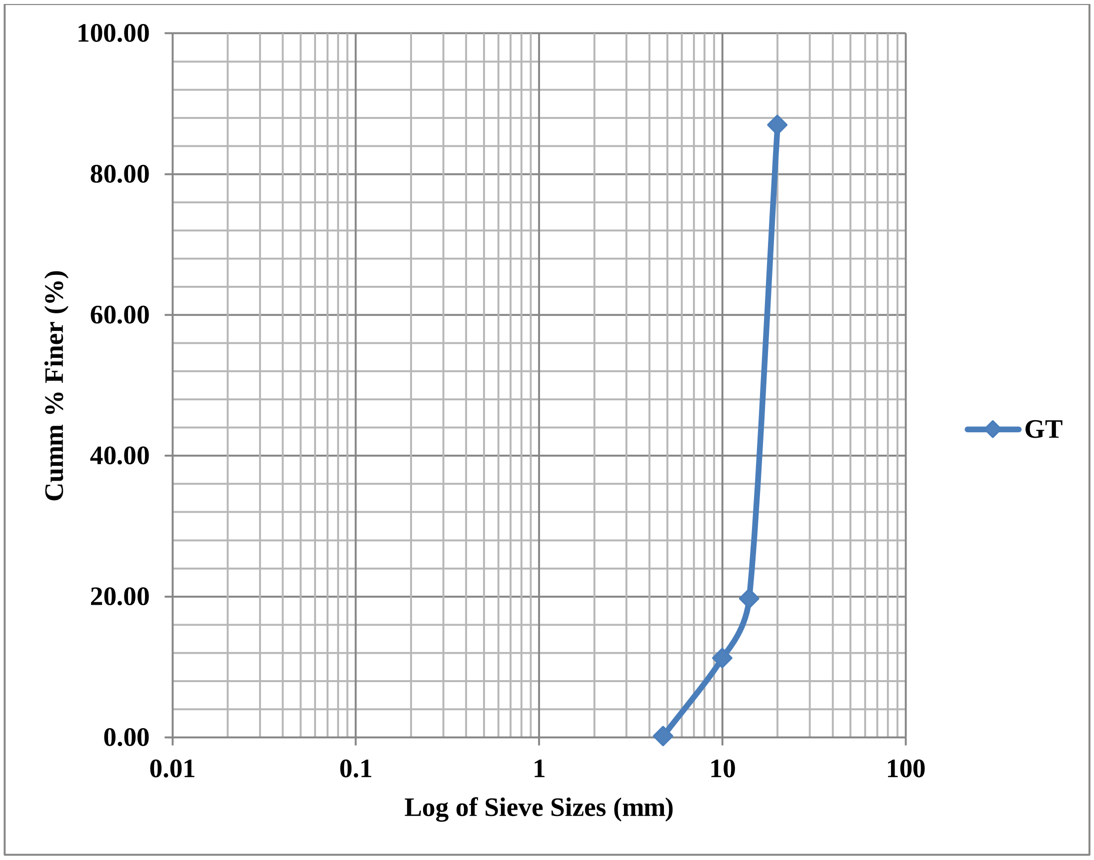


Figure F3 Particle Size Distribution Curve for GT.

A STUDY ON COMPRESSIVE STRENGTH CHARACTERISTICS OF CONCRETE ON DIFFERENT DATES

BY

EZENWEKE ANASTESIA CHINENYE

NAU/CVE/2016224044

SUBMITTED TO

THE DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING DEGREE (B.ENG) IN

CIVIL ENGINEERING

NNAMDI AZIKIWE UNIVERSITY

AWKA

FEBRUARY 2022

CERTIFICATION

This is to certify that this research study carried out by Ezenweke Anastesia Chinenye (Registration Number 2016224044) from the department of civil Engineering Nnamdi Azikiwe University, Awka, Anambra State.

……………………………………..   …………………….

Ezenweke Anastesia Chinenye   Date

APPROVALS PAGE

This project has been read and approved by the undersigned as meeting the requirement of the Department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka for Award of B.ENG in Civil Engineering.

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Engr. I. Omaliko   Date

……………………………………….   …..………………….

Engr.Dr.C.A.Ezeagu

(Head of Department)

………………………………………   ………………………

External Examiner   Date

DEDICATION

This project is most importantly dedicated to Almighty God, who through his ceaseless love, protection and mercies brought me this far in the cause of my academic pursuit.

ACKNOWLEDGEMENT

First of all and most importantly, I give thanks to almighty God for his favor, grace, guidance, strength and mercies upon by life and his abundant wisdom to push through my academic sessions.

My unending gratitude goes to my supervisor, Engr. I. Omaliko for his patience, guidance, encouragement and wonderful aid he gave me in getting this project research done. Thank you sir

I thank profusely all my lecturers in the department of civil engineering for their guidance, support, endurance and love

I owe a deep sense of gratitude to also Engr. B. Joseph of M.I.O. Construction Company for his love, care and guidance towards the success of my research work.

My heartfelt appreciation and deepest sense of gratitude goes to my family, my parents Mr and Mrs Arinze Ezenweke for their love, prayers, caring and sacrifices for educating and preparing me for my future. I am very much thankful to my siblings for their love, understanding, prayers, and continuing support to complete this research work.

I an extremely thankful to my friends Ruth, Vivian, Precious, Stanly and Anthony, this would have been a much difficult feast without you. Thank you all for your unwavering support and for reminding me to take breaks when I have been stressed out.

I thank profusely all my lecturers in the department of civil engineering for their guidance, support, endurance and love

ABSTRACT

This research investigation was based on the variation in the compressive strength of concrete cast on different dates. Thus, this experiment showcased the investigative results of concrete cast on different dates using different size of aggregates. This test was cured and crushed with different number of days, 7, 14, 21 and 28 days to test its compressive strength. The test was conducted under constant environmental conditions with the mix ratio 1.2.4 of cement, fine aggregate and coarse aggregate. Hand compaction was used and curing was by immersion i.e. deeping the cubes inside the curing tank and crushed after 7, 14, 21, and 28 days respectively. The variation in strength on curing age from the graph shows that there was rapid increase of strength gain for the first 7 days after which it reduced from the 14th day and then increases from 21 to 28 days. The result of analysis carried out from the crushing strength showed that concrete strength increases with curing age of 7 to 28 days. It also show that the strength of concrete increases progressively with the age of curing and there is rapid strength gain in the first 7 days of curing and concrete gains its maximum strength at 28 days of curing. In this research, different sizes of coarse aggregates ranging from 10mm, 16mm and 25mm were used to cast Concrete. Compressive strength test and slump consisting for different sizes were measured. The result shows that the compressive strength of concrete made with 16mm at 28days of curing period was much higher followed by 25mm and 10mm. The factors affecting the compressive strength of concrete were also discussed, while aggregate parts were buttressed extensively. Also, particle size distribution analysis was conducted in the course of this project for proper grading and classification. The entire test was done with the British standard (BS) specifications.

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CAPTER ONE

INTRODUCTION

Concrete is a composite material produced by mixing homogeneously selected proportions of water, cement, aggregates (fine and coarse). Concrete is said to be the second substance most used in the world after water, and is one of the most frequently used building materials. Approximately, three quarter of the volume of concrete are occupied by aggregates (Gumede and Franklin, 2004.The most dominant construction material is Concrete and the most collapse structure is Concrete structure. A number of researches (Ayininuola and Olalusi,2011) have identified the use of substandard materials, particularly Concrete as the leading cause of building collapse in Nigeria. Concrete failure still occurs despite adequate design and mix ratio. This advocates the existence of a breach in requirement for production of quality Concrete. Previous works confirm the use of inferior concrete aggregates materials as among the causative elements of structural Concrete failure in building. Gollu et al.(2016)mentioned unsuitable materials, unsound aggregate, reactive aggregate, and contaminated aggregate as part of the sources of concrete failure in buildings.Akineleyeand Tijani(2017) stated that the use of low quality aggregates also affect the performance of asphalt Concrete in southwest Nigeria. Concrete will only become a quality material for construction when their constituents are properly sourced. The quality of aggregate can vary significantly due to the geographical location and environmental condition (Ajagbe et al., 2018).

Fowler and Quiroga (2003) reported that aggregates are expected to have important effects on the properties of concrete since they occupy 70-80% of it. Concrete aggregates and paste are the major factors that affect the strength of concrete (shetty, 2005), the properties of aggregate greatly affect the durability and structural performance of concrete as aggregate with undesirable propertiescannot produce strong Concrete (Neville,2001).According to Mehta and Menterio (2001), the aggregates exercise a significant influence on strength, dimensional stability, and durability of concrete. Ajagbeand Tijani (2016) stated the assessment of concrete aggregate is vital to overcome the problem of structural collapse due to Concrete failure in a certain environment. De Larrard (1999) and Dewar (1999) agreed that the aggregate source has an impact on concrete strength. Concrete strength is govern by aggregate size, type, and source (Hassan, 2014: Aginam et al., 2013; Jimoh and Awe, 2017; Abdullahi, 2012).

Comprehensive strength is the most significant mechanical property of concrete. It is obtained by measuring Concrete specimen after curing for days. Some of the factors that influence the Concrete strength include aggregate quality, cement strength, water content and water/ cement ratio (Noorzaei ET el., 2007).

Concrete should be strong enough, when it has harden, to resist the various stresses which it will be subjected to. Hardened Concrete has a number of properties, including:

1. Mechanical strength, in particular compressive strength.
2. Durability
3. Porosity and density
4. Thermal and acoustic insulation properties.
5. Impact resistance.

When freshly mixed, it must be of such mixed it must be of such a consistency that it can readily be handled with segregation and easily compacted in the formwork leading to the homogeneity of the finished work. The strength of concrete is governed by several factors such as ratio of cement to water, ratio of cement to aggregates, maximum size of aggregates, grading, surface texture, shape, strength and stiffness of aggregate particles. Fresh concrete has many applications and can be cast into circle, rectangle, squares and more. It can also be used for staircases, columns, doors, beams, lintels and other familiar structures.

BACKGROUND

The role of aggregate in concrete is central to this report. While the topic has been under study for many years, an understanding of the effect of coarse aggregate has become increasingly more important with the introduction of high strength concrete, since coarse aggregate plays a progressively more important role in concrete behavior as strength increases.

In normal strength concrete, failure in compression almost exclusively involves deboning of cement paste from the aggregate particle at what, for the purpose of this report, will be called matrix aggregate interface. In contrast, in high strength concrete, the aggregate particle as well as the interface undergoes failure, clearly contributing to overall strength. As the strength of the cement paste constituent of concrete increases, there is greater compatibility of stiffness and strength between the normally stiffer and stronger coarse aggregate and the surrounding mortar. Thus, micro cracks tends to propagate through the aggregate particle since, not only is the matrix aggregate bond stronger than in concrete of lower strength , but the stresses due to a mismatch in elastic properties are decreased. Thus, aggregate strength becomes an important factor in high strength concrete.

This report describes work that is aimed at improving the understanding of the role of aggregate in concrete. The variables considered are aggregate type, aggregate size and aggregate contenting normal and high strength concrete. Compression, flexural, and fracture test are used to better understand the effects aggregates have in concrete

1.1 THE BENEFITS OF CONCRETE

There is numerous positive aspect of concrete:

1. It is relatively cheap material and has a relatively long life with few maintenance requirements.
2. It is strong in compression.
3. Before it hardens, it is a very pliable substance that can easily be shaped.
4. It is not combustible.

1.2 THE LIMITATIONS OF CONCRETE INCLUDE:

1. Relatively low tensile strength when compared to other building materials.
2. Low Durability
3. Low strength to weight ratio.
4. It is susceptible to cracking

1.3 THE TYPES OF CONCRETE

Concrete is made in different grades, including normal, standard and high- strength grades. This grades indicate how strong the Concrete is and how it will be used in construction. They are three grades or classes of cement in Nigeria, namely grades 32.5,45.5,and 52.5.These grades corresponds to the minimum 28 day compressive strength of cement mortar after curing(COREN,2017). It is important to note that the most common type of cement in Nigeria is the Portland limestone cement (PLC)and not Ordinary Portland cement (OPC). The cement available in the open Market of Nigeria is the Portland limestone cement designated as CEM II in NIS 444-1(2003). PLC is a modified OPC which is produced by adding 6-35% of limestone to OPC. It has a lower clinker content rage of 65-94% compared with OPC's range of 95-100 (Joeland and Mbapuun, 2016). It has lower carbon footprint than the OPC and is deemed more environmental friendly. The types of concrete include:

1. Normal strength Concrete
2. Plain or ordinary Concrete
3. Reinforced concrete
4. Pre-stressed Concrete
5. Lightweight Concrete
6. High density Concrete
7. Air-Entrained Concrete
8. Ready-mixed Concrete
9. Volumetric Concrete

10. Decorative concrete
11. Rapid set Concrete
12. Smart Concrete
13. Previous Concrete
14. Pumped Concrete
15. Limecrete
16. Glass Concrete
17. Asphalt Concrete
18. Shortcrete Concrete.

1.4 AIMS AND OBJECTIVES

The aim of this project is to investigate the compressive strength of concrete casted on different dates.

The objectives of this research are as follows:

1. To gather an abundance of pertinent information through an in-depth review of previous studies and pinpoint the areas that need to be addressed.
2. To carry out a sieve analysis of the fine and coarse aggregate.
3. To design the mix proportions.
4. To determine the workability of the fresh concrete.
5. Curing of all the concrete specimens for 7, 14, 21 and 28 (days).
6. To determine the compressive strength of the hardened concrete.

1.5 Scope of this Report

The purpose of this research work is to compare the compressive strength of concrete cast on different dates and also to compare the strength exhibited by the concrete cubes after different dates of curing. Because of the nature of this project, the investigations conducted were limited to particle size distribution, slump test and compressive strength test for 7days, 14 days, 21days and 28days of curing. This test provides an idea about the characteristics of concrete. By this single test one judge that whether concreting has been done properly. The mould size for the practical used is 150mm by 150mm and the water cement ratio used was 0.5 liter and the mix ratio is 1:2:4.

1.6 SIGNIFICANCE OF STUDY

Concrete being the major consumable material after water makes it quite inquisitive in its nature. The compressive strength of concrete is the strength of hardened concrete measured by the compression test to determine the concrete ability to resist loads which tends to compress it where as other stresses such as axial stresses are catered by reinforcements and other means. The significant/ important of conducting this test is to have an idea about the characteristics of concrete. By this single test one judges whether concrete has been done properly or not. The compressive strength of concrete depends on different factors such as water cement ratio, its constituents, cement strength, air entrainment, mix proportion, curing method, temperature effect quality of concrete material and quality control during the production of concrete. The aim of this project is to determine the strength of a concrete cube cast on different dates, to determine its strength after 28days curing period and also know the correct mix proportion to use for casting of concrete.

CHAPTER TWO

2.0 LITERATURE REVIEW

INTRODUCTION

In building construction, concrete is used for the construction of foundations, columns, beams, slabs and other load bearing elements. Various types of cements are used for concrete works which have different properties and applications. Some of the type of cement are Portland Pozzolana Cement (PPC), rapid hardening cement, Sulphate resistant cement e.t.c. Materials are mixed in specific proportions to obtain the required strength. Strength of mix is specified as M5, M10, M15, M20, M25 andM30. Where M signifies Mix and 5, 10, 15 etc. as their strength in KN/m2.Water cement ratio plays an important role which influences various properties such as workability, strength and durability.

Adequate water cement ratio is required for production of workable concrete. When water is mixed with materials, cement reacts with water and hydration reaction starts. This reaction helps ingredients to form a hard matrix that binds the materials together into a durable stone-like material. Concrete can be casted in any shape. Since it is a plastic material in fresh state, various shapes and sizes of forms or formworks are used to provide different shapes such as rectangular, circular etc. Various structural members such as beams, slabs, footings, columns and lintels are constructed with concrete.(ACI 318 Building code requirements for structural concrete).

There are different types of admixtures which are used to provide certain properties. Admixtures or additives such as pozzolans or superplasticizers are included in the mixture to improve the physical properties of the wet mix or the finished material. Various types of concrete are manufactured these days for construction of buildings and structures. These have special properties and features which improve quality of construction as per requirement.

2.1 COMPONENTS OF CONCRETE

Components of concrete are cement, sand, aggregates and water. Mixture of Portland cement and water is called as paste. So, concrete can be called as a mixture of paste, sand and aggregates. Sometimes rocks are used instead of aggregates. The cement paste coat the surface of the fine and coarse aggregates when mixed thoroughly and binds them. Soon after mixing the components, hydration reaction starts which provides strength and a rock solid concrete is obtained. Grade of concrete denotes its strength required for construction.

Based on various lab tests, grade of concrete is presented in Mix Proportions. For example, for M30 grade, the mix proportion can be 1:1:2, where 1 is the ratio of cement, 1 is the ratio of sand and 2 is the ratio of coarse aggregate based on volume or weight of materials. The strength is measured with concrete cube or cylinders by civil engineers at construction site. Cube or cylinders are made during casting of structural member and after hardening it is cured for 28 days. Then compressive strength test is conducted to find the strength. Regular grades of concrete are M15, M20, and M25 etc. For plain cement concrete works, generally M15 is used. For reinforced concrete construction minimum M20 grade of concrete are used.

Concrete is manufactured or mixed in proportions with respect to cement quantity. There are two types of concrete mixes, i.e. nominal mix and design mix. Nominal mix is used for normal construction works such as small residential buildings. Most popular nominal mix are in the proportion of 1:2:4.Design mixed concrete are those for which mix proportions are finalized based on various lab tests on cylinder or cube for its compressive strength. This process is also called as mix design. These tests are conducted to find suitable mix based on locally available material to obtain strength required as per structural design. A design mixed offers economy on use of ingredients. Once suitable mix proportions are known, and then its ingredients are mixed in the ratio as selected. Two methods are used for mixing, i.e. Hand mixing or Machine Mixing. Based on quantity and quality required, the suitable method of mixing is selected. In the hand mixing, each ingredient is placed on a flat surface and water is added and mixed with hand tools. In machine mixing, different types of machines are used.

In this case, the ingredients are added in required quantity to mix and produce fresh concrete. Once it is mixed adequately it is transported to casting location and poured in formworks. Various types of formworks are available which as selected based on usage. Poured concrete is allowed to set in formworks for specified time based on type of structural member to gain sufficient strength. After removal of formwork, curing is done by various methods to make up the moisture loss due to evaporation. Hydration reaction requires moisture which is responsible for setting and strength gain. So, curing is generally continued for minimum 7 days after removal of formwork.

2.2 TYPES OF CONCRETE CONSTRUCTION

Concrete is generally used in two types of construction, i.e. plain concrete construction and reinforced concrete construction. In PCC, it is poured and casted without use of any reinforcement. This is used when the structural member is subjected only to the compressive forces and not bending. When a structural member is subjected to bending, reinforcements are required to withstand tension forces structural member as it is very weak in tension compared to compression. Generally, strength of concrete in tension is only 10% of its strength in compression. It is used as a construction material for almost all types of structures such as residential concrete buildings, industrial structures, dams, roads, tunnels, multi storey buildings, skyscrapers, bridges, sidewalks and superhighways etc. Example of famous and large structures made with concrete are Hoover Dam, Panama Canal and Roman Pantheon. It is the largest human made building materials used for construction.

2.2.1Steps of Concrete Construction

1. Selecting quantities of materials for selected mix proportion
2. Mixing
3. Checking of workability
4. Transportation
5. Pouring in formwork for casting
6. Vibrating for proper compaction
7. Removal of formwork after suitable time
8. Curing member with suitable methods and required time.

The variations on the compressive strength of concretes made with respect to tropical climate as patterning to Nigeria in particular has not been fully worked on by many researchers. As a result, it became difficult to lay hands on such information.

Originally, aggregates according to Neville, were viewed as an inert material dispersed throughout the cement paste, largely for economic reasons. He went further to state the fact that aggregates are not truly inert and its physical properties influence performance of concrete. The strength requirement is generally specified in terms of characteristic strength (BS 8110: Part 1) coupled with a requirement that the probability of the strength falling below this shall not exceed certain value. Neville stated that the shape of aggregate, its surface texture and cleanliness influence the bond strength of concrete.

He also stressed that in experimental concrete, entirely smooth coarse aggregates led to lower compressive strength, typically by 10% than when roughened. Also on the effect of sizes, Aggregates with maximum size of coarse aggregates has lower compressive strength. Also, according to the University of Technology Malaysia, on the effect of aggregate shape, surface texture and cleanliness; “a smooth rounded aggregate will result in a weaker bond between the aggregates and the matrix than an irregular aggregate with rough surface texture”.

Explaining further, “a fine coating of impurities such as silt and clay on aggregate surface hinders the development of a good bond. The aggregate size can also affect strength. For a given matrix proportion, the concrete strength decreases as the maximum size of aggregates increases. Concrete of a given strength can be produced with well graded aggregates. I. This just mentioned case, segregation does not occur”. According to national ready mixed concrete association, they carried out a research work on coarse aggregate and in their conclusion, at a given water ratio, within the range employed in most structural concrete, smaller maximum size of aggregate will tend to produced higher concrete strengths than larger ones. Secondly, the larger sizes will require less mixing water and hence for a given cement factor, will produce of lower water ratio than the smaller sizes.

Bloem and Gaynor (1963) jointly studied the effects of aggregate properties on the strength of concrete and they reported' that, tests were made with 546 combinations of fine and coarse aggregate to study the effect of shape, surface texture, fine coatings, strength, and maximum size other properties on water requirement and strength of concrete. The results showed that at equal water-cement ratio, irregular shaped smaller sized aggregates without coatings, and those of higher concrete strength. Also according to the same report, depending on circumstances such as richness of concrete mix, individual properties of the particular aggregates and the magnitude of the size difference, and increase or decrease in concrete strength at a fixed cement content.

Stantom and Bloem(1960) reported that at different water-cement ratio, strength levels prevail for the maximum sizes. Without exception, the level increased with reduction in maximum size. This implies that at same water-cement ratio, there is always a reduction of strength of concrete as the maximum size of aggregate increases. The presence of clay or crush dust, or silt or rather generalizing; presence of over coatings of aggregates is not surprising because it interferes with the bond between the aggregates and cement paste. Another fine material which may be present on a coating on aggregates is silt. Silt possesses some tendencies similar to that of clay and it may undergo like clay, considerable shrinkage and expansion when exposed to changes in moisture content. Clay, silt, crush and dust should not be in excess on aggregates so as not increase the amount of water necessary to wet all particles in the mix.

The IPRF (Innovative Pavement Research Foundation) report on the effect of micro fine coatings hinders the development of a good bond thereby reduces the compressive strength of concrete and at the same time increases the shrinkage of the concrete. Aggregates are also to be seen as anti-crackers in concrete because of its great function in bonding. They can be as the skeleton of concrete. Consequently, an excess amount of organic materials in or on the aggregates prevents cement paste from forming and adequate bond with aggregates particles. According to an online article in press, the effect of coarse aggregate size on concrete under compression shows that the concrete strength slightly increases when at low confinement. At high confinement, the coarse aggregates size has a slight influence on concrete deviatory behavior and a significant influence on concrete strain limit state.

In conclusion, the higher the coarse aggregates size, the lower is the mean stress level corresponding to concrete strain limit state. Cement paste volume also has effect on concrete behavior. Otherwise decreasing cement paste volume increases concrete deformation capacity. Since this work deals mostly with the determination of variations that exists on compressive strength of concrete casted on different days, it then becomes necessary to analyze some factors which generally affect the strength of concrete as well as some properties of concrete, and also the effects of size of coarse aggregates on concrete.

2.2.3 LIMITATIONS OF CONCRETE

1. Concrete is quasi-brittle
2. Concrete has low toughness
3. Concrete has low specific strength
4. Formwork is required
5. Long curing time
6. Demands strict quality control
7. Relatively low tensile strength when compared to other building materials
8. Low Duct ability
9. Low strength to weight ratio
10. It is susceptible to cracking

2.3 CLASSIFICATION OF CONCRETE

Based on unit weight:

1. Ultra-light concrete	$< 1,200$ kg/m^3
2. Lightweight concrete	1200- 1,800 kg/m^3
3. Normal-weight concrete	2,400 kg/m^3
4. Heavyweight concrete	$> 3,200$ kg/m^3

Based on strength:

1. Low-strength concrete	< 20 MPa compressive strength
2. Moderate-strength concrete	20 -50 MPa compressive strength
3. High-strength concrete	50 - 200 MPa compressive strength
4. Ultra high-strength concrete	> 200 MPa compressive strength

2.4 PROPERTIES OF CONCRETE

To obtain a good quality concrete, its properties in both fresh and hardened states play important rules.

Properties in Fresh State Include

1. Workability
2. Segregation
3. Bleeding
4. Hardness

The properties in hardened state include

1. Strength
2. Durability
3. Impermeability
4. Dimensional change

2.5 Workability of Concrete

Workability of concrete is a broad and subjective term describing how easily freshly mixed Concrete can be mixed, placed, consolidated and finished with minimal loss of homogeneity .ASTMC 125-93. Workability is a property that directly to impact strength, quality, appearance, and even the cost of labor for placement and finishing operation.

Types of workability of concrete

According to the American Concrete institute (ACI) standard 116R-90(ACI 1990), Workability of concrete can be classified into three types

1. **Unworkable Concrete:** An unworkable Concrete also known as harsh Concrete, is a concrete with a very little amount of water. The hand mixing of such Concrete Is difficult, such type of concrete had high segregation of aggregates and it is very difficult to maintain the homogeneity of Concrete mix.
2. **Medium workable Concrete:** Medium workable Concrete is used in most of the construction works. This Concrete is relatively easy to mix, transport, place and compact without much segregation and loss of homogeneity.
3. **Highly workable Concrete:** This type of concrete is very easy to mix, transport, place and compact. It is used where effective compaction of concrete is not possible. The problem is that they are high chances of segregation and loss of homogeneity in highly workable Concrete.

The desirable Workability depends on two factors which are the section sizes, amount and spacing of reinforcement and the method of compaction.

2.6 Strength of Concrete

The strength of concrete is the most important property for us. It depends on density ratio or compaction and compaction depend on sufficient Workability BSI (1983), part 108. The different types of concrete strength are;

1. **Compressive strength:** It is widely accepted measure to access the performance of a given concrete mixture. It accurately tells you whether or not a particular mix is suitable to meet the requirements of a specific project.

2. **Tensile strength of concrete:** The tensile strength of concrete is its capacity to resist cracking or breaking under tension. Although Concrete is rarely loaded under pure pressure in a structure, determining the tensile strength is necessary to understand the extent of the possible damage. Breaking and cracking arise when tensile forces surpass the tensile strength.
3. **Flexural strength of concrete:** Flexural strength establishes the ability of concrete to withstand bending. It is an indirect measure of tensile strength. The Flexural strength of concrete is usually determined by testing a simple beam where the concentrated load is applied at each of the third points. The numbers are expressed in a modulus of rupture (MR) in psi.

2.6.1 Factors Affecting the Strength of Concrete

The strength of concrete is usually affected by many factors, in this project work; such factors are discussed with particular reference to the compressive strength. The factors include:

Cement

The influence of cement on concrete strength, for a given mix proportion is determined by its fineness and chemical composition through the process of hydration. Generally, cement can be described as a material with adhesive and cohesive properties which make it capable of bonding mineral fragments into a compact whole. For construction purposes, which are the case in this project work, the term cement is restricted to the bonding material used with stones, sand, bricks and building blocks. The gain in strength as the fineness of its cement particles increases cannot be underestimated. The gain in strength is most marked at early ages and after 28days the relative gain in strength is much reduced.

The role of the chemical composition of cement in the development of concrete strength can always be appreciated. It is apparent that cement which contain a high percentage of tricalcium silicate (Ca3S) gain much more strength rapidly than those rich in dicalcium silicate (Ca2S). The sulphate resistance of concrete can be improved by the use of sulphate resisting cement which has low tricalcium Aluminates content.

However, there is a tendency for concretes made with low- heat cements eventually to develop slightly higher strengths. This is possible due to the formation of a better quality gel structure in the course of hydration. Because we are in the tropics, low heat cements best advisable to use in concreting. This is because the heat evolved during the cement hydration process needs to be reduced. The use of low heat cement can minimize this effect. However, most (OPC) ordinary Portland cements we use are (LH) i.e. Low heat cement. The specification for Portland cement is the BS 12:1991 of the British standard.

Water

A concrete mix containing the minimum amount of water required complete hydration of its cement, if it could be fully compacted, would develop the maximum attainable strength at any given age. Water plays a critical role, particularly the amount used. The strength of concrete increases when less volume of water is used to make it. The hydration reaction itself consumes a specific amount of water. A water-cement ratio of approximately 0.25 (by weight) is required for full hydration of the cement but with this water content normal concrete mix would be extremely dry and virtually impossible to compact. Concrete is actually mixed with more water than is needed for the hydration reaction.

This extra water is added to give concrete sufficient workability. Flowing concrete is desired to achieve proper filling and composition of the forms. The water not consumed in the hydration reaction will remain in the micro- structure pore space. Adequate compaction will then be introduced to reduce the pore space. A partially compacted mix will contain a lot of voids and subsequently or rather consequently the concrete strength will drop. On the other hand, while placing and compacting, water in its excess for full hydration would consequently produce some porous structure resulting from loss of excess water. Consequently, in practice if the ratio of water to cement increases the strength of that particularly concrete decreases. (BS EN 1008:2002 specifies-Mixing specification for water in concreting).

Aggregate

Aggregate is an important ingredient in concrete, which can be regarded as the skeleton of the concrete. The aggregate must have a minimum inherent strength requirement for structural concrete; the coarse aggregate must not be weaker than the concrete paste. Therefore, the bond between aggregate and cement paste is an important factor in the strength of concrete. The discussion of the aggregate as a factor that affects the strength of concrete will be based here on shape, surface texture, grading, size and strength of the aggregates. When a concrete mass is stressed, failure may originate within the aggregate, the matrix or at the aggregate-matrix interface; or any combination of these may occur.

The aggregate-matrix interface is an important factor determining concrete strength. Bond strength is influenced by the shape of the aggregate, its surface texture and cleanliness. Surface texture is generally only considered in relation to concrete flexural strengths, which are frequently found to reduce with increasing particle smoothness. However, inadequate surface texture can similarly adversely affect compressive strength in high strength concrete (say 50N/mm^2) when the bond with the cement matrix may not be sufficiently strong to enable the maximum strength of the concrete can be realized. Bonding mostly is due, in part, to the interlocking of aggregates and the paste owing to the roughness of the surface of the former.Coating of impurities, such as silt, clay and oil, on the aggregate surface hinders the development of a good bond. Aggregates with micro fine coatings hinder the development of a good bond thereby reducing the compressive strength of concrete and at the same time increasing the shrinkage of concrete.The size of aggregate also affects the strength of concrete. As the maximum size of aggregate is increased, the concrete strength decreases for a particular mix proportion. But invariably, in concrete works, the bigger or larger the aggregate size for a particular size of project the stronger the concrete required for the project.

The optimum maximum aggregate size varies with the richness of the mix, being smaller for the less rich mixes. Generally aggregate sizes lies between 10mm and 50mm in accordance with BS 812: part 1/1975.Good concrete can be made by using different types of aggregates (considering shapes) like rounded and irregular gravel and crushed rock which is mostly angular in shape. The grading of aggregates is a major factor, influencing the workability of a concrete mix. The grading should be such as to ensure that the voids between the larger aggregates are filled with smaller fractions and mortar so as to achieve maximum density and strength. The coarser and finer fractions of aggregates available at site can be suitably combined to obtain the desired standard grading. Aggregates which react with alkali content of cement adversely affect concrete strength.

Aggregates containing some forms of silica will react with alkali hydroxide in concrete to form a gel that swells as it absorbs water from the surrounding cement paste or the environment. These gels can swell and induce enough expansive pressure to damage concrete. Typical indicators of Alkali- silica Reaction (ASR) are random map cracking and, in advanced cases, closed joints and attendants spalled concrete. Cracking due to ASR usually appears in areas with a frequent supply of moisture, such as close to waterline in piers, near the ground behind retaining walls, near joints and free edges in pavements, or in piers or columns subject to wicking action. Petro graphic examination can conclusively identify ASR. ASR can be controlled using certain supplementary cementitious materials like silica fume, fly ash, and ground granulated blast-furnace slag in proper proportions. There also exists Alkali Carbonate Reactions (ACR), but is relatively rare.

It is common practice in Nigeria for construction to be carried out using locally founded aggregates of different sizes i.e. 8mm, 12mm and 14mm. This project engulfs the attainment of the functionality of locally found coarse aggregates of different sizes casted on different dates. The core functions which will aid this work are strength and economy. The specified standard and requirements available in recent times are based on materials which are from different sources and bearing in the fact that no two materials which are from different sources behave like, it is mostly likely they share the same properties but differs.

2.6.2 Classification of Aggregates

1. **Artificial aggregates:** They are manufactured industrial products. They are generally lighter than ordinary aggregates. The uses of these artificial aggregates arise not just from its light weight properties but because in many countries, there is a shortage of naturally occurring aggregates.

2. **Natural aggregates:** They are naturally occurring i.e. they are fond naturally. Distinction can be between aggregates reduced by natural agents to its present size and crushed aggregates obtained by deliberate rock fragmentation.

Fine aggregates either occur naturally in deposit distribution to some privileged locations over the earth surface or could be delivered by the reduction of some larger gravel to smaller sizes in quarry plants. Locally found fine aggregates are:

1. **River sand:** Sand deposits in river beds obtained by dredging or by locally divers scooping from the river beds up to the collection boats. River sand in Awka locality is often gotten from Amansea River. River sand is used in making concrete works, sandcrete and concrete blocks.
2. **Fine sand:** This is often used in rendering or plastering and mortar making. When these aggregates pass through sieve, they are usually of 0.06 - 0.6mm.
3. **Laterites:** This is used as filling sand or backfill for foundations and road basement

COARSE AGGREGATE

Coarse aggregates are irregular broken stone or naturally occurring gravel used in construction. The aggregate which will get retained on a 4.75mm sieve or the aggregate which have size more than 4.75mm are known as Coarse aggregate. They are commonly obtained by crushing the naturally occurring rocks. Aggregates are mainly classified into two types which are fine aggregates and coarse aggregates. The aggregates which are used in the construction must be durable, hard and strong, should not be soft and porous, must be free from the dust and organic materials and should be chemically inert. Aggregates are use in construction for even distribution of load and to increase the volume of concrete. Coarse aggregates are classified based on the nature or source of formation, according to size and according to shape.

Naturally occurring aggregates are obtained from the stone quarries and the stone crushers. Natural aggregate materials originate from bedrock. Artificially manufactured aggregates are gotten from the broken brisk or blast furnace slag. The air cooled slag is also used as a coarse aggregate. Coarse aggregate can come in different shapes which include rounded aggregates, angular aggregates, flaky aggregates and irregular aggregates. The properties of the coarse aggregate include size, shape, surface texture, water absorption, soundness, specific gravity and bulk modulus.

2.7 Water/Cement Ratio

The water-cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix. (Abrams, (1918) A lower ratio leads to higher strength and durability but may make the mix difficult to work with and form. Workability can be resolved with the use of plasticizer or super plasticizer. Often, the ratio refers to the ratio of water to cementitious materials, W/cm. Cementitious materials include cement and supplementary cementitious materials such as fly ash, ground granulated blast furnace slag, silica fume, rice husk ash and natural pozzolans (Duff, 1997).

Coarse and fine aggregates ratio

The maximal fine to coarse aggregate ratio described in ACI544.3R-2008is 0.6. Coarse and fine aggregate comprises almost 75%of total concrete volume, therefore, balancing the usage of fine aggregate and coarse aggregate plays vital role in determining the performance and quality of the concrete.

Aggregate/ cement ratio

Aggregate cement ratio is the ratio of weight of aggregate to the weight of cement. When the weight of cement is less, i.e. aggregate cement ratio is more, and then there will be very less cement paste to coat aggregate surfaces and fill the voids, thus mixing, placing and compacting of concrete will be higher than previous case.

2.7.1 Age of Concrete

Concrete increase in strength with age when moisture is available. This is initially greatest but progressively decreasing over time. The rate will be affected by cement type, cement content and internal concrete temperature. Moisture content of concrete also affect the age of concrete where by dried concrete immediately exhibits high strength due to the drying process but will not gain strength thereafter unless returned to and maintained in a moist condition.

2.7.2 Compaction of concrete

Compaction is the process which expels entrapped air from freshly placed Concrete. Compaction also allows the fresh Concrete to reach its potential design strength, density and low permeability. The different methods of Compaction of concrete are Manual compaction, Concrete compaction by pressure and jolting, concrete compaction by spinning and mechanical compaction by vibration. The four types of vibrators commonly used for Concrete compaction are

1. Internal vibrators
2. Form vibrators
3. Surface vibrators
4. Vibrating Tables

2.8 Curing of Concrete

Curing of concrete is a method by which the concrete is protected against loss of moisture required for hydration and kept within the recommended temperature range. (Agbede and Manasseh, 2008; Wazin, et al, 2011).Generally speaking, the longer concrete is kept under curing condition the greater its strength. The gain of strength during curing depends on a number of factors such as relative humidity, wind velocity and size of structural member or test specimen. The temperature at which concrete is cured is also an important factor in the development of its strength with time. It has been suggested that the strength of concrete can be related to product of age and curing temperature, commonly known as maturity. Curing will increase the strength and decrease the permeability of hardened Concrete. Curing also helps in mitigating thermal and plastic cracks

2.8.1 Shrinkage of Concrete

Shrinkage is the phenomenon which occurs in wet concrete when it loses moisture and invariably loses volume. It can be of two kinds: plastic shrinkage and drying shrinkage. Drying shrinkage in concrete is caused by loss of moisture in the paste. It is influenced by a variety of factors, which includes: environmental conditions (temperature and relative humidity), size of member (surface area to volume ratio), and etc. On the other hand plastic shrinkages result from surface evaporation due to environmental conditions such as humidity, wind speed or ambient temperature and restrained stresses.

In reinforced concrete structures, the restrains may be caused by the reinforcement bars or by supports. Shrinkages show as miniature cracks on the concrete surface. Concrete swells under moist conditions, but shrinks when there is change in volume by shrinkage or restrained stresses, as the case may be.

2.8.2 Creep in Concrete

Compressive strength is set up in concrete because of development of the menisci in the capillaries as drying of concrete progresses. These stresses transform to stresses we can see on the concrete surface as cracks. Creep of concrete develops gently and slowly. Creep of concrete results from the action of sustained stress which graduates into gradual increase to strain in time; it can be of the same magnitude as drying shrinkage. Creep does not include immediate elastic strains caused by loading or shrinkage or swelling caused by moisture changes. When a concrete structural element is dried under load that which occurs is one to two times as large as it would be under constant moisture conditions. Adding normal drying shrinkage to this and considering the fact that creep can be several times as large as the elastic strain on loading, it may be seen that these factors can cause considerable deflection and that they are of great importance in structural mechanics.

If a sustained load is removed, the strain decreases immediately by an amount equal to the elastic strain at given age; this is generally than the elastic strain on loading since the elastic modulus has increased in an intervening period. This instantaneous recovery is followed by a gradual decrease in strain, called creep recovery.There are numerous factors that affect creep in concrete as well as shrinkage. Relative humidity is first; when hydrated cement is completely dried, little or no creep occurs; for a given concrete the lower the relative humidity the higher the creep.

Second factor is the strength of concrete.

It has a considerable influence on creep within a wide range creep is inversely proportional to the strength of concrete at the time of load application. From this it follows that creep is closely related to water-cement ratio Modulus of elasticity of aggregates is the fourth factor that affect or influence creep in concrete. It is realized that concretes made with different aggregates exhibit creep in varying magnitudes. The fifth factor is age. Experiments have shown that creep for a very long time; detectable changes have been found after as long as 30years.The rate decreases continuously, however, and it generally assumed that creep tends to a limiting value.

The effects of creep on concrete cannot be underestimated .Creep hastens the approach of limiting strain at which failure takes place.

The influence of creep on the ultimate strength of a simply supported, reinforced concrete beam subjected to a sustained load is insignificant, but deflection increases considerably and in many cases may be a critical consideration in design. Another instance of the adverse effects of creep is its influence on the stability of the structure through increase in deformation and consequent of loads to other components. The loss of pre-stress concrete due to creep is well known and accounted for the failure of early attempts at pre-stressing. Only with the introduction of tensile steel did pre-stressing become a successful operation. The effects of creep may thus be harmful. On the whole, however, creep unlike shrinkage is beneficial in relieving stress concentrations and has to the success of concrete as a structural material.

2.8.3 Bleeding

In concrete, bleeding is a phenomenon in which free water in the mix rises up to the surface and forms a paste of cement on the surface known as laitance. Bleeding occurs in concrete when coarse aggregates tend to settle down and free water rises up to the surface. This upward movement of water while traversing from bottom to top makes continuous channels. These continuous bleeding channels are often responsible for permeability in structure. In the process of upward movement, the water gets accumulated below the aggregate and creates water void and reduces the bond between the aggregates and the paste.

Bleeding is a type of segregation, in which water comes of concrete. Segregation is the cause of bleeding in the concrete mix. Bleeding will be more frequent on the surface of concrete, when water to cement ratio is higher. The type of cement used, quality of fine aggregate also plays a key role in rate of bleeding. The effect of bleeding is that concrete losses its homogeneity and it is also responsible for causing permeability in concrete. Bleeding in concrete can be reduced by adding a minimum water content in the concrete, use chemical admixture to reduce demand to water for a required workability. Also the use of a proper design mix and fly ash or supplementary cementitious materials can reduce bleeding in concrete.

Influence of test conditions

The condition under which tests to determine the strength of concrete are carried out can have a considerable influence on the strength obtained and it is important that these effects are understood if test results are to be correctly interpreted.

Specimen shape and size

These are commonly used shapes for the compressive strength of concrete determination namely cubes cylinder and prism. Each shape gives different strength results. Also for a give shape, it varies in size. From the test conducted by Neville A. M.1963, based on specimen shape and size influence, it was found out that as size increases, the apparent strength increases. Also pertaining to their findings, height diameter ratio [for cylinder test] affects compressive strength. The specimens with lesser height diameter ratio came out with higher compressive strengths compared with the specimen with higher height diameter ratio. BS 1881 Part 116 specified the use of concrete cubes for determining compressive strength and quality control purposes, while

BS 1881 part 120 specifies cored cylindrical specimens for measuring the compressive strength in-situ and pre-cast members.

Method of loading

The compressive strength of concrete increases as the lateral pressure in concrete increases. The rate at which concrete is loaded affects the apparent strength of the Concrete. Generally, for static loading, the faster the loading rate the higher the indicated strength. High strength matured concrete cured in water are most sensitive to loading rate and particularly so for loading rates greater than 600N/mm^2/min.BS 1881: Part 4 requires concrete in compression test to be loaded at 15N/mm2/min while for flexural strength is 18N/mm2/min.

Placing and compacting of concrete

The operations of placing and of compacting of concrete are independent and are carried out almost simultaneously as they are most important for purpose of ensuring the requirements of strength, impermeability and durability of hardened concrete in the actual structure. The placing of concrete has to do with the direct introduction of concrete mix in the formwork. A good workable concrete with target class S3 (>100mm<150mm) is desirable for placing concrete in the formwork and around reinforcement, whether by skip or by pump.

Stiff mixes are difficult to place and compacting and most times consequently result in honey combing on concrete. In small scaled concrete works, concretes are normally placed with head pans and wheelbarrows. But in large scaled concrete works, concrete is often placed with skips from cranes and concrete pumps. Although some concrete are self-compacting, compacting is highly essential in concreting. It is used to eliminate the major air voids between aggregates in wet concrete. Compaction aids in achieving concrete with strong outcome. With adequate water-cement ratio administered in concreting, definitely a strong concrete will be result after compaction, devoid of honey combs, sand scouring, etc.

2.10 Crushing Strength

The crushing strength of concrete is influenced by a number of factors in addition to water cement-cement ratio and degree of compaction. The more important ones are:

1. **Cement type and quality**: The rate of strength gain and the ultimate strength may be affected. OPC cement concretes when prepared well and cured adequately can possess more compressive strength than RPC (Rapid Hardening Portland Cement).On the other hand, concretes whose qualities have been upgraded, that is, added admixtures like plasticizers or Retarders can bear more strength than ordinary concrete without admixture.
2. **Temperature**: Initial rate of hardening concrete is generally induced/ increased by an increase in Temperature but may lead to lower ultimate strength. At low temperature, the crushing strength may remain low for some time, particularly when cements of lower strength gain are used, but invariably may lead to higher ultimate strength.
3. **Efficiency of Curing**: A loss of strength of up to 40% may result from premature drying out. The method of curing concrete test cubes given in BS 1881: Part 3, 1983 should be strictly adhered to. Concrete properly cured is stronger and less susceptible to chemical attack, water tight and traffic wear.
4. **Type and Surface Texture of Aggregates**: This is considerable- to suggest that some aggregates produce concrete of greater compressive strength and tensile strength than others. This is as a result or consequence of type, surface texture, chemical properties, e.t.c.

5. **Moisture Content**: Concrete dried immediately exhibits high strength due to the drying process but will not gain strength thereafter unless returned to and maintained in a moist condition. Notably, dry concrete will exhibit a reduced strength when moistened thereafter.

2.11 Citations of Previous Works

Walker and Bloem (1960) studied the effect of coarse aggregates on the compressive strength of concrete. This work demonstrates that an increase in aggregate in a concrete mix increases the strength of the concrete. The study also shows that the flexural to compressive strength ratio remain at approximately 12 percent for concrete with compressive strength between 35 MPa (5100 psi) and 46 MPa (6700psi).

Ruiz (1966) in research on the effect of aggregate on the behaviour of concrete found out that the compressive strength of concrete increases along with an increase in coarse aggregate content. The increase is due to the reduction in the voids with the addition of aggregates.

Giaccio, Rocco, Violini, Zappitelli, and Zerbino (1992) studied the effect of coarse aggregate on the mechanical properties of high strength concrete.

Maher and Darwin (1976,1977) observed that the bond strength between the interfacial region and aggregate plays a less dominant role in the compressive strength of concrete than generally believed. Finite element model were used to evaluate the effect of matrix aggregate bond strength on the strength of concrete

2.12 Summary

The need for conducting the compressive test on concrete is to determine the strength of concrete cast on different dates and also to determine the necessary steps and from aggregate to avoid the use of substandard aggregate materials that might contribute to failure of structures and also to determine whether a given concrete mixture will meet the needs of a specific job. Compressive strength test also gives an idea of the overall strength of concrete and quality of a concrete produced.

CHAPTER THREE

3.0 MATERIALS AND METHOD

The objective of the preliminary test was to determine some physical properties of the concrete constituents and materials used in this work. These include the particle size distribution of fine

3.1 MATERIALS

The following concrete constituent materials and equipment were used during the process of carrying out this project. Since the investigation was on coarse aggregate, 3 different coarse aggregates were used while that of fine was one only.

Coarse aggregate

Aggregates used in this project (coarse) were made of three different sizes. The coarse aggregates were washed thoroughly with water to remove any impurity or dirt therein and then it was sun-dried to obtain saturated dry surface condition to ensure that the water-cement ratio is not affected. Some properties of coarse aggregates which affect the workability and bond between concrete matrixes are shape, texture, gradation and moisture content. The coarse aggregate size used was 10mm, 16mm and 25mm.

Fine aggregate

The fine aggregate used was dry river sand from Amansea River. The soil sample was thoroughly washed with clean water to remove any debris, organic matter and impurities present in the sand and then sun dried to obtain a dry surface condition and ensure that the water cement ratio is not in any way affected.

Cement

Ordinary Portland cement (Dangote Brand) was used for this work.

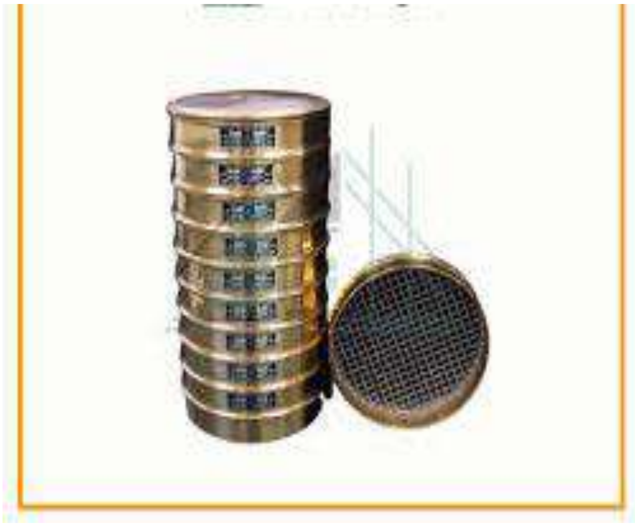
Water

The water for all the purpose in this work is fresh clean water gotten from the civil engineering laboratory water tank, which was clear, clean in appearance and without damaging amounts of oil, acid, salt, organic material and other substances that may impact the resistance of the concrete.

METHODOLOGY

3.3.1 Sieve Analysis

Sieve analysis is referred to as the simple operation of separating a sample of aggregate into fractions (groups), each consisting of particles of the same size. In practices, each fraction contains between specific limits, these being openings of standard test sieves. It is also shown graphically on particle size distribution curve for the purpose of obtaining the grade of the aggregate. The main aim is to determine the various sizes of particles present in aggregates.



Apparatus

In the analysis, the following apparatus were used:

1. B.S test sieves of different sizes complying with the requirements of B.S 410, full tolerance
2. A weighing balance
3. Metal brush
4. Stop watch
5. Plate

Procedure

1. The fine aggregate samples were collected in a suitable quantity. Note: the larger the particle size, the quantity required.

2. The aggregate were dried and kept free from moisture and was also protected from containing any lumps.
3. The sample is sieved through a 5mm sieve; the portion retained on the sieve was discarded while those passing through were used for the particle size analysis.
4. The sample gotten from the 5mm sieve is placed in the top sieve and the set of sieves is kept on a mechanical shaker and the machine is started.
5. The machine is allowed for 10 minutes of shaking for sufficient particles to pass.
6. The mass of the samples retained on each sieve and on pan is obtained to the nearest 0.1gm.
7. The mass of the retained aggregate is checked against the original mass.
8. A graph is plotted to ascertain the grade of samples.

3.4 PRODUCTION OF CONCRETE

Batching

Batching is the process measuring ingredients or materials to prepare concrete mix. Batching can be done of two methods, volume batching and weight batching. Batching should be done properly to get quality concrete mix. Batching by Weight is considered to be more accurate than volume batching hence; batching was done by weight for the Purpose of this work. As much as possible, there would always be variation in the proportion of voids in the aggregates; volume batching therefore is considered as not being very reliable and accurate for the test. Method of batching adopted in this work was based on the calculation of the necessary number of specimen to be cast for each of the coarse aggregate. The moulds used were of each of the dimensions and so their volume could be calculated.

3.4.1 Mix Design

The concrete mix design adopted for this research is as stated below; the design was adopted based on the availability of the material and also the aim of the experiment.

Density of concrete = 2400Kg/m^3

Volume of cube sample = 150mmx150mmx150mm =3375cm^3 =3375cm^3/100^3 =3.375x10-^{3}m^3

Density =mass/volume

Where mass =2400kg/ m^3 x0.003375 m^3 = 8.1Kg

Using mix ratio = 1: 2: 4 =1+2+4+0.45 = 7.45

W/C= W/1.16 =0.45 = W=1.16 x 0.45= 0.522kg =522ml.

Cement =10x 1.16Kg =11.6kg

Fine aggregate=10 x 2.3Kg =23kg

Coarse aggregate=10x 4.6Kg=46kg.

Concrete characteristic Strength, Fcu at 28 days = 30 MPa

3.4.2 Mixing of concrete

The process of mixing was performed on the floor of the concrete technology laboratory by hand using trowel. After weighing out the various quantities of materials, the cement and the fine aggregate were first mixed under dry condition until the mixture became thoroughly blended, then the coarse aggregate was introduced, mixed with the already mixed cement and sand until the mix becomes uniformly distributed throughout the batch. As the mixing process continued the quantity of water calculated for was carefully and gradually added. The mixing proceeded until a homogeneous concrete mix appears and the desired consistency emerged.

3.4.3 Casting of Concrete

The moulds used for the casting was 150mmx 50mmx150mm. Before the casting operation was carried out, the moulds were properly cleaned and inside oiled with used engine oil (as releasing agent) to ensure easy de-molding operation. The concrete in the mould were filled in three layers approximately 50mm thick with the Concrete (that is, about 50mm depth). Adequate compaction by hand was done using a standard steel tamping rod; each layer was compacted with at least 25 strokes per layer using the tamping rod before the cube mold is fully filled up with concrete and then compact completed. The trowel was used to give smooth finish on the surface after casting.

3.5 Workability of Concrete

Workability of concrete has never been precisely defined. Practical purpose it generally implies the case with which concrete mix can be handled from the mixer to its final compacted shape. The three main characteristics of the property are consistency, mobility and compatibility.

Consistency is a measure of wetness or fluidity .Mobility defines the ease with which a mix can flow into and completely fill the mould or formwork. Compatibility is the ease with which all trapped a given mix can be fully compacted to remove all air. Four tests are widely used for ensuring workability such as slump tests, compacting factor, and time and flow test. But for the purpose of this research, slump test was used.

3.5 Slump Test

Slump test is used for the measurement of a property of fresh concrete. The test is an empirical test that measures the Workability or flow of fresh concrete. ASTM C143 More specifically, it measures Consistency between batches. The slump test is used to ensure uniformity for different batches of similar concrete under field conditions.

Apparatus

1. A truncated slump cone: height =300mm Tamping Rod
2. Measuring Tape

3. Trowel
4. Base plate
5. Brush

Procedure

A freshly mixed concrete with water-cement ratio of 0.5 was made. The following steps were undertaken to carry out the slump test:

1. The cone was placed on the flat form tray in a position such that the wider surface is on the form.
2. The cone was filled in 3 layers of equal height with trowel giving each layer 25 stokes or taps.
3. After leveling and smoothing the top of the concrete and clearing around the cone of any dropping, the cone was lifted upright with two hands.
4. After pulling the cone, it was placed close to the concrete without applying any vibration or jointing round plat form.
5. The sprit level was trace on top of the cone to span across the concrete.
6. The measuring tape was then place perpendicular to the straight edge and lowered to the top of the slump concrete.
7. The difference in height between the top of the cone and the top of the slumped concrete was then measured and recorded.

3.6 Curing of Concrete

After the casting, proper identification marks were given showing time interval and the type of coarse aggregate used. Then the concrete moulds were left in the laboratory for 24 hours. It was left uncovered because the relative humidity of the period was fairly high since it was done during the rainy season. The cube were demoulded after 24 hours and then transferred into the curing tank.

3.7 Compressive Strength Test

The compressive strength test was carried out using the compressive strength test machine as find in the test method BS 1881 part 116, 1983. An increasing compressive strength was introduced to the cube specimen until failure occurred to obtain the maximum compressive load. The specimen dimension was taken before testing. The testing was carried out for 7, 14, 21 and 28 days after curing.

$$\text{Compressive strength} = \frac{Compressive\ Load, P\ (KN)}{Surface\ Area, A\ (mm^2)} \qquad (1)$$

Procedure

1. Remove the specimen from water after specified curing time and wipe out excess water from the surface.
2. Take the dimension of the specimen to the nearest 0.2m.
3. Clean the bearing surface of the testing machine.
4. Place the smoothest side of the specimen in the machine in such a way that the loads shall be applied to the opposite sides of the cube.
5. Align the specimen centrally on the base plate of the machine.
6. Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
7. Apply the loads gradually without shock and continuously at the rate of 140Kg/cm/minute till the specimen fails.

Record the maximum load and note any unusual features in the type of the failure.

CHAPTER FOUR

4.0 RESULTS AND ANALYSIS OF ALL TESTS

SIEVE ANALYSIS (PARTICLE SIZE DISTRIBUTION OF FINE AGGREGATE)

TABLE 4.1

Weight of sample=500gms

Sieve size (m)	Weight retained (g)	% weight retained	Cumulative weight retained (%)	Cumulative weight passing (%)
4.75	4.63	0.926	0.926	99.070
2.00	8.82	1.764	2.690	97.310
1.80	16.23	3.226	5.916	94.084
0.85	20.30	4.060	9.976	90.024
0.60	49.74	9.948	19.924	80.076
0.45	91.81	18.362	38.286	61.714
0.30	154.01	30.802	69.088	30.912
0.15	142.84	28.568	97.656	2.344
0.075	10.30	2.060	99.716	0.284
Plate	1.42	0.284	100.00	1.000
Total	500			

PARTICLE SIZE DISTRIBUTION OF COARSE AGGREGATES

TABLE 4.2

Weight of test sample=1250gms

Sieve sizes (mm)	Weight retained (g)	% weight retained	Cumulative % passing	Cumulative % retained
54.40			100.00	
25.40	5.00	0.40	99.60	0.40
16.52	380.00	30.40	69.20	30.80
9.52	570.75	46.14	23.06	76.94
4.76	283.75	22.70	0.36	99.64
Plate		0.36	0.00	100.00
Total	1250			

SLUMP TEST RESULTS

Table 4.3

Mix size	Mix Ratio	Height of cone	Height of slump Concrete	Slump value
10mm	1:2:4	300mm	203mm	92mm
16mm	1:2:4	300mm	205mm	93mm
25mm	1:2:4	300mm	207mm	95mm

DETERMINATION OF THE COMPRESSIVE STRENGTH OF CONCRETE TEST RESULTS FOR COARSE AGGREGATE OF SIZE 25mm

Table 4.4

Specimen	Age of Curing (Days)	Area of Specimen (150mm by 150mm)	Weight of Specimen (kg)	Average Test load (KN)	Mean compressive strength (N/mm^2)
B11	7	150	8.4	582.5	17.43
C11	14	150	8.3	630.28	18.60
D11	21	150	8.4	690.35	20.99
E11	28	150	8.5	756.30	21.99

DETERMINATION OF THE COMPRESSIVE STRENGTH OF CONCRETE TEST RESULTS FOR COARSE AGGREGATE OF SIZE 16mm

Table 4.5

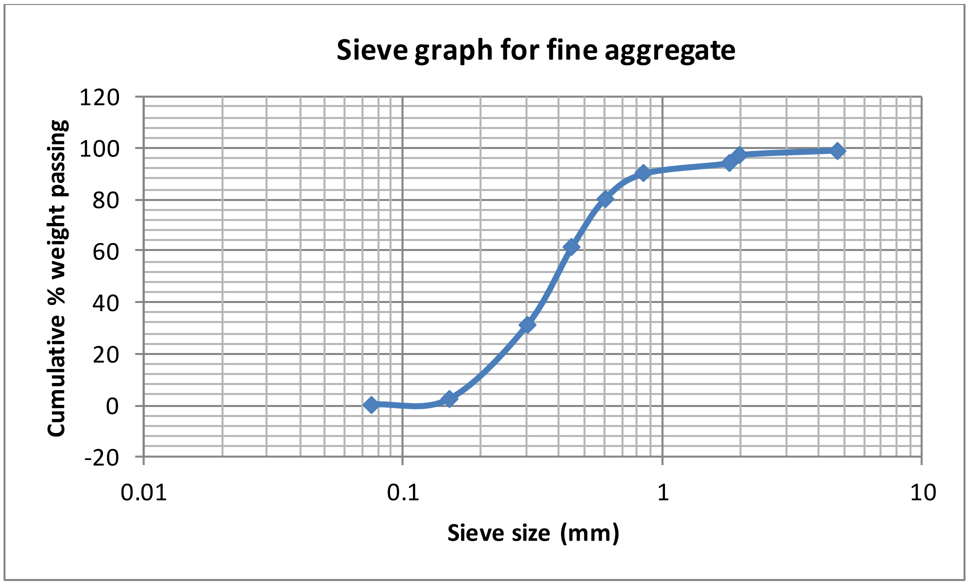
Specimen	Age of curing (Days)	Area of specimen (150mm by 150mm)	Weight of specimen (kg)	Average Test Load (KN)	Mean compressive strength (N/mm^2)
B11	7	150	8.4	642.67	19.62
C11	14	150	8.5	666.90	20.03
D11	21	150	8.4	774.85	23.67
E11	28	150	8.3	801.00	24.02

DETERMINATION OF THE COMPRESSIVE STRENGTH OF CONCRETE TEST RESULTS FOR COARSE AGGREGATE OF SIZE 10mm

Table 4.6

Specimen	Age of curing (days)	Area of specimen (150mm by 150mm)	Weight of specimen (kg)	Average test load(KN)	Mean compressive strength (N/mm^2)
B11	7	150	8.8	320.40	14.02
C11	14	150	8.7	356.76	15.20
D11	21	150	8.7	380.00	16.78
E11	28	150	8.9	426.06	18.05

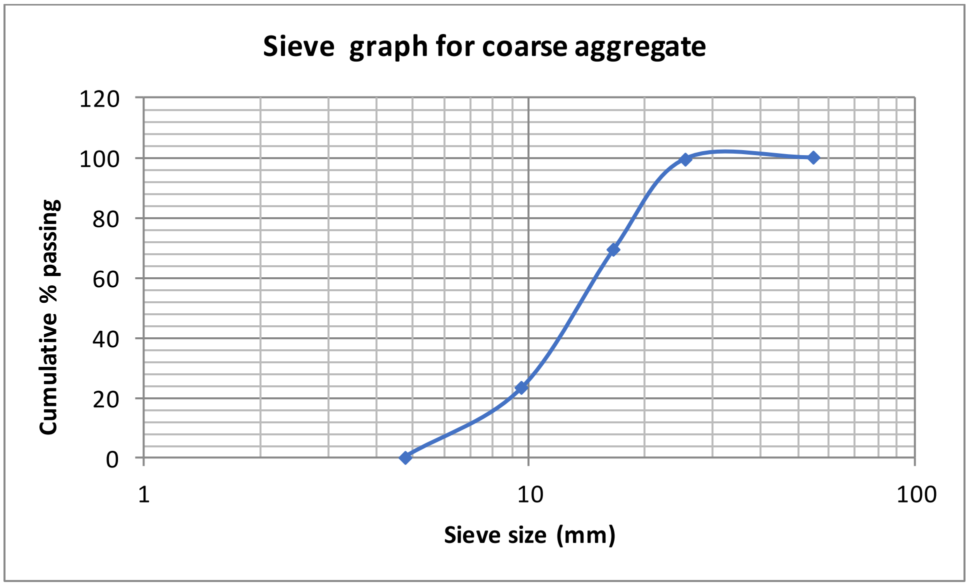
Figure 1 fine aggregate sieve analysis graph



Aggregate Analysis (Fine Aggregate)

The result of sieve analysis from figure 4.1 clearly show the grade distribution of fine aggregate from the graph deduced from the table. It is seen that the aggregate is of uniform fine grading.

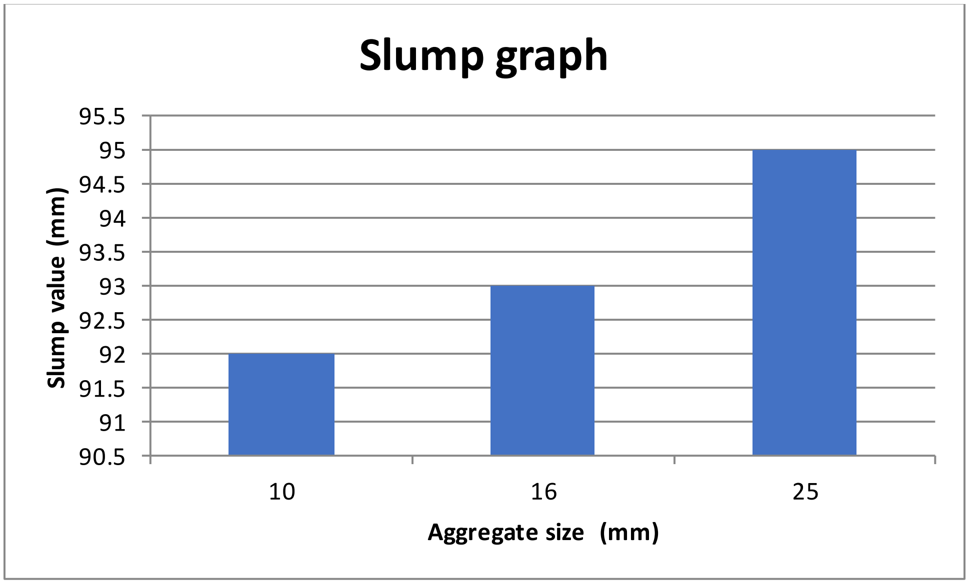
Figure 2 coarse aggregate sieve analysis graph



Aggregate Analysis (Coarse Aggregate)

The result of the test of the coarse aggregate from the graph shows that the coarse aggregate were well and uniformly graded.

Figure 3 Slump test graph

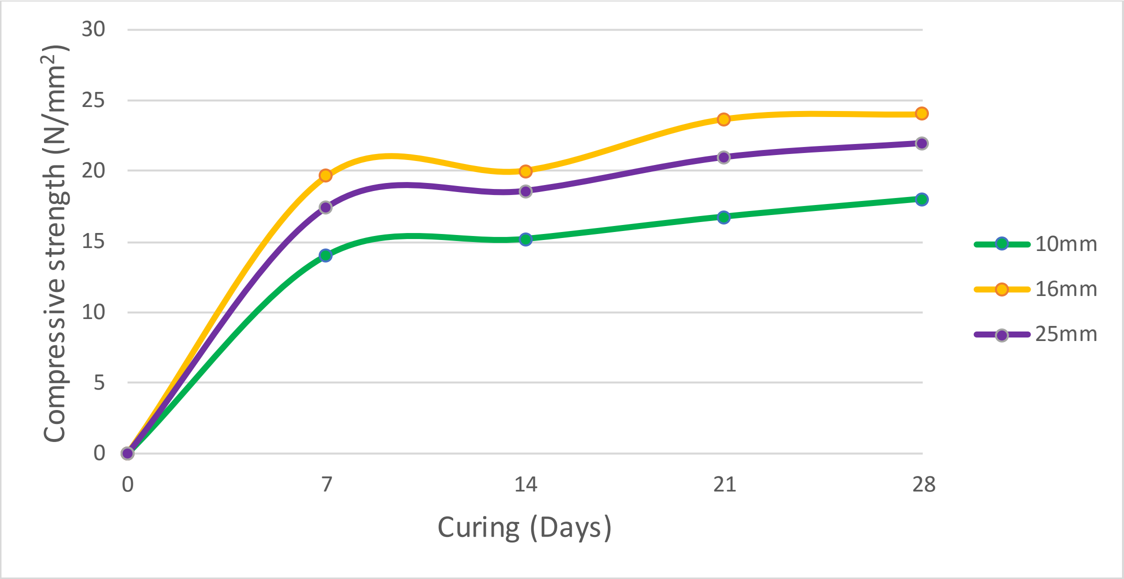


Workability

The workability of a concrete mix is affected by the mix proportion. Figure 3 above shows that for a given water cement ratio, workability decreases as the coarse aggregate size (proportion) increases in a concrete mix, this is probable because there is insufficient paste to lubricate the aggregate. It is also observed that the workability is decreased as the quality of fine aggregate is increased and this is likely due to the increase in the surface area of the aggregate proportion and the dryness of the concrete mix.

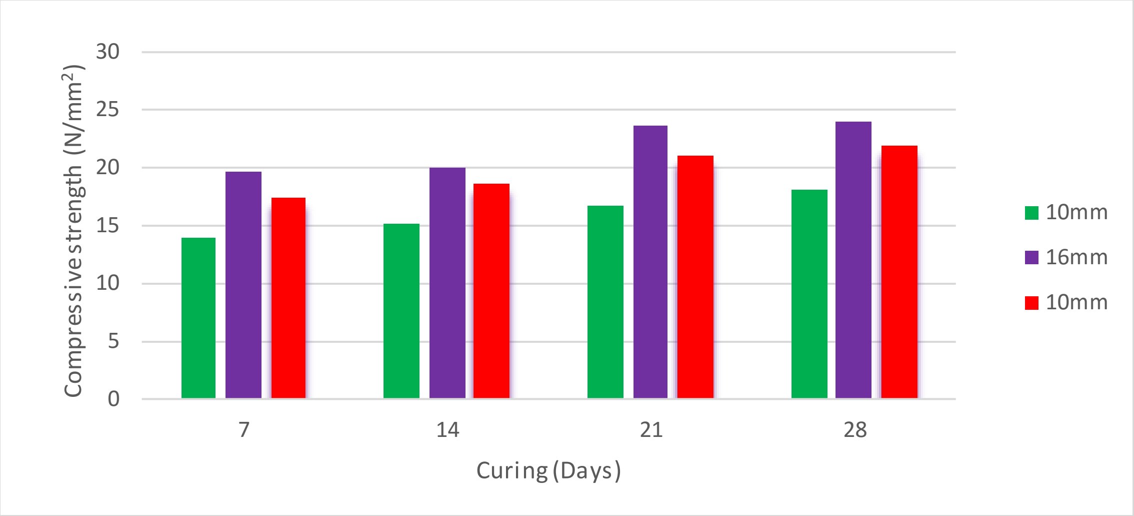
This result indicates that adequate paste content and aggregate surface area is required to achieve a certain degree of workability.

Figure 4 graph of coarse aggregate 10mm, 16mm and 25mm



The result of the compressive strengths of concrete specimen using a constant water cement ration are presented in the figure 4 above. It shows that the compressive strength increases progressively with increase in curing age for the different aggregate proportion in the concrete. Figure 4 also shows that the compressive strength of the concrete improved when the concrete aggregate proportion was varied i.e. when the concrete was slightly sandy and stony. It was also notice from the figure above that an early strength was obtained when the concrete was cured for the first seven days/ from the figure 4 about, the concrete made with coarse aggregate size of 16mm gave the highest strength gain followed by aggregate size 25mm and aggregate size 10mm

Figure 5 comparison of 10mm, 16mm and 25mm aggregate



From the chart above, it shows that the strength of concrete is affected by the variation in the aggregate size of the concrete. The compressive strength of the 16mm coarse aggregate size was highest because there was sufficient paste to completely fill all the voids in the concrete mix. This increase in strength as the curing age increases is in agreement with the finding of James etal, 2011 and Joseph etal, 2012.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

The compressive strength of the concrete has been measured at ages 7, 14, 21 and 28 days respectively. The tests are summarized in the tables above. The results from the crushing test shows in fig 4.3 shows that there is progressive increase in average compressive strength of concrete from 7-28 days respectively. The variation in numbers of days of curing increases the compressive strength of the concrete cube crushed. Observation shows that at 28 days, the concrete has achieved its maximum strength.

5.1 CONCLUSION

a. There is rapid increase in strength again during the first seven (7) days of curing followed by 14 days, 21 days and 28 days.

b. Concrete strength increase progressively with the age of curing.

c. Concrete gain its maximum strength at 28 days of curing

d. From the study, it can be concluded that the compressive strength of a Concrete is affected by the size, shape and surface texture of the aggregate.

e. It was observed that during the mixing of the concrete, the aggregate with the smallest surface area tends to be covered with cement paste wholly while the one with large surface area is not properly covered.

f. The curing days also affect the strength of the Concrete. As the curing days increases, the compressive strength also increase.

g. No matter the aggregate sizes, the failure patterns of the test specimens were the same. The failure patterns were pyramidal.

5.2 RECOMMENDATIONS

Based on the obtained results of the tests carried out and considering the importance of this investigation, the following recommendations are made

1. In this study, varying ages were used to obtain the compressive strength of concrete with different specimen of coarse aggregate (10mm, 16mm, and 25mm) and constant specimen of cement, water and fine aggregate. The author wish to suggest that other aggregates types within our area be used with the aim of determining the best aggregate size to be used in construction of reinforced concrete and mass concrete which should equally be more cost effective.

2. Machine mixing and machine compaction could be used in future studies for more uniform and adequate compaction to see if the compressive strength would be affected. The aggregate/cement ratios as well as water/ cement Ratio for aggregate type should be varied. The flexural and the tensile strength of the concrete with different aggregate sizes should also be studied to be able to draw a general conclusion.

3. Since there is increase and decrease in variation strength of concrete, it is good to conduct compressive strength of concrete without curing of the cubes to determine the compressive strength of the cubes

4. In this project, ten specimens (concrete cubes) were produced per aggregate type, only two samples were used for each of the 7, 14, 21, and 28 day tests. The author wishes to suggest that for effective study a greater number specimens per age be used in order to plot the best diagram

and obtain best fit curves. It will then be possible to observe the abnormal specimen(s) effectively at all water/ cement ratios and at all ages for each maximum size of aggregate.

5. from the test conducted for the compressive strength of concrete cast on different dates using different coarse aggregate size ,It is equally recommended that 16mm be used for reinforced concrete during construction since its compressive strengths are high while 25mm for mass concrete because of its low compressive strength.

6. Also for workability, the use of 10mm is recommended for beams and columns so as to achieve maximum compaction and less honey comb.

7. For the purpose of cost and economy in use of materials, the use of 25mm is recommended because of its large surface area.

8. Other types of cement should be used to see if the compressive strengths will be affected. And there should be awareness about the importance of recommending aggregate sizes for every structural element during design stage

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USE OF PALM KERNEL SHELL AS AN AGGREGATE IN CONCRETE MIXTURE

BY

MUOMAIFE ODERA KELLY DENNIS

(NAU/2016224057)

FINAL YEAR PROJECT

SUBMITTED TO

THE DEPARTMENT OF CIVIL ENGINEERING, FACULTY OF ENGINEERING

NNAMDI AZIKIWE UNIVERSITY AWKA.

IN PARTIAL FUFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF

BACHELOR OF ENGINEERING (B.ENG) DEGREE IN CIVIL ENGINEERING

FEBRUARY, 2022

CERTIFICATION

This is to declare that this research work “Use of palm kernel shell as an aggregate in concrete mixture” was carried out by Muomaife Odera Kelly Dennis with the registration number (NAU/2016224057) and that all the information used as contained in the work is a reflection of my personal research. All other sources of information obtained from other literary publication have been duly acknowledged.

Muomaife Odera Kelly Dennis

Date

APPROVAL PAGE

This research work “Use of palm kernel shell as an aggregate in concrete mixture” is an authentic academic work undertaken by Muomaife Odera Kelly Dennis and is presented to the department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University Awka for approval in partial fulfillment of the requirement for the award of Bachelor of Engineering (B. Eng).

____________________________ __________________
Engr. Dr. Adinna Boniface Okafor Date
(Project Supervisor)

____________________________ __________________
Engr. Dr. Ezeagu Akaolisa Celestine Date
(Head of Department)

____________________________ __________________
Engr. Prof. D. O Onwuka Date
(External Examiner)

DEDICATION

This work is dedicated to the owner of destiny, the creator of the universe, almighty God for the gift of life and also for guiding me throughout my sojourn in school, and also to my lovely parent Mr & Mrs Muomaife who serve as a real source of inspiration toward my academic pursuit.

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ABSTRACT

This study was carried out to investigate the use of palm kernel shell in replacement of coarse aggregate and fine aggregate on compressive strength of 1:1:2, 1:1.5:3, 1:2:4 and 1:3:6 concrete mix design. 0.6 water/cement ratio was adopted. The test conducted include: Sieve analysis test of fine aggregate and Palm kernel shell (PKS), Slump (Workability) test and Compressive strength test of the mix design when PKS is used as fine aggregate and when used as coarse aggregate. From Sieve analysis result obtained, PKS aggregate has uniformity coefficient (Cu) of 1.04 and coefficient of curvature (Cc) of 0.94. The values obtained show that the PKS used is Poorly graded and will contain lot of voids. While the uniformity coefficient (Cu) of the fine aggregate used is 2.5. this indicate that the aggregate is uniformly grade since the value is less than 4 and on the other hand the coefficient of curvature (Cc) is 1.5 which fall within the range of 1 to 3, the aggregate is said to be well graded. The Slump test conducted show that PKS as fine. From slump test conducted, shear slump was obtained for PKS as fine aggregate replacement while for PKS as coarse aggregate replacement, the slump value obtained fall within the range of 50-100, which is the medium workability range. From the compaction result, it is observed that the compressive strength of PKS as coarse aggregate replacement has an appreciable strength compared to concrete of PKS as fine aggregate replacement. palm kernel shell is recommended to be used as a partial replacement of coarse aggregate (substitute material) in making a light weight concrete.

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CHAPTER ONE

INTRODUCTION

1.1 Background of study

Concrete is a widely used construction material in civil engineering projects throughout the world for the following reasons: It has excellent resistance to water, structural concrete elements can be formed into a variety of shapes and sizes and it is usually the cheapest and most readily available material for the job (Mehta and Monteiro, 2006). From the various kinds of concrete, lightweight concrete (LWC) is one of the most interesting subjects for researchers because of its advantages such as the savings on foundation costs as well as the savings derived from the reduced cost of transport and erection. Furthermore, better fire resistance, heat insulation, sound absorption, frost resistance, superior anti-condensation properties and increased damping are other advantages of lightweight concrete (CEB/FIP, 1977).

The most popular way of achieving LWC production is by using lightweight aggregate (LWA) (Polat et al., 2010). Lightweight aggregate concrete (LWAC) is not a new invention in concrete technology; it has been used since ancient times. The fact that some of these structures are still in good condition validates the durability of concrete (Chandra and Berntsson, 2002). LWA may be subdivided into two groups: Those that occur naturally and those that are manufactured. The main natural LWAs are diatomite, pumice, scoria, volcanic cinders and tuff (Neville and Brooks, 2008). Manufactured aggregates can be divided into two groups. Naturally occurring materials that require further processing (produced by the application of heat)such as expanded clay, shale, slate, perlite and vermiculite and materials that occur as industrial by-products such as sintered pulverized-fuel ash (fly ash),sintered slate and colliery waste, foamed or expanded blast-furnace slag (CEB/FIP, 1977).An alternative LWA in tropical regions and countries that have a palm oil industry is Palm Kernel Shells (PKS), sometimes called Oil Palm Shells (OPS). The use of PKS as a lightweight aggregate or porous aggregate in producing lightweight concrete was researched early in 1985 by Salam and Abdullah in Malaysia. The oil palm industry is important in many countries such as Malaysia, Indonesia and Nigeria.

Research shows that PKS can be used as a lightweight aggregate for producing structural lightweight aggregate concrete (Teo et al., 2007; Abdullah, 1996; Teo et al.,2006; Basri et al., 1999; Mannan and Ganapathy, 2001; Mannan and Ganapathy, 2004). Furthermore, it was found that PKS structural lightweight concrete is a good thermal performance material for low cost housing (Harimi et al., 2007). The utilization of this agricultural solid waste as a lightweight aggregate in the construction industry does not only reduce the cost of construction materials but also resolves the problem concerning the disposal of waste products generated at the palm oil mills.

1.2 Statement of problem

The increasing cost of construction materials and the environmental degradation caused by high utilization of aggregates for concrete in civil engineering construction is a global challenge. High demand and continuous use of crushed granite for concrete in construction will overtime deplete the natural stone deposits and this will affect the environment by causing ecological imbalance.

Earthquakes have been reported to have occurred as a result of activities relating to continuous production of chippings from natural stone deposits (van poollen and Hoover,1970). On the other hand, the production of palm kernel shell promotes environmental pollution and nuisance with reference to its disposal. Recently, research has been conducted by Alengaram et al., (2011, 2013), and Mahmud (2008, 2010), on the use of palm kernel shell as aggregate replacement in concrete. Palm kernel shells are underutilized and are usually abandoned as waste materials or used in a small scale as fuel in furnaces and materials for filling potholes. There is need, therefore, to explore and find suitable replacement material to substitute coarse or fine aggregate in the production of light weight concrete.

1.2 Aim and objectives of study

1.3.1 Aim

The aim of this project is to evaluate the compressive strength properties and the weight of 150× 150 × 150mm concrete cube at 28days curing when palm kernel shell is used as fine aggregate and when it is used as coarse aggregate in concrete.

1.3.2 Objective

The objective of this study includes:

1. To classify the fine aggregate, coarse aggregate and palm kernel shell (PKS) used in the research.
2. To study the effect of palm kernel shell on the compressive strength at 28days curing when used as fine aggregate (crushed) and when used as coarse aggregate (crushed).
3. To study the effect of palm kernel shell on the weight of 150 × 150 × 150mm cube at 28days curing when used as fine aggregate and when used as coarse aggregate.

.1.4 Scope of study

The scope of this work involves the use of palm kernel shell as a replacement for fine aggregate and coarse aggregate respectively in the production of 150 ×150×150mm concrete cube in the mix ratio: 1:2:4, 1:1:2, 1:1.5:3 and 1:3:6. The laboratory test to be conducted include: Sieve analysis of fine aggregate, coarse aggregate and palm kernel shell (PKS) and Compressive strength test of the concrete cube at 28days curing. Concrete properties such as flexural strength, shrinkage, water absorption, fire resistance is not included in research.

1.5 Significance of study

The finding of this study will provide adequate information on the various compressive strength of concrete made by different replacement of aggregates with palm kernel shell and hence serve as a guide to builders on its suitable applications in concrete works.

CHAPTER TWO

LITERATURE REVIEW

2.1 Preamble

Concrete is the most commonly used material employed for construction purpose in the world today (Menthe et al., 2013), the expensive cost of concrete constituents such as cement, fine and coarse aggregate has necessitated the need to search for alternative construction materials (Menthe et al., 2103, Nguyen et al., 2013). The general importance of concrete application in construction projects and civil works cannot be overemphasized.

The overwhelming demand for concrete in construction adopting normal weight aggregates (NWAs), such as gravel and sand has led to tremendous depletion in naturally occurring aggregates causing numerous damage to the environment which are irreparable (Vishwa and Sanjay, 2015). As a result, the need to search for more sustainable and renewable materials has been intensified. Some waste agricultural materials such as saw dust, maize comb, rice husk, and coconut shell, palm kernel shell etc. can serve as a good substitute or admixture for some of these traditional construction materials.

These local materials are in most cases dumped as waste in our environments, causing environmental pollution. Many of which can be used as lightweight aggregate(LWA) to produce light weight concrete which has the advantage of reducing the self-weight of concrete structures as compared to conventional concrete which possess heavy dead load, they can also be used for purposes of structural stability and versatility as well as economic viability (Nguyen et al., 2013). Hence incorporating these waste materials will help reduce the rate of exploitation of nonrenewable natural resources (Milutiene et al., 2012) and provide more sustainable concrete

(Pelisser et al., 2011). Furthermore, the idea of using raw materials as concrete constituents is capable of proffering solution to energy saving problems encountered in many agro industries (Ismail 2013).

An agricultural waste that has proven successful in concrete production is palm kernel shell (PKS). In the last three decades, palm kernel shell (PKS) has been used by scientists as LWA to substitute conventional NWA inbuilding and road construction in Africa and Southeast Asia.

2.2 Concrete

Concrete in construction is a structural material consisting of a hard, chemically inert particulate substance, known as aggregate (usually sand and gravel), that is bonded together by cement and water.

Among the ancient Assyrians and Babylonians, the bonding substance most often used was clay. The Egyptians developed a substance more closely resembling modern cement by using lime and gypsum as binders. Lime (Calcium oxide), derived from limestone, chalk or Oyster shells, continued to be the primary Pozzolanic, or cement – forming agent until the early 1800s. in 1824 an English inventor, Joseph Aspdin, burned and ground together a mixture of limestone and clay. This mixture, called Portland cement, has remained the dominant cementing agent used in concrete production.

Concrete is characterized by the type of aggregate or cement used, by the specific qualities it manifests, or by the methods used to produce. Many other non-cementitious types of concrete exist with other methods of binding aggregate together, including asphalt concrete with a bitumen binder, which is frequently used for road surfaces, and polymer concretes that use polymers as a binder. Concrete is distinct from mortar. Whereas concrete is itself a building material, mortar is a bonding agent that typically holds bricks, tiles and other masonry units together. When aggregates are mixed with dry Portland cement and water, the mixture forms a fluid slurry that is easily poured and mold into shape.

Concrete is one of the most frequently used building materials. Its usage worldwide, ton for ton, is twice that of steel, wood, plastics and aluminum combined. Concrete is a brittle material, which exhibit low resistance to tensile stress. The failure of concrete at very low tensile force is attributed to the spreading of micro cracks, which are inherent in concrete due to heat formations in cement hydration (Hashem et al, 2002).

2.2.1 Curing of concrete

According to Neville (1981), curing is the process used for promoting the hydration of cement and consists of a control of temperature and of the moisture movement from and into the concrete; with the aim of keeping the concrete saturated or as nearly saturated as possible until the originally water-filled space in the fresh cement paste has been filled to the desired extent by the products of cement hydration. The goal of curing is to ensure thatair-filled void is filled with the products of hydration of cement as time progresses (Mannan et al., 2002). Increase in compressive strength, permeability, durability and other mechanical properties of concrete by continuous water curing are attributable to improved gel/space ratio in concrete (Neville, 1981). Mannan et al., (2002) observed that among the factors influencing the strength development of concrete is the curing environment. Curing is usually done in a fully saturated environment to ensure proper hydration of the cement over time thereby leading to significant strength development.

Price (1991) refers to curing as the process of protecting concrete for a specified period of time after placement, to provide moisture for hydration of the cement, to provide proper temperature and to protect the concrete from damage by loading or mechanical disturbance. Curing is designed primarily to keep the concrete moist by preventing loss of moisture from it during the period in which it is gaining strength. Curing can be achieved by keeping the concrete element completely saturated or as much saturated as possible until the water-filled spaces are substantially reduced by hydration products (Gowripalan et al., 1992). The chemical reaction that takes place during curing is termed hydration of cement and virtually ceases when the relative humidity within capillaries drops below 80percent (Neville, 1996). Nilsson, (1980) in his experimental investigation into hygroscopic moisture in concrete had observed a substantial decrease in the rate of hydration when the ambient humidity fell below 80percent. It's important to note that if concrete is not cured and is allowed to dry in air, it will gain only 50percent of the strength of continuously cured concrete. As a result, if concrete is cured for only three days, it will reach about 60percent of the strength of continuously cured concrete; if it is cured for seven days, it will reach 80percent of the strength of continuously cured concrete. If curing stops for some time and then resumes again, the strength gain will also stop and reactivate (Mamlouk and Zaniewski, 2006). However, long period of moist curing has been reported to reduce the incidence of cracking (Kong and Evans, 1994). If concrete is not well cured, particularly at the early age, it will not gain the required properties at desired level due to a lower degree of hydration, and would suffer from irreparable loss. Mamlouk and Zaniewski (2001) also observed that improper curing would entail insufficient moisture and this has been found to produce cracks, compromise strength, and reduce long-term durability. The strength development and permeability of concrete is greatly affected by the processes of hydration, leaching and curing.

2.2 Cement

Cement in its general term, can be described as a material with adhesive and cohesive properties which make it capable of binding the material fragments into the compact whole. Basically, the raw materials used in the manufacture of Portland cement consist mainly of lime, silica, alumina and iron oxide. These compounds interact with one another in the kiln to form a series of more complex products and apart from a small residue of uncombined lime which has not had sufficient time to react, a state of chemical equilibrium is reached.

The principal constituents of cement are compounds of lime. On adding water to cement a chemical reaction known as hydration of cement takes place and a large quantity of heat-liberates. On hydration of cement, gel is formed which binds the aggregate particles together and provides strength and water tightness to concrete on hardening. Thus, cement has the property of setting and hardening under water by virtue of a chemical reaction with it. Such cements are called hydraulic cements. They consist mainly of aluminates and silicates of lime.

The history of cementing material is as old as that of Engineering Construction. In ancient times Romans, Egyptians and Indians used some kind of cementing materials in their constructions. It is believed that Egyptians used burnt gypsum ($CaSO_4$) as cementing material in their constructions. Not much is known about the cementing material used by Indians in the construction of the cities of Harappa and Mohenjo-Daro.

The analysis of mortar used in the construction of Great Pyramid showed that it contained 81.5 percent of calcium sulphate and about 9.5 percent calcium carbonate only. It is believed that early Romans and Greeks used cementing materials obtained by calcination (burning), of lime stone. The remarkable hardness of the mortars used by early Romans in their constructions obtained from some of the existing works provides sufficient evidence of the perfection of art of preparing cementing materials in ancient times. The superiority of Roman mortar is attributed to the thorough mixing and continued ramming for a long period.

Latter Romans and Greeks learnt that better cementing material may be obtained by mixing certain volcanic ash and tuff with lime stone, sand and water. This mixture produced a cementing material of superior strength and durability. The tuff used in the mix was found near the village Pozzuoli near Mount Vesuvius in Italy. The tuff or ash mostly is siliceous in nature. This type of tuff or ash was given the name of Pozzolana. After wards any material natural or artificial having the same properties as those of tuff or ash found near Pozzuoli was called pozzolana.

In the absence of natural volcanic ash, Romans used powdered pottery or tiles as Pozzolana. In India surkhi (brick powder) has been used as Pozzolana in the mortar. In India the thorough mixing and long continuous ramming of lime mortar with or without the use of surkhi yielded strong and imperious mortar which confirmed the secret of Roman mortar superiority.

After 1756, John Smeaton carried out extensive experiments and made enquires to find out the best material to withstand severe action of sea water. On the basis of his experiments he concluded that lime stones containing considerable proportion of clayey matter produced better lime possessing superior hydraulic properties. However, the findings of John Smeaton made little advancement and the old practice of a mixture of lime and Pozzolana remained in use for a long time.

Neville (1997) described cement as a material with adhesive and cohesive properties that make it capable of bonding mineral fragments (stones, sand, bricks, building block) into a compact whole. The cement referred here is the hydraulic cement having the property offsetting and hardening under water by virtue of a chemical reaction with it. The principal constituents of this cement are mainly of silicates and aluminates of lime. This hydraulic cement which is commonly known as 'Portland' cement is due to its resemblance of the colour and quality of the hardened cement to Portland stone, limestone quarried in Dorset, United Kingdom. The various types and classifications of Portland cement and its properties are stipulated in accordance with ASTM C 150-2005 and BS EN 197-1:2000.

Many types of cements have been developed to ensure good durability of concrete under avariety of conditions. Table-2.1 shows a list of different types of Portland cement in the British classification together with the American classification (Neville, 1997).

Table 2.1 Some Main Types of Portland Cement

Description	**BS**
Ordinal Portland	12:1978
Rapid-hardening Portland	12:1978
Low-heat Portland	1370:1979
Sulphate-resisting Portland	4027:1980
White Portland	12:1978

2.3 Aggregate

The term aggregate is used to describe the gravels, crushed stones and other materials which are mix with cement and water to make concrete. As aggregate form bulk of the volume of concrete, the selection of suitable material is important. Of the materials in concrete, aggregate is the most variable. The overall grading of the aggregate affects the amount of water that must be added because 'fine' grading requires more water than 'coarse' grading to obtain the same degree of workability (Murdock,2001). Aggregate particles which have sharp edges or rough surface, such as crushed stones, need more water than smooth and rounded particles to produce concrete of the same workability. It may be necessary to increase the cement content of a mix made with crushed aggregates or irregular shaped gravels to allow water to be added in order to make the concrete sufficiently workable without reducing the strength below the required level. However, due to interlock between aggregate particles, a crushed aggregate concrete may have higher strength than a smooth or rounded aggregate concrete with the same water / cement ratio, and this extra strength may be sufficient to offset the effect of the extra water.

As the maximum size of the aggregate is reduced, the cement content of the mix will need to be increased to give the same workability with the same water / cement ratio. This is because the surface area of aggregate to be wetted is greater with the smaller aggregate size. The fine and coarse aggregates should be proportioned to obtain the required workability with the minimum amount of water. Badly proportioned constituents require an excessive amount of water to give adequate workability, and this will result in concrete of low strength and poor durability. Moreover, aggregates should be hard, durable, firm, appropriately cleaned and suitably graded. The presence of harmful substances such as dust, mud, organic imparities, chlorides or any other harmful substance should not be in larger amount than allowable limits (Siddique,2003).

2.4 Water

Mixing water for concrete is usually required to be fit for drinking, or to be taken from an approved source. This is to ensure that the water is reasonably free from such impurities as suspended solids, organic matter and dissolved salts, which are frequently contained in natural water and which may adversely affect the properties of concrete.

Water is the most consistent of the constituents of the concrete but water quantity, and in particular the water / cement ratio, is most important for the production of concrete of consistent strength. The amount of water used should be the minimum necessary to give sufficient workability for full compaction of the concrete. When deciding how much water to use, allowance must be made for absorption by dry or porous aggregates and for the free surface moisture of wet aggregates.

2.5 Palm kernel shell

Palm kernel shell is a by-product of agro-processing from palm oil palm. They are available in very giant quantities where oil palm processing is carried out. For some time now, the Nigerian government has been clamoring for the use of local materials in the construction industry to cut down cost of construction. There has therefore been a greater call for the sourcing and development of alternative, non-conventional local construction materials. Palm kernel shells are derived from the oil palm tree (elaeis guineensis), an economically valuable tree, which is native to Western Africa and widespread throughout the tropics.

In Nigeria, the oil palm trees are grown in the rain forest region close to the coastal areas. Palm kernel shells are used mostly as a source of fuel for domestic cooking in some areas. The shells are often dumped as waste products of the oil palm industries which sometimes constitute environmental hazards, hence the necessity for research on finding other means of utilizing palm kernel shell (Ndoka, 2006).

2.5.1 Properties of palm kernel shell (PKS)

Palm oil processing is separated into six stages: Sterilization, threshing, pressing, separation of kernel and shell and clarification (Abdullah,1996). Shells are one of the wastes produced during this process. Their colour ranges from dark grey to black. The shells are of different shapes, such as angular, polygoneutic., depending on the breaking pattern of the nut. The surfaces of the shells are fairly smooth for both concave and convex faces. However, the broken edge is rough and spiky. The thickness varies and depends on the species of palm tree from which the palm nut is obtained and ranges from 0.15 - 8 mm (Basri et al., 1999, Okpala,1990).

The shell has a 24 hours water absorption capacity range of21 - 33%. This value implies that the PKS have highwater absorption compared to conventional gravel aggregates that usually have water absorption of less than 2% (Neville, 2008). This high-water absorption could be due to the high pore content. It was reported that the porosity of the shell is 37% (Okpala, 1990). Mannan et al. (2006) reported an improvement in the quality of PKS by using pre-treatment methods such as 20% poly vinyl alcohol as a PVA solution. This decreased the water absorption of PKS significantly from 23.3 to 4.2%.Because of the higher porosity of PKS than conventional aggregates, loose and compacted bulk densities and the specific gravity range from about 500-550, 590 - 620 kg/m3 and 1.14 - 1.37, respectively. These ranges of densities show that PKS are approximately60% lighter than conventional coarse aggregates.

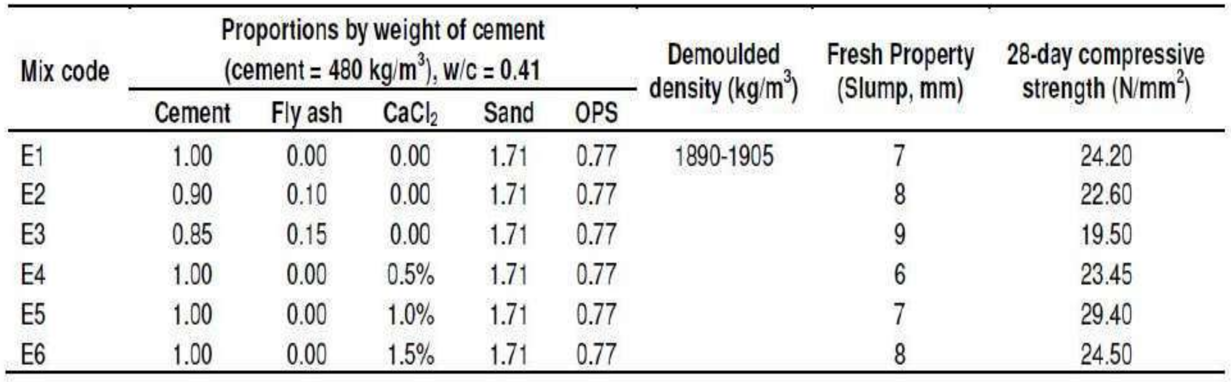
The densities of the shell are within the range of most typical lightweight aggregates (Okpala, 1990; Okafor, 1988). The shell is hard and does not easily suffer deterioration. The Los Angeles abrasion value of the PKS and crushed stone was reported as (Basri et al., 1999) 4.8 and 24%respectively. This shows that it is much lower than conventional coarse aggregates and has a good resistance to wear. Furthermore, the aggregate impact value and aggregate crushing value of PKS aggregates were much lower compared to conventional crushed stone aggregates. This shows that the aggregate has a good absorbance to shock (Teo et al., 2007). Koya and Fono (2009) demonstrated that because these shells are subjected to hard and variable braking forces, therefor the particles can be effectively used in brake lining formulations when properly combined with other additives.

2.5.2 PKS as aggregate in light weight concrete

In well-proportioned mixtures, the cement content and strength relationship are fairly constant for a particular source or one type to another. Therefore, trial mixtures with varying cement contents are required to develop arrange of compressive strengths, including the strength specified (Komatke et al., 2002). Because the palm kernel shells are lighter than the cement matrix, the shells tend to segregate in wet concrete mixes. Abdullah (1996) suggested that trial mixes are necessary to achieve a good mix design. Lightweight concrete mix design is usually established by trial mixes. Mix design methods that apply to normal weight concrete are generally difficult to use with lightweight aggregate concrete (Shetty, 2005).

A study for finding a mix design method for PKS lightweight concrete was conducted by Mannan and Ganapathy (2001). They found that the 28-daycompressive strength of OPS concrete, designed according to the America concrete institute (ACI) method for conventional concrete, is not suitable for PKS lightweight concrete because the strength is very much less than the targeted design strength. Even with this method and the use of superplasticizer, the strength could not be increased. Furthermore, they followed the mix design method for lightweight aggregate such as Leca and Fumed slag. However, these methods were not suitable for PKS concrete. They explained that the PKS aggregate is a natural organic material with a smooth texture and different shapes. Finally, they suggested six acceptable mix proportions for PKS concrete with different ingredients, as shown in Table 2.2

Table 2.2 Acceptable mix proportion of OPS concrete reported by (Mannan and Ganapathy, 2001).



Mix code	Proportions by weight of cement (cement = 480 kg/m^3), w/c = 0.41					Demoulded density (kg/m^3)	Fresh Property (Slump, mm)	28-day compressive strength (N/mm^2)
	Cement	Fly ash	$CaCl_2$	Sand	OPS			
E1	1.00	0.00	0.00	1.71	0.77	1890-1905	7	24.20
E2	0.90	0.10	0.00	1.71	0.77		8	22.60
E3	0.85	0.15	0.00	1.71	0.77		9	19.50
E4	1.00	0.00	0.5%	1.71	0.77		6	23.45
E5	1.00	0.00	1.0%	1.71	0.77		7	29.40
E6	1.00	0.00	1.5%	1.71	0.77		8	24.50

Olanipekun et al. (2006) investigated the effect of crushed, granular coconut and palm kernel shells as substitutes for conventional coarse aggregate in two mix ratios of 1:1:2 and 1:2:4 with a water to cement ratio of0.75 and 0.50 and a 28-day compressive strength of 35and 27.5 MPa respectively. They concluded that by using these lightweight aggregates, grades 20 and 15lightweight concrete can be obtained if the percentage replacement levels of the conventional coarse aggregate with both lightweight aggregates do not exceed 25 and50% respectively, for both mix ratios tested .Irrespective of other mix proportions of PKS structural lightweight concrete, the PKS content in 1m^3 for achieving the compressive strength for grades of 20 - 35,ranged from 290 - 450 kg. (Teo et al., 2007; Teo etal.,2006; Mannan and Ganapathy, 2004; Mannan and Ganapathy, 2002; Mannan and Ganapathy, 2001; Mannan et al., 2002; Alengaram et al., 2008). In these researches, the cement content was in the range of 400 -600 kg/m3. It should be noted that, generally, the cement content in lightweight aggregate concrete varies from the same as normal weight aggregate to 70% more for the same strength of concrete (Neville and Brooks, 2008).

According to ACI-213R, for structural lightweight concrete (compressive strength ranges from 17 to 41 MPa) the cement content is in the range of 240 - 500 kg/m3 (Mehta and Monteiro, 2006). density is often more important than the strength(Rossignolo et al., 2003). The density of LWC typically ranges from 1400 to 2000 kg/m3 compared with that of2400 kg/m3 for normal-weight concrete (NWC) (Chen and Liub, 2005). Okafor (1988) reported that the production of concrete with a density of approximately 1758 kg/m3using this agricultural solid waste is possible. According to Basri et al. (1999) investigation, the 28-day air-dry densities of PKS concrete were 19 - 20% lower than ordinary crushed stone concrete. Other studies show that PKS concrete is 22% (Mannan and Ganapathy, 2004) and 24% (Alengaram et al., 2008) lower than the normal weight concrete. Furthermore, it was reported (Mannanand Ganapathy, 2004) that PKS concrete containing 10and 15% fly ash are 2 and 3% lower than PKS concrete without fly ash content.

2.5.3 Bond characteristics of palm kernel shell in concrete

Some research had been done in assessing the bond characteristics of the palm kernel shell in concrete matrix like works of Raheem et al., (2008) and Jumaat et al., (2009). According to Raheem et al., (2008) and Jumaat et al., (2009), the poor bond between palm kernel shell aggregate and the concrete matrix produced a poorly compacted concrete because of the smooth and convex nature of the shell.

However, higher sand content has been reported to improve significantly the bond strength of palm kernel shell concrete (Babafemi and Olawuyi, 2011). Previously, researchers like Okafor, (1988), Mannan and Ganapathy, (2002) and Jumaat et al., (2009) have shown that a poor bond between palm kernel shell and the cement matrix resulted in bond failure. This contributed to lower mechanical properties in palm kernel shell concrete. They reported that bond failure may be attributed to the smooth and convex surface of palm kernel shell. Jumaat et al., (2009) reported that the ordinary failure in tension occurs as a result of breakdown of bond between the matrix and the surface of the aggregate or by fracture of the matrix itself, and not as a result of fracture of the aggregate. Since gravel stone have rough surface compared to palm kernel shell, it tends to have better bonding with the cement paste (Jumaat et al., 2009). The behavior of palm kernel shell concrete in a marine environment had been previously reported by Mannan and Ganapathy (2001) and they revealed that the compressive strength of palm kernel shell concrete was 28.1MPa at an age of 28days.They also observed that the bond property of palm kernel shell concrete is comparable to other types of lightweight concretes.

2.5.3 Palm kernel shell (PKS) as a sustainable building material in Nigeria

Palm Kernel Shell as a Sustainable Building Material in Nigeria is useful in constructing affordable housing system for both the rural and urban population of Nigeria and other developing countries, various proposals focusing on cutting down conventional building material costs have been put forward. One of the suggestions in the forefront has been the sourcing, development and use of alternative, non-conventional local construction materials including the possibility of using some agricultural and industrial wastes and residues (e.g. palm kernel shells) as construction materials (Tukiman and Mohd, 2009). The quality and cost effectiveness of construction materials employed in housing developments are among the major factors that determines the optimal delivery of housing projects. Therefore, materials to be used for building construction must provide objective evidence of quality and cost effectiveness in terms of functional requirements and low-income economy respectively. In view of this, the search for low-cost material that is socially acceptable and economically available, at an acceptable quantity within the reach of an ordinary man becomes a subject of continuous interest. The belief that the African region is full of raw materials suitable for local uses encourages this, yet the construction sector is not making optimal use of them (Ramachandran, 1983).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

The materials required for this research work are fine aggregate (river sand) designated as FA. Coarse aggregate (granite) designated as CA, additive (palm kernel shell) designated as PKS, ordinary Portland cement and water.

3.1.1 Cement

The Portland cement designated as PLC used for this experiment is Dangote cement. The cement brand complied with the requirements of BS EN (1995) and it was purchased from local dealer at Eke-Awka market in Anambra State. The grade of the cement is 42.5R. The cement was conveyed to school laboratory where it was kept in a dry place.

3.1.2 Water

The water used was fetched from a water tank, which is in Nnamdi Azikiwe University civil engineering workshop. The water was used both for the mixing of concrete as well as in curing of the cubes.

3.1.3 Palm Kernel Shell (PKS).

The palm kernel shell designated as PKS was obtained from Ekwulobia in Aguta local government area, Anambra state. It was collected in two empty rice bags and was conveyed to a grading site where it was washed, dried before been graded into suitable sizes.

3.1.4 Coarse Aggregate

The coarse aggregate designated as GT was bought from Agu-Awka building material market, Anambra state. The aggregate was sieved and 12mm size of aggregate which is to be used for the practical were collected in bags.

3.1.5 Fine aggregate

The fine aggregate designated as FA was purchased from Agu-Awka building material market, Anambra state. The aggregate was bought in bags and was conveyed to civil Engineering laboratory. The fine aggregate was air-dried then after it was stored in a dry place.

3.2 Equipment.

The equipment used were:

3.2.1 Shovel:

Shovel is a tool used to dig as well as move loose, granular materials from one spot to another. In concrete work shovel is used to mix material components of the concrete.

3.2.2 Mechanical sieve shaker:

Mechanical sieve shaker is sieve shaker that utilizes several moving parts to oscillate, tap, and otherwise agitate the sieve stack to help the particle find openings in the mesh.

3.2.3 Tamping bar:

This is used for compacting concrete into cube molds. This rod is made of steel bar, it is 25mm square face by 380mm long with round side handle.

3.2.4 Concrete cube mold:

A concrete cube mold hold concrete during the curing process and can be easily dismantled so the molded concrete cube can then be either lab tested or kept in curing tank for quality control purposes.

3.2.5 Trowel:

A trowel is a small tool with a flat blade that is used for spreading things such as cement and plaster onto walls and other surfaces.

3.2.6 Weighing scale:

A weighing scale is an instrument which is used to determine the weight or mass of an object.

3.2.7 Measuring cylinder:

Measuring cylinder is a common piece of laboratory equipment used to measure the volume of a liquid.

3.2.8 Bowl:

A bowl is a round dish or container typically used to contain materials like cement, sand and aggregate etc. in concrete work.

3.2.9 Curing tank:

The concrete curing tanks are constructed of galvanized steel or heavy plastic. They are used for lab or field curing of concrete beams, cylinders, or other concrete specimens.

Plate3.1 Picture of curing tank and metallic cube mould

Plate 3.2 Picture of weigh balance and universal testing machine

3.3 Practical procedure.

3.3.1 Sieve analysis test:

The required quantities of the representative sample were weighed-out using a measuring scale balance. The palm kernel shell used were first washed in other to remove its fibres and some other impurities and then dried. The sieves were stacked on the sieve shaker in decreasing order of their aperture after which the weighed representative sample was poured into the top sieve of the sieve stack, then the sieve lid was placed on to prevent the sample from falling off the edges.

The sieve shaker was turn-on and was allowed to vibrate for 5-10 minutes. The sieve stack was removed from the shaker and the weight of sample on each sieve size was recorded.

3.3.2 Mixing and curing of concrete cube:

The required quantities of cement, palm kernel shell, fine and coarse aggregate were weighed out in a mix ratio of1:2:4, 1:1:2, 1:1.5:3 and 1:3:6. The water/cement ratio used was 0.6. Volume batching was adopted in measuring out the materials used for the mix design. Fine aggregate and the measured amount of cement was mixed thoroughly before the addition of coarse aggregate. Then after proper mixing, a uniform mix was obtained. The measured water was then added to the mix and properly mixed with hand shovel. Cube molds to be used were prepared and well oiled. The concrete sample were filled into the cube molds in 3layers and each layer was approximately 5cm deep. In placing each scoopful of concrete, the scoop was moved around the top edge of the mold as the concrete slide from it. Each layer of the concrete filled in the mold was compacted by not less than 35 strokes using a tamping bar. The strokes were ensured to penetrate into the underlying layer. After tamping the third layer, excess concrete was removed and the top surface was smoothed. The casted cubes were stored under shed at a place free from vibration and at a temperature 22˚C to 33˚C for 24hours. Immediately after initial curing of the cubes, they were clearly marked. The cubes were removed from the molds and immersed in clean water at a temperature 24˚C to 30˚C till 7 or 28-days age of testing. The cubes were tested in saturated and surface dry condition.

3.3.3 slump test:

Firstly, the internal surface of the cone mold was cleaned carefully and then oiled. The cone mold was placed on a clean, smooth, horizontal and non-porous base plate. The quantities of the materials to used were batched by volume. The concrete materials were mixed at 0.6water/cement ratio. After the mixing, the mold was filled with fresh concrete in three layers and each layer was tamped 25time with a steel rod. After filling the mold, excess concrete was removed and the top surface was levelled. The base plate was firmly held as the mold was been lifted gently in the vertical direction. The unsupported concrete slumped and the decrease in height at the center point was measured.

3.3.4 Crushing of concrete cubes:

Compressive strength of the casted cubes was tested at 28days age of curing. The cubes to be crushed was air before been placed on the universal testing machine. weight of the cubes was noted. The cube to be test was placed in the space between bearing surfaces. Care was taken to prevent the existence of any loose material or grit on the metal plates of machine. The cube placed on bearing plate was aligned properly with the center of thrust in the testing machine plates. The loading was applied axially on the specimen without any shock and was increased at the rate of 140kg/sq. cm/min. till the specimen collapse. Due to constant application of load, the specimen cracked at a point and the breakdown of the specimen was noted.

3.4 Formula used for computation

3.4.1 Compressive strength

The compressive strength of concrete cube is computed as follows:

Compressive Strength (N/mm^2) = $\frac{Applied\ load\ (N)}{Area\ of\ Cube\ (mm \times mm)}$

Applied load = Force (N)

Now conversion of applied load from Ton force to KN or N.

1 Ton force = 10kN or 10,000N.

Area of cube = 150mm×150mm = 22,500mm^2

3.4.2 Sieve analysis

Percentage retained (%) =$\frac{mass\ of\ soil\ retained\ (g)}{total\ mass\ of\ soil\ sample(g)} \times 100$

Cumulative percentage retained = $\sum Percentageretained$ (%)

Cumulative Percentage Finer (%) = 100-Cummulative percentage retained.

Coefficient of Curvature =$\frac{D60}{D10}$

Coefficient of Uniformity =$\frac{(D30)\text{^}2}{D10\times D60}$

Where

D10= particle size such that 10% of the soil is finer than the size

D30= particle size such that 30% of the soil is finer than the size.

D60= particle size such that 60% of the soil is finer than the size**.**

3.4.3 Density

Density (P) =$\frac{mass\ (kg)}{volume\ (mm\text{^}3)}$

Volume of cube = 150mm × 150mm × 150mm = 3375000mm^3

Plate 3.3 Practical picture 1

Plate 3.4 Practical picture 2

Plate 3.5 Practical picture 3

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, various tests conducted on the specimen will be looked into. The present study aims to investigate the particle size distribution of the aggregate used, slump values of PKS as fine aggregate replacement and PKS as coarse aggregate replacement, the compressive strength of both PKS as fine and coarse aggregate replacement and the densities of the specimen.

This chapter show the results of particle size distribution, slump test and the compressive strength test performed on 16 concrete cube specimens. The specimen was cured, weighed and results were collected for 28 days with 2 specimens crushed and the average of the two values taken. The mix ratio of the concrete is 1:1:2, 1:1.5:3, 1:2:4 and 1:3:6. The size of aggregate used is 12mm with a water cement ratio of 0.6 maintained throughout the experiment. All the tests were done as described in the chapter three of this thesis.

4.2 Particle size distribution analysis

Particle size analysis is used to characterize the size distribution of particles in a given sample. from fig 4.1 below, the uniformity coefficient (Cu) of the fine aggregate used is 2.5. this indicate that the aggregate is uniformly grade since the value is less than 4 and on the other hand the coefficient of curvature (Cc) is 1.5 which fall within the range of 1 to 3, the aggregate is said to be well graded.

Fig 4.2. shows the particle size distribution of PKS, the uniformity coefficient (Cu) obtained is 1.04 and the coefficient of curvature (Cc) obtained is 0.94. The values obtained show that the

PKS used is Poorly graded and will contain lot of voids. Hence, it will require more amount of cement paste to fill the voids and therefore, adequate compaction is required.

The particle size of the coarse aggregate used is 12mm.

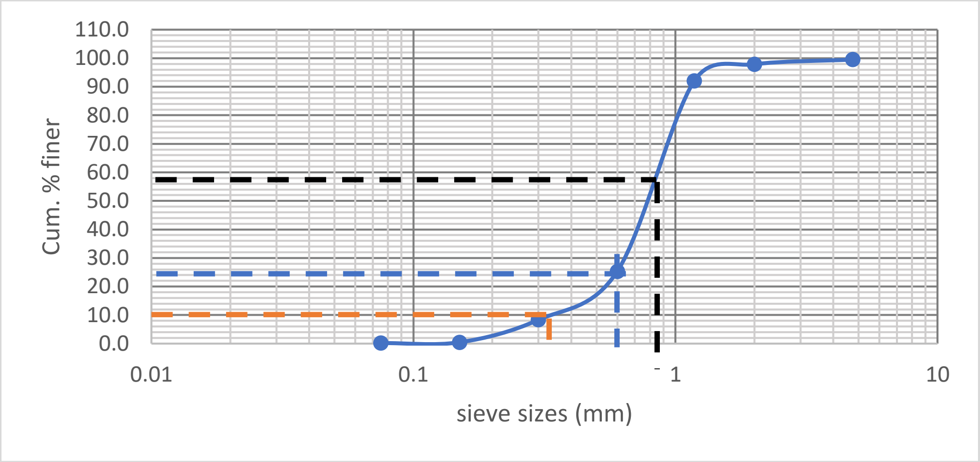


Figure 4.1 Sieve Analysis Graph of fine Aggregate.

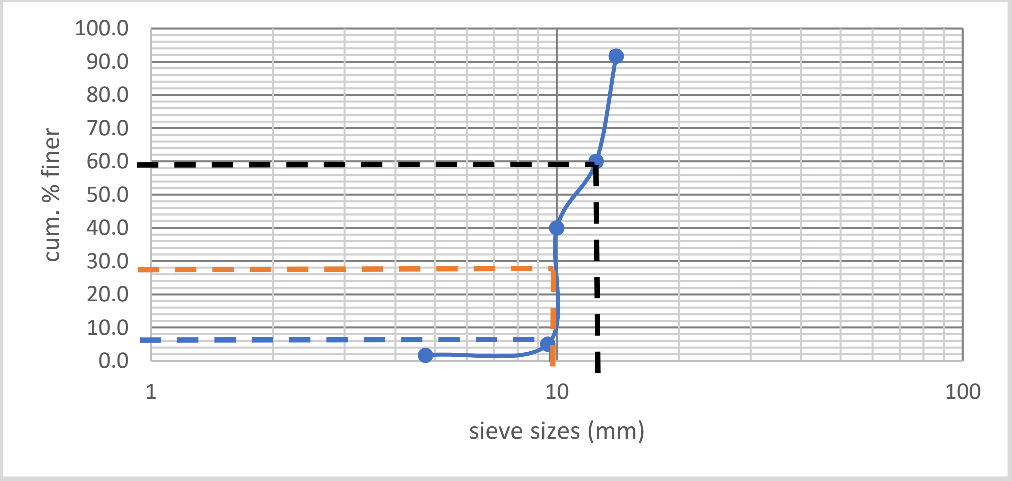


Figure 4.2 Sieve Analysis Graph of PKS Aggregate.

4.3 Slump test

The slump test values obtained were presented in the table below.

Table 4.1 slump test result

mix ratio	**slump (mm)**			
	PKS as fine aggregate	**remark**	**PKS as coarse aggregate**	**remark**
1:1:2	61.2	shear	85.4	medium
1:1.5:3	89.2	shear	61.4	medium
1:2:4	64	shear	50	medium
1:3:6	75.3	shear	72.1	medium

From table 4.2, shear slump is observed on the concrete when PKS is used to replace fine aggregate at 0.6 water/cement ratio. This could be as a result of the absence of fine aggregate in the mix and also the smooth surface texture of PKS. Fine aggregate in concrete prevent possible segregation of paste and coarse aggregate. For PKS as coarse aggregate replacement, the slump value obtained for 1:1:2, 1:1.5:3, 1:2:4 and 1:3:6 are 85.4mm, 61.4mm, 50mm and 72.1mm repectively. These values fall within the range of 50-100, which is the medium workability range i.e according to BS 1881: Part 103 (1983) specification.

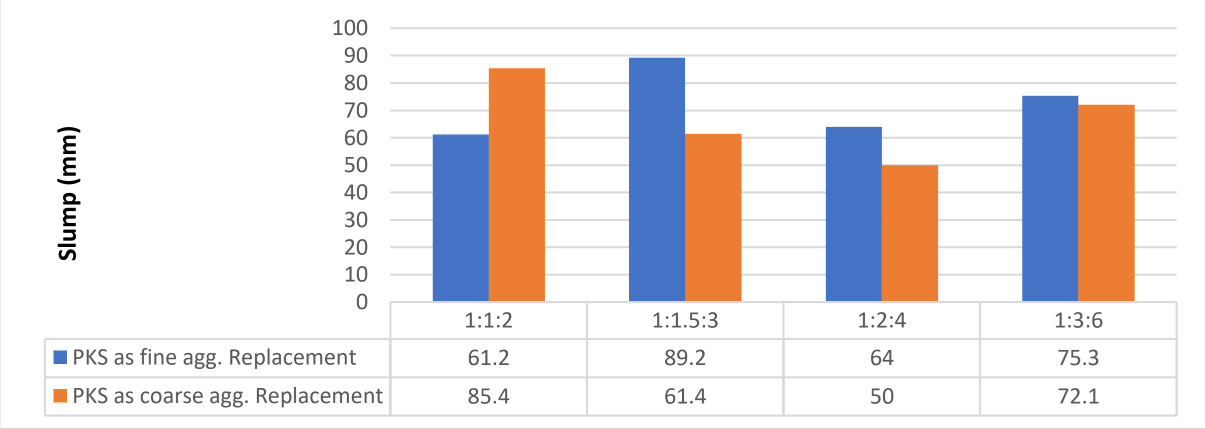


Figure 4.3 Slump graph

4.4 Density

The density values of the concrete mix obtained were presented in the table below.

Table 4.2. Density value result

mix ratio	Av. Density (Kg/m³)	
	PKS as fine aggregate	**PKS as coarse aggregate**
1:1:2	2029.6	1339.3
1:1.5:3	2148.1	1419.3
1:2:4	2077.0	1425.2
1:3:6	2112.6	1413.3

=

From fig 4.1 below, it is observed that concrete of PKS as fine aggregate replacement has more density than the concrete of PKS as coarse aggregate replacement. The density of PKS as coarse aggregate replacement fall with the range of 1350 to 1920kg/m3. ACI 213,2001 classified concrete density within the range as structural lightweight concrete.

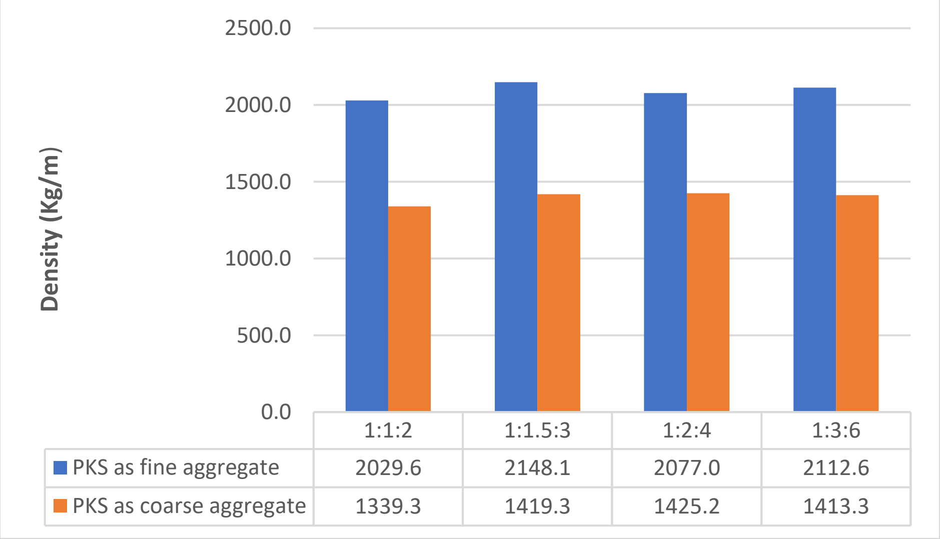


Fig 4.3 Density Value Graph

4.5 Compressive strength

Compression cube test is used to determine the mechanical strength of concrete to sustain the axial force applied on the surface of concrete. The test was carried out evaluate the effect of replacement of palm kernel shell as coarse aggregates and fine aggregate on the compressive strength of 1:1:2, 1:1.5:3, 1:2:4 and 1:3:6 concrete. The average compression strength for all the mix design is summarized in Table 4.3 below.

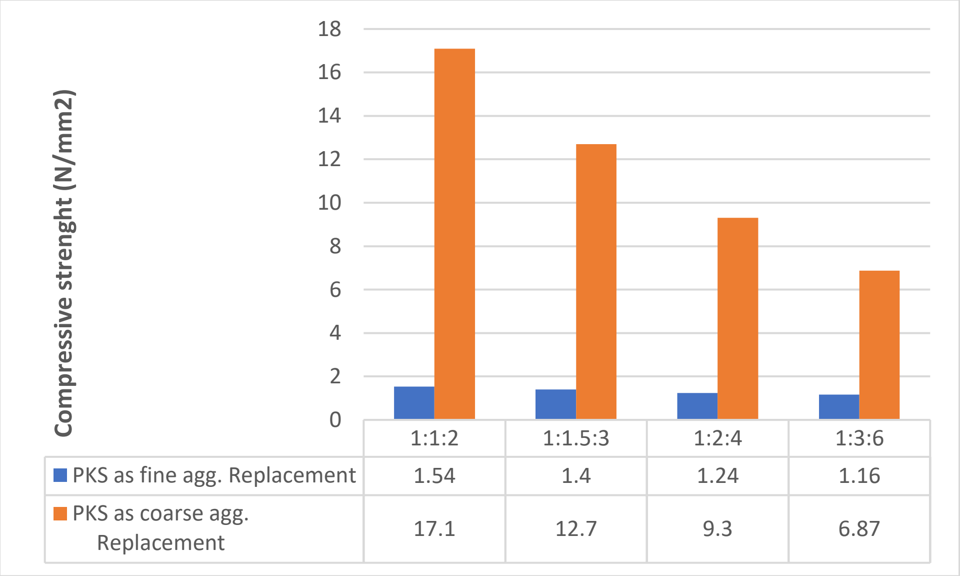
Table 4.3 compressive strength result

	Av. compressive strength (N/mm^2)	
mix ratio	**PKS as fine aggregate**	**PKS as coarse aggregate**
1:1:2	1.54	17.1
1:1.5:3	1.4	12.7
1:2:4	1.24	9.3
1:3:6	1.16	6.87

From fig 4.4, it is observed that the compressive strength of PKS as coarse aggregate replacement has an appreciable strength compared to concrete of PKS as fine aggregate replacement. The compressive strength of 1:1:2 and 1:1.5:3 mix ratio of PKS as coarse aggregate replacement is about 87% greater than concrete of PKS as fine aggregate replacement. The compressive strength of 1:2:4 and 1:3:6 mix ratio of PKS as fine aggregate replacement are 1.24 N/mm^{2}and 1.16 N/mm^2 respectively.

As reported by Amarnath and Ramachandrudu (2012), bond between particles is to a large extent dependent on surface texture, cement paste bonds more adequately with rough surface. However, smooth surface on the interior part of the PKS aggregate in addition to the continuous presence of water will deter adhesive bonding between the aggregate, which leads to reduction in the bonding strength. Surface area of contact between the palm kernel shells require more cement for proper bonding. Since the content of cement in the concrete remained constant, the needed extra bonding was lacking leading to reduction in compressive strength.

Furthermore, reduced compressive strength can also be attributed to the mechanical properties of coarse aggregate, since palm kernel shells are weaker in weight than granite, a reduction in the quantity of coarse aggregate.



	1:1:2	1:1.5:3	1:2:4	1:3:6
🟦 PKS as fine agg. Replacement	1.54	1.4	1.24	1.16
🟧 PKS as coarse agg. Replacement	17.1	12.7	9.3	6.87

Fig 4.4 Graph of Compressive Strength of Concrete.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In general, palm kernel shell has a promising potential as a coarse aggregate in making a light weight structures then as fine aggregate. The PKS as coarse aggregate replacement can even be used for low strength application. Base on this investigation, the following conclusions were being drawn:

1. The slump values obtained at 0.6 water/cement ratio for PKS as coarse aggregate replacement fall within the range of medium workability as stated in BS 18811: part 103 (1988) while shear slump is obtained when PKS is used to replace fine aggregate in concrete. This shear slump occurs due to the absence of fine aggregates.

2.Accord to ASTM specification, the density obtained when PKS is used as coarse aggregate fall under lightweight concrete. Therefore, PKS as coarse aggregate can be adopted as filler in general, by so doing it will help in reducing dead weights on structures.

3. The compressive strength obtained for the specimen when PKS is used as coarse aggregate showed a remarkable decrease in strength when compared to the expected strength at 28 days curing of the mix ratios therefor the use of PKS completely in replacing aggregate in concrete should be discouraged.

5.2 Recommendations

From the result obtained, palm kernel shell is recommended to be used as a partial replacement of coarse aggregate (substitute material) in making a light weight concrete.

Further studies should be done on introduction of additives and to determine the effect it will have on concrete workability.

Subsequent studies on palm kernel shell concrete should allow a curing age of up to 90 days and above. More research is needed to reduce water absorptive nature of palm kernel shell in concrete.

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APPENDIX

1. Particle size distribution

Table for Sieve Analysis Result for Sand.

Sieve Sizes	Mass Retained	Mass retained2	Cum % Retained	Cum % finer
(mm)	1.21	0.40	0.4	99.60
4.75	7.83	2.61	3.01	96.99
2	15.44	5.15	8.16	91.84
1.18	225.21	75.07	83.23	16.77
0.6	40.99	13.66	96.89	3.11
0.3	8.04	2.68	99.57	0.43
0.15	0.62	0.21	99.78	0.22
0.075	0.66	0.22	100.00	0.00
Tray	300g			

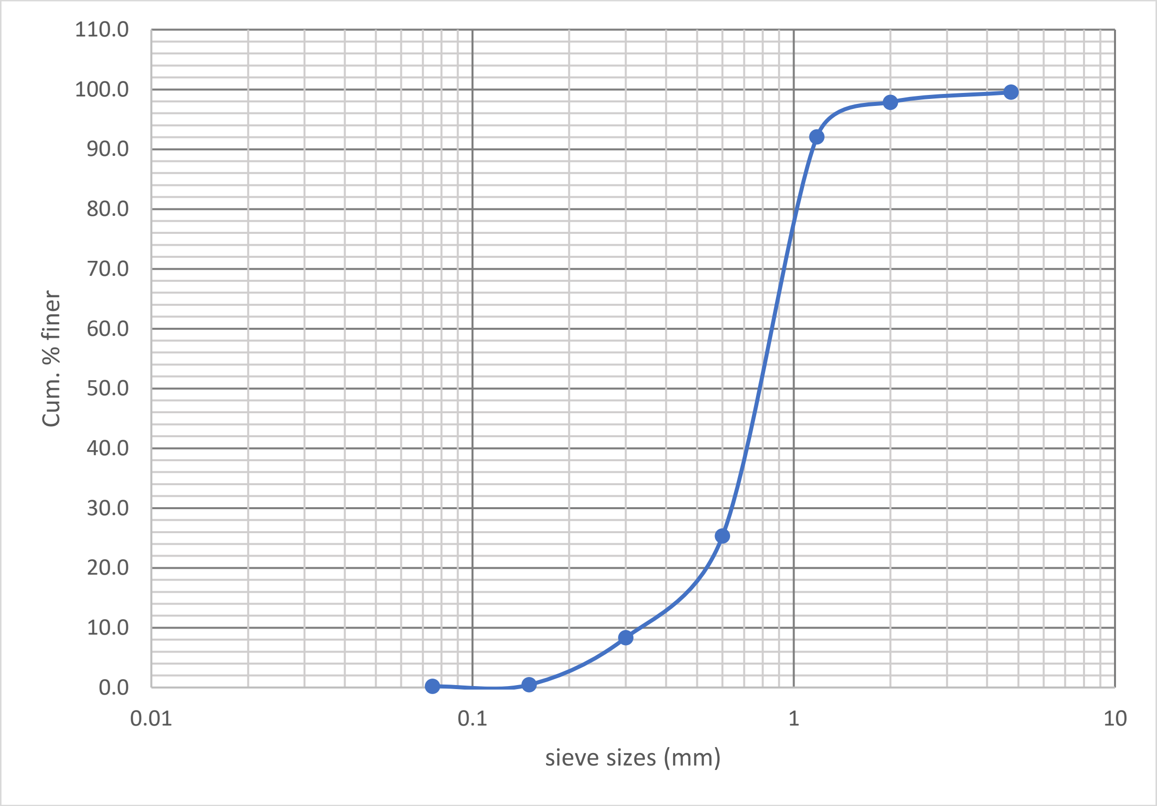
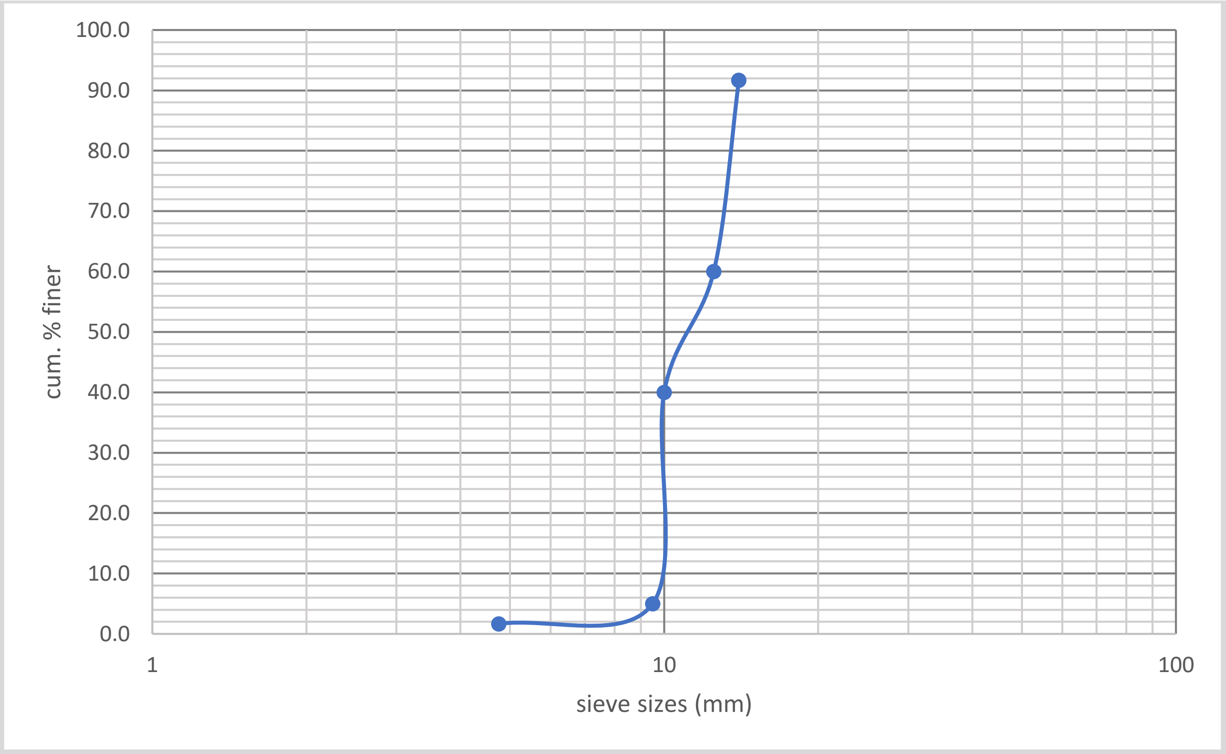


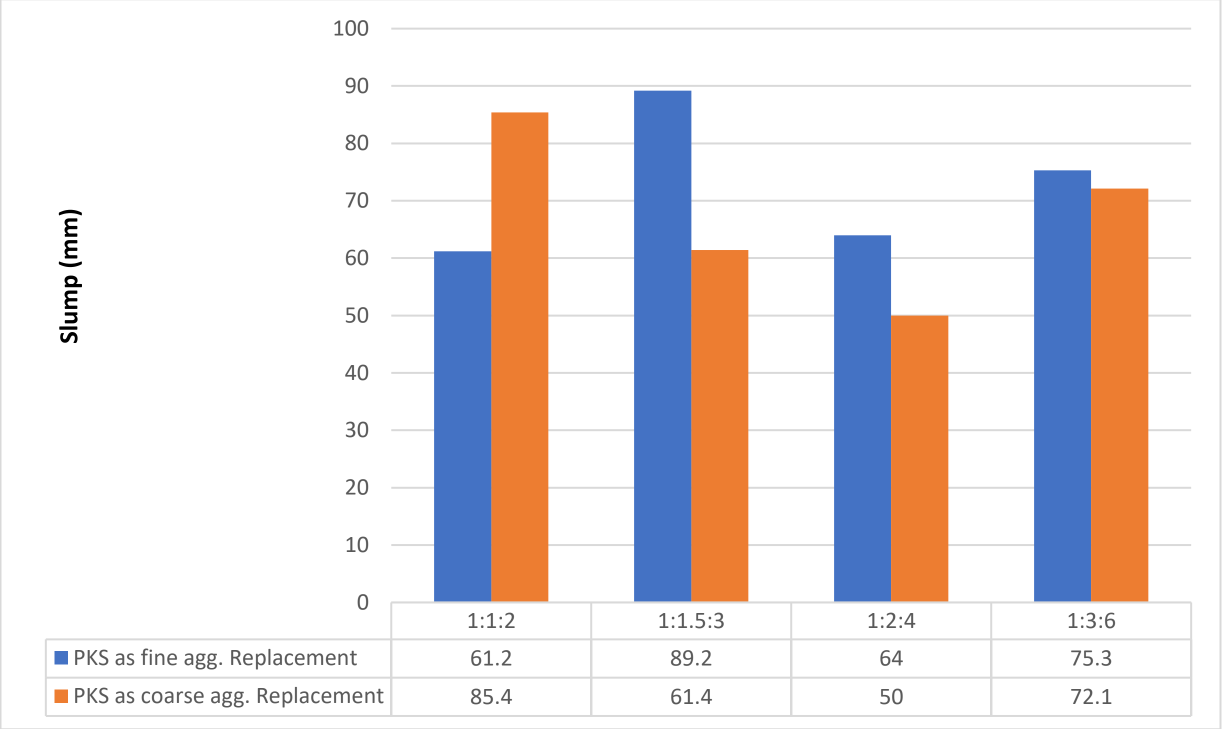
Table for Sieve Analysis Result for PKS.

Sieve Sizes (mm)	**Mass Retained**	**Mass retained2**	**Cum % Retained**	**Cum % finer**
14	**25**	**8.33**	**14.49**	**91.67**
12.5	**95**	**31.67**	**46.16**	**60.00**
10	**60**	**20.00**	**66.16**	**40.00**
9.5	**105**	**35.00**	**101.16**	**5.00**
4.75	**10**	**3.33**	**104.49**	**1.67**
Tray	**5**	**1.67**	**106.16**	**0.00**
Total	**300**	**37.50**		



2.Slump test table

	Slump value (mm)	
Mix ratio	**PKS as fine agg. Replacement**	**PKS as coarse agg. Replacement**
1:1:2	61.2	85.4
1:1.5:3	89.2	61.4
1:2:4	64	50
1:3:6	75.3	72.1



EFFECTS OF DIFFERENT SIZE OF COARSE AGGREGATE ON THE COMPRESSIVE STRENGTH OF CONCRETE

BY

MUONEKE, VIVIAN CHISOM

REG. NO: NAU/2016224045

A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING,

FACULTY OF ENGINEERING.

NNAMDI AZIKIWE UNIVERSITY, AWKA

JANUARY, 2022.

CERTIFICATION

This is to certify that this work titled “Effects of different size aggregate on the compressive strength of concrete” was carried out by me, Muoneke Vivian Chisom with registration number 2016224045 in the Department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka.

…………………………...   …   ……………………………

Muoneke, Vivian Chisom   Date

(Student)

APPROVAL

This project titled “Effects of different size of coarse aggregate on the compressive strength of concrete” has been approved for submission in the Department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka.

…………………………...
Engr. I. K. Omaliko
(Project Supervisor)

………………………………
Date

…………………………...
Engr.Dr. C. A. Ezeagu
(Head of Department)

…………………………………
Date

…………………………...
Engr, Prof. D.O. Onwuka
(External Supervisor)

…………………………………
Date

DEDICATION

I dedicate this work to God Almighty for his providence, grace and love he showed me throughout my stay in this university.

ACKNOWLEDGEMENT

I give tremendous thanks to Almighty God who made this work a success. My sincere gratitude goes to my impeccable project supervisor, Engr. I. K. Omaliko for his efforts, guidelines and encouragement which led to the success of this work.

I appreciate the Head of Department, Dr. A.C. Ezeagu for his dedication towards the affairs of the department, my lecturers and the entire staff of the Department of Civil Engineering for their various forms of assistance.

This acknowledgment will be incomplete without mentioning my beloved parents Chief and Lolo Lawrence Muoneke for your lovely care and dedication towards my life and my education, May God reward you. To my siblings, Chinenye, Kosi, and Chinaemerem I say, "I love you". I appreciate my supportive uncle, Hon, Chief Fabian Muoneke. I cherish also the time we shared my darling friends of mine, Chinenye, Chidera, Ruth, Bernard, Eke Emmanuel, Mairo, and Rafaela.May the good Lord continue to bless and guide you all in Jesus name.

ABSTRACT

Coarse aggregates, which is the interest of this study, make the difference. Three different types of coarse aggregates, with 20mm maximum size, employed in this investigation, these are; 12mm, 16mm, and 20mm. The grading and compressive strength of the aggregates were studied. The mix ratio and water/cement ratio adopted for the study was 1:2:4 and 0.55 respectively. Two concrete cubes (150mm x 150mm x 150mm) were cast for each coarse aggregate type of which two were crushed at each curing age namely; 7, 14, 21, and 28 days. The 28 day strengths of the concretes made with 20mm, 16mm, and 12mm were 26.20N/mm^2, 24.02N/mm^2, and 22.03N/mm^2 respectively, The 21 day strengths of the concretes made with 20mm, 16mm, and 12mm were 23.23N/mm^2, 21.85N/mm^2, and 18.17N/mm^2 respectively, The 14 day strengths of the concretes made with 20mm, 16mm, and 12mm were 21.24N/mm^2, 20.03N/mm^2, and 17.47N/mm^2 respectively and The 7 day strengths of the concretes made with 20mm, 16mm, and 12mm were 19.34N/mm^2, 17.55N/mm^2, and 15.53N/mm^2 respectively. Therefore, result shows that as the aggregate size increases, the compressive strength increases also with increasing curing days.

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CHAPTER ONE

INTRODUCTION

1.0 Introduction

Concrete is a composite material made of aggregate bonded together by liquid cement, which hardens over time (Woodford, 2016). The major components of concrete are cement, water, and aggregates (fines and coarse aggregate) with aggregates taking about 50 to 60% of the total volume, depending on the mix proportion. The amount of concrete used worldwide is twice that of steel, wood, plastics, and aluminum combined (Rajith and Amritha, 2015). According to Yaqub and Bukhari (2006), concrete's use in the modern world is exceeded only by that of naturally occurring water.

Concrete can be used either singular or reinforced with steel in order to achieve the required strength. Concrete builds durable, long lasting structures that will not rust, rot, or burn. It is widely used for making architectural structures, foundations, brick walls, bridges and many other civil engineering works. Concrete is used in large quantities almost everywhere humanity has a need for infrastructure because of its high compressive strength and durability (Ajamu and Ige, 2015).

Concrete is one of the most widely used construction materials. The raw material from which it is prepared: cement, aggregates and water affect both the quality and cost of construction. Aggregates are usually cheaper than cement and constitute over 70% of the volume of concrete. The availability and proximity of aggregate to the construction site also affect the cost of construction.

The compressive strength of concrete is one of its major properties that structural engineers take into consideration before erecting any structure (Hollaway, 2010). This property can be affected by many factors including water to cement ratio, degree of compaction, aggregate size and shape. Aggregate gradation plays an important role in concrete mixing. Unsatisfactory gradation of aggregates leads to segregation of mortar from the coarse aggregates, internal bleeding, need for chemical admixtures to restore workability, excessive water use and increased cement use (Loannides and Mills, 2006).

Aggregates constitute about 50 to 60% of the concrete mix depending on the mix proportion used. The larger the aggregate percentage in concrete mix, the stronger the concrete becomes (Waziri et al., 2011). Aggregates are the most mined material in the world. They are a component of composite materials such as concrete and asphalt concrete.

Curing can be achieved by keeping the concrete element completely saturated or as much saturated as possible until the water-filled spaces are substantially reduced by hydration products. According to (Hassan and Mohammed, 2014), curing concrete increase strength by up to 50% and also improve durability, making it more water tight and improve its appearance. If the concrete is not cured and is allowed to dry in air, it will gain only 50% of the strength of continuously cured concrete (Raheem, 2013).

A number of concrete structures around the globe cracks and lose stiffness when subjected to external load. Having premature deterioration of concrete is an international problem; the building industry needs to increase the load carrying capacity of structures by using concrete of high strength. In concrete structures, the mix proportion of the different components together with the aggregate type and size determine the compressive strength of hard concrete. According to (Adiseshu and Ganapati, 2011), larger aggregates demand lower water on its mix thus reducing the workability and increasing the compressive strength of concrete.

1.1 Background of study

Coarse aggregate plays an important role in concrete. To predict the behavior of concrete under general loading requires an understanding of the effects of aggregate type, aggregate size, and aggregate content. This understanding can only be gained through extensive testing and observation.

In normal-strength concrete, failure in compression almost exclusively involves deboning of the cement paste from the aggregate particles at what, for the purpose of this report, will be called the matrix-aggregate interface (Rozalija K., David D., 1997). In contrast, in high-strength concrete, the aggregate particles as well as the interface undergo failure, clearly contributing to overall strength. As the strength of the cement paste constituent of concrete increases, there is greater compatibility of stiffness and strength between the normal stiffer and stronger coarse aggregate and the surrounding mortar. Thus, micro cracks tend to propagate through the aggregate particles since, not only is the matrix-aggregate bond stronger than in concretes of lower strength, but the stresses due to a mismatch in elastic properties are decreased. Thus, aggregate strength becomes an important factor in high-strength concrete.

1.2 Statement of problem

It is a common practice in Nigeria to use locally found aggregates (washed and unwashed gravels) for construction purposes. The integrity of these aggregates should be investigated to ascertain their performance in structural members. Recent constructions in Nigeria, especially in Awka and its environs make indiscriminate use of aggregates notwithstanding their sources and not considering their physical condition at the time of use.

Coarse aggregates are obtained naturally or artificially and occupies up to 60% by weight or volume of the concrete, depending on the mix proportion adopted which, in turn, depends on the expected compressive strength. The compressive aggregate strength is an important factor in the selection of aggregate. When determining the strength of normal concrete, most concrete aggregates are several times stronger than the other components in concrete and therefore not a factor in the strength of normal strength concrete. For this reason, the quality of the coarse aggregates is essential when considering the quality of the concrete itself. The properties of coarse aggregates do grossly affect the durability and structural performance of concrete. Such properties as size, shape, and surface conditions of aggregates are considered alongside the mineral composition of the rock material from which theaggregate formed a part.

1.3 Aims and objectives

The aim of this project is to investigate the effects of different size of coarse aggregate on the compressive strength of concrete.

The objectives of this research are as follows:

1 To gather an abundance of pertinent information through an in-depth review of previous studies and pinpoint the areas that need to be addressed.

2 To carry out a sieve analysis of the fine and coarse aggregate.

3 To design the mix proportions.

4 To determine the workability of the fresh concrete.

5 Curing of all the concrete specimens for 7, 14, 21 and 28 days.

6 To determine the compressive strength of the hardened concrete.

1.4 Scope of work

The present work aims to determine the effects of different coarse aggregate sizes on the compressive strength of concrete using aggregates of sizes; 12mm, 16mm and 20mm, sieve analysis conducted to grade the aggregate. A cement mix ratio of 1:2:4, water cement ratio of 0.55 and curing days of 7, 14, 21 and 28 days was adopted for 24 cubes of size 150mm×150mm×150mm. They were casted with the components of the concrete batched by weight. The concrete cubes cured in water 24 hours after casting using the ponding method of curing. The compressive strength of the concrete at each aggregate size is determined using the load-testing machine available at the Engineering Laboratory Nnamdi Azikiwe University Awka.

1.5 Significance of study

Aggregate is commonly considered an inert filler, which accounts for 60 to 80 percent of the volume and 70 to 85 percent of the weight of concrete. Although aggregate is considered an inert filler, aggregates are necessary component that defines the concrete's thermal and elastic properties and dimensional stability.

For this reason, the quality of the coarse aggregates is essential when considering the quality of the concrete itself. The results from the work aim to serve as a guide in the building and construction industry while recommending the optimum size of coarse aggregate to use at a mix ratio of 1:2:4 and a water cement ratio of 0.55 to achieve maximum strength of hardened concrete after curing.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Concrete is a relatively new construction material when compared to earth, stone, timber and steel. However it is now the most widely used material for building and civil engineering constructions.

In 2011 alone, over of 27 billion tons was used (in comparison to only about 0.7 billion used in 1993) (Garba, 2014). Besides, if a concrete is to be suitable for a particular purpose, it is necessaryto select the constituent materials and combine them in such a manner as to develop constituents of concrete depends on the quality and economy of the particular concrete required.

Concrete is a composite material composed of coarse granular material (the aggregate) embeddedin a hard matrix of material (the cement or binder) that fills the space between aggregate particlesand glues them together. We can also consider concrete as a composite material that consists of a binding medium within which are embedded particles of fragments of fine aggregates (sand) and coarse aggregate (crushed granite, quartzite, or river gravel). So basically the simplest representation of concrete is;

Concrete = cement + fine aggregate +coarse aggregate +water

In light of the controversy, this report describes work that is aimed at improving the understandingof the role that coarse aggregate plays in the compressive strength of concrete. The role of coarse aggregate in concrete is central to this report. While the topic has been under study for many years,an understanding of the effects of coarse aggregate has become increasingly more important with the introduction of high strength concretes, since coarse aggregate plays a progressively more important role in concrete behavior as strength increases.

Concrete is the most widely used construction material in the world. It is used in many different structures such as dams, pavements, building frames and bridges. Also its worldwide production exceeds that of steel by a factor of 10 in tonnage and by more than a factor of 30 in volume. The present consumption of concrete is over 10 billion tons a year. It is more than 10 times of the consumption of steel by weight.

Concrete is the most inexpensive and the most readily available material. The cost of production of concrete is low compared with other engineering construction materials. Because concrete is a low temperature bonded inorganic material and its reaction occurs at room temperature, concrete can gain its strength at ambient temperature.

It can be formed into different into different desired shapes and sizes right at the construction sites. Concrete has low energy consumption for production compared with that of steel. Unlike wood and steel, concrete can harden in water and can withstand the action of water without serious deterioration. This makes concrete an ideal material for building structures to control, store and transport water examples include dams and concrete pipelines. Concrete conducts heat slowly and is able to store considerable quantities of heat from the environment and thus can be used as protective coating for steel structures.

2.2 Limitations of concrete

Besides being an ideal construction material, it does have the following limitations. Concrete has low tensile strength and hence cracks easily. Therefore, concrete is to be reinforced with mild steel bars, high tensile steel or mesh. Concrete expands and contracts with the changes in temperature.

Hence expansion joints are to be provided to avoid the formation of cracks due to thermal movements.

Fresh concrete shrinks on drying. It also expands and contracts with wetting and drying. Provision of contraction joints is to be made to avoid the formation of cracks due to dry shrinkage and moisture movements. Concrete is not entirely impervious to moisture and contains soluble salts which may cause efflorescence. This requires special care at the joints. Creeps develop in concrete under sustained loads and this factor is to be taken care of while designing dams and pre- stressed concrete structures.

2.3 Classification of concrete

based on Unit Weight

1. Ultra-light concrete: < 1,200 kg/m^3
2. Lightweight concrete: 1200- 1,800 kg/m^3
3. Normal-weight concrete: 2,400 kg/m^3
4. Heavyweight concrete: > 3,200 kg/m^3

Based On Strength

1. Low-strength concrete: < 20 MPa compressive strength
2. Moderate-strength concrete: 20 -50 MPa compressive strength
3. High-strength concrete: 50 - 200 MPa compressive strength
4. Ultra high-strength concrete: > 200 MPa compressive strength

2.4 Properties of concrete

To obtain a good quality concrete, its properties in both fresh and hardened states play important rules.

2.4.1 Properties of fresh concrete

Workability

Workability is a general term to describe the properties of fresh concrete. Workability is often defined as the amount of mechanical work required for full compaction of the concrete without segregation. This is useful definition because the final strength of the concrete is largely influenced by the degree of compaction. A small increase in void content due to insufficient compaction could lead to a large decrease in strength. The primary characteristics of workability are consistency (or fluidity) and cohesiveness. Consistency is used to measure the ease of flow of fresh concrete. And cohesiveness is used to describe the ability of fresh concrete to hold all ingredients together without segregation and excessive bleeding.

Segregation

Segregation of concrete means separation of ingredients from design fresh concrete resulting in the non-uniform mix. More specifically this implies the separation of coarse aggregates from the mortar because of differences in size, density, shape and other properties of ingredients in which they are composed. Because of segregation honeycomb is created in the concrete and it basically affects the strength of the concrete and its porosity. During construction work, segregation and concrete can occur on site and it affects the durability of your structures. If you are constructing your own house or working on a site you have to understand about segregation and concrete. In good concrete all the ingredients are properly distributed and make a homogeneous mixture. If a concrete sample exhibits a tendency for separation of coarse aggregates from the rest of the ingredients, it indicates segregation and concrete depending upon the dryness or wetness of the concrete mix.

Types of Segregation of Concrete

There are mainly 2 types; the coarser and the heavier particles tend to separate out or setting down from the rest of the mix because they tend to travel faster along a slope or settle more than finer materials. This type of segregation may occur if the concrete mix is too dry. Grout (water + cement) separating out from the rest of the material because of lowest specific gravity. This type of segregation may occur if the concrete mix is too wet. A well-designed concrete does not segregate if rightly mixed and batched.

Causes of Segregation in Concrete

The following are the major causes:

1. The difference in the specific gravity of the mix constituents (fine aggregates and coarse aggregate).
2. The difference in the size of aggregate.
3. Improper grading of aggregates.
4. Improper handling of aggregates.
5. Bad practices and handling and transporting of concrete.
6. Too much vibration of concrete.
7. Concrete that is not proportioned properly and not mixed adequately for 2 workable mix.
8. Placing of concrete from a greater height.
9. Concrete is discharged from a badly designed mixer or from a mixture with worn-out blades.

How to Prevent Segregation of Concrete

1. At the time of construction, especially while using transit mixers care should be taken that the concrete is not poured from a height greater that 1.5 meter.
2. Aggregates should be properly graded as it will prevent the segregation.
3. To improve the viscosity of concrete which prevents the segregation, air entraining agents can be used.
4. In case of mass concreting where mechanical vibrators are used care should be taken that they are not used for longer period.

Bleeding

Concrete mix design is a very precise science to achieve design concrete strength. If concrete ingredients are not mixed properly many concrete related problems can result and affect the strength and durability of concrete. Bleeding is one of the concrete related problems. It is mostly observed in a highly wet mix and badly proportioned concrete ingredients after placing of the fresh concrete. Free water in a mix rises upward to the concrete surface due to the settlement of solid particles by gravity action. This process is known as 'Bleeding of Concrete". In certain situation though bleeding water does not come up to the surface but bleeding does take place. The bleeding water gets trapped on the underside of coarse aggregates or of reinforcements. This is known as internal bleeding.

Effects of bleeding of concrete

1. The main effect of is that the concrete mixture loses its homogeneity, which results in weak and porous concrete.
2. It affects the bond between hardened cement paste and aggregates for reinforcement on account of higher water cement ratio.

3. Such concrete is easily prone to the micro cracking due to shrinkage stresses caused by dissipation of heat of hydration and drying shrinkage.
4. If the bleeding water carries with it more amount of the cement particles, a layer of laitance will be formed.
5. Due to bleeding the ability of pumping is very much reduced, which makes it difficult where concrete is to be pumped for higher elevations.

How to prevent bleeding of concrete

1. Bleeding of concrete depends on the properties of cement. Bleeding gets decreased by increasing the fineness of cement because finer particles hydrate earlier and also their rate of sedimentation is lower.
2. The properties of cement are not an only soul factor influencing the bleeding of concrete.
3. The presence of fine aggregates and higher water cement ratio also lead to bleeding. A higher rate of the water cement ratio can lead to excessive bleeding and if evaporation of water from the surface of the concrete is faster than the bleeding rate plastic shrinkage cracking may result.
4. Use of air entraining admixtures can also reduce the bleeding in concrete

2.4.2 Properties of Hardened Concrete

Hardness

The hardness of concrete is referenced by its compressive strength. The higher the compressive strength, the harder the material.

Strength

Strength with regard to concrete for structural purposes it can be defined as the unit force required to cause rupture. Concrete is considered by many to be a strong and durable material, and rightfully so. But there are different ways to assess concrete strength. Perhaps even more importantly, these strength properties each add different qualities to concrete that make it an ideal choice in various use cases

Compressive strength

Concrete is used mainly so as to exploit its good compressive strength. The compressive strength of concrete is the load applied on hardened concrete per unit area of the specimen symbolized by N/mm^2. Neville and Brooks (2000) consider the fracture mechanics approach for concrete under bi-and tri-axial stresses and under uniaxial compression.

Tensile strength of concrete

Tensile strength is the ability of concrete to resist breaking or cracking under tension. It affects the size of cracks in concrete structures and the extent to which they occur. Cracks occur when tensile forces exceed the tensile strength of the concrete.

Traditional concrete has a significantly lower tensile strength as compared to compressive strength. This means that concrete structures undergoing tensile stress must be reinforced with materials that have high tensile strength, such as steel.

It is difficult to directly test the tensile strength of concrete, so indirect methods are used. The most common indirect methods are flexural strength and the split tensile strength.

The split tensile strength of concrete is determined using a split tensile test on concrete cylinders. The test should be performed according to the ASTM C496 standard.

Flexural strength of concrete

Flexural strength is used as another indirect measure of tensile strength. It is defined as a measure of an unreinforced concrete slab or beam to resist failure in bending. In other words, it is the ability of the concrete to resist bending.

Flexural strength is usually anywhere from 10 to 15 percent of the compressive strength, depending on the specific concrete mixture.

There are two standard tests from ASTM that are used to determine the flexural strength of concrete C78 and C293. Results are expressed in a Modulus of Rupture (MR) in psi.

Flexural tests are very sensitive to concrete preparation, handling, and curing. The test should be conducted when the specimen is wet. For these reasons, results from compressive strength tests are more typically used when describing the strength of concrete, as these numbers are more reliable.

Factors affecting the strength of concrete

The strength of concrete is usually affected by many factors, in this project work, such factors are discussed with particular reference to the compressive strength. The factors include:

Cement

Cement is considered as the main constituent of concrete in terms of strength development. (Gupta and Gupta 2012) define cement as a material having adhesive and cohesive properties which makes it capable of bonding material fragments into a compact mass. Cement and water constituents of concrete chemically react to form a binding medium (Garba, 2014). When cement paste hardens, it binds the aggregate into an artificial stone-like material called concrete. According to

Dunuweera (2017), Cement is produced by utilizing an extensive amount of raw materials treated and reacted at extreme conditions such as high temperatures.

Aggregate

Aggregates constitute the skeleton of concrete. Approximately three-quarters of the volume of conventional concrete are occupied by aggregate. It is inevitable that a constituent occupying such a large percentage of the mass should contribute important properties to both the fresh and hardened product. Aggregate is usually viewed as an inert dispersion in the cement paste. However, strictly speaking, aggregate is not truly inert because physical, thermal, and, sometimes, chemical properties can influence the performance of concrete (Neville and Brooks, 2000).

Water

Water is one of the most important ingredients of concrete as it actively participates in the chemical reaction with cement. This is why (Neville and Brook2000) reiterates that the quality of water is important because impurities in it may interfere with the setting of cement, may adversely affect the strength of the concrete or cause staining of its surface, and may also lead to corrosion of reinforcement.

However, according to Shetty (2009), MacCarthy (2010), Sabraini (2010) Garba et al. (2014), mixing water induce hydration process in concrete production (which is responsible for strength development) and assist in workability (which enables concrete to be easily mixed, transported placed and compacted). The reaction between cement and water is as follows;

$$2Ca_3SiO_5 + 6H_2O \rightarrow 3Ca(OH)_2 + Ca_3Si_2O_7.3H_2O \quad (2.1)$$

$$Ca_3(AlO_3)_2 + 6H_2O \rightarrow Ca_6(AlO_3)_2.6H_2O \quad (2.2)$$

Numerous studies have been carried out on the effect of water quality on the strength and durability characteristics of a cement concrete. It was generally observed by virtually all the researchers suchas McCarthy (2010), Sabraini (2010), Gupta and Gupta (2012) and Garba (2014) that the quality of mixing water for concrete production should be as good as drinking water. However, this statement was not agreed by Shetty (2009), he argues that some water containing small amount ofsugar could be suitable for mixing concrete and conversely water suitable for mixing concrete maynot necessary be fit for drinking.

He emphasizes that the best course to find out whether a particular type of water is suitable for concrete making or not, is, to make concrete with this water and compare its 7 days' and 28 days' strength with comparison cubes made with distilled water. If the compressive strength is up to 90%, the source of water may be accepted. Besides that, there is relationship between the quality of mixing waters used in the construction of a structure with the setting time strength, stability, safety and serviceability of that structure. Noruzman et al. (2012) carried out a research in which they noted that the initial setting time of cement paste and the compressive strength tests are the two methods by which questionable water may be tested with respect to its suitability for concrete production.

Also, the presence of harmful oxides, such as MgO, SO_3 and other alkalis, in mixing water affects the quality of the hardened concrete (Reddy, 2013). Since water may contain some impurities suchas clay, sugar, oil, salt etc., which may not be within the tolerable concentration as clarified by (Shetty 2009). The quality of water is to be critically monitored and controlled during the process of concrete making.

Water to cement ratio

Water to cement ratio (W/C) ratio is one of the most important parameters governing the strength of concrete. The density of hardened cement (in terms of a gel/space ratio) is governed by the water/cement ratio. With higher w/c ratio, the paste is more porous and hence the strength is lower. The strength continues to increase with decreasing w/c ratio only if the concrete can be fully compacted.

For concrete with very low w/c ratio, if no water-reducing agent is employed, the workability can be so poor that a lot of air voids are entrapped in the hardened material. The strength can then be lower than that for concrete with higher w/c ratio. For a given set of materials and environment conditions, the strength of a concrete age depends only on the water-cement ratio, providing full compaction can be achieved. The standard water-cement ratio is 0.5.

Coarse to fine aggregate ratio

The following points should be noted for coarse/fine aggregate ratio:

1. If the proportion of the aggregate is increased in relation to the coarse aggregate, the overall aggregate surface area will increase.
2. If the surface area of the aggregate has increased, the water demand will also increase.
3. Assuming the water demand has increased, the water-cement ratio will increase.
4. Since the water-cement ratio has increased, the compressive strength will decrease.

Aggregate to cement ratio

The following points should be noted for aggregate-cement ratio:

1. If the volume remains the same and the proportion of cement in relation to that of sand is increased, the surface area of the solid will increase.

2. If the surface area of the solid has increased, the water demand will stay the same for the constant workability.
3. Assuming an increase in cement content for no increase in water demand, the water-cement ratio will decrease.
4. If the water-cement ratio reduces, the strength of the concrete will increase.

Age of concrete

The degree of hydration is synonymous with the age of concrete provided that the concrete has not been allowed to dry out or the temperature is too low. In theory, provided that the concrete is not allowed to dry out, then it will always be increasing albeit at an ever reducing rate. For convenience and for most practical applications, it is generally accepted that the majority of the strength has been achieved by 28 days.

The 7th day strength can range from 60% - 80% of the 28th day strength, with a higher percentage for a lower w/c ratio. After 28 days, the strength can continue to go up. Experimental data indicates that the strength after one year can be over 20% higher than the 28 days strength. The reliance on such strength increase in structural design needs to be done with caution, as the progress of cement hydration under real world conditions may vary greatly from site to site.

Compaction of concrete

Once the concrete has been placed, it is ready to be compacted. The purpose of compaction is to get rid the air voids that are trapped in loose concrete. Air voids reduce the strength of the concrete. For every 1% of entrapped air, the strength falls by somewhere between 5% and 7% (Gambhir, 1999). This means that concrete containing a mere 5% air voids due to incomplete compaction can lose as much as one third of its strength. Air voids also increase concrete permeability. That in turn reduces its durability.

If the concrete is not dense and impermeable, it will not be watertight. It will be less able to withstand aggressive liquids and its exposed surfaces will weather badly. The difference between air voids and entrapped air bubbles should be noted at this stage. The air bubbles that are entrained are relatively small and spherical in shape, increase frost resistance. Entrapped air on the other hand tends to be irregular in shape and is detrimental to the strength of the mix. In order to remove both, the concrete must be properly compacted.

Curing of Concrete

It should be clear from what has been said above, that the detrimental effects of storage of concrete in a dry environment can be reduced if the concrete is adequately cured to prevent excessive moisture loss. Curing is the process of protecting the freshly poured concrete from evaporation and temperature extremes which might adversely affect cement hydration. Curing ensures the continuation of hydration of cement and the strength gain of concrete. Concrete surfaces are cured by sprinkling with water. Most of the strength gain and take place within the first month of concrete's life cycle but hydration continues at slower rate for many years. Concrete continues to get stronger as it gets older.

Durability

Concrete has been considered as a material that can bear both internal and external exposure conditions requiring little or no maintenance. This assumption proved valid except when it is subjected to severe or aggressive environment. A durable concrete is one that serves the purpose for which it was designed for, for the specified service condition and the lifespan. Gambo (2014), defines durability of cement concrete as its resistance to deteriorating agencies to which it may be exposed during its service life or which may inadvertently reside inside the concrete itself.

The durability of concrete is affected by physical, mechanical and chemical causes but is mostly affected by chemical causes, which result in volume change, cracking of concrete and ultimately leading to deterioration of concrete. This is the reason why Gupta and Gupta (2012) discussed the effect of chemical causes on the durability of concrete under the following headings: sulphate attack; acid attack; Sea water attack; alkali aggregate reaction; deicing salts effect and carbonation.

Impermeability

The impermeability of concrete refers to the property of concrete that cannot be pervaded by water oil and other liquids with pressures. It plays an important role in the durability of concrete.

Dimensional change

The dimensions of concrete change when there is elastic deformation under applied loading, creep deformation under sustained loading, thermal expansion or contraction under temperature variation, and swelling or shrinkage under moisture content variation.

Workability of concrete

Workability is a general term to describe the properties of fresh concrete. Workability is often defined as the amount of mechanical work required for full compaction of the concrete without segregation. This is useful definition because the final strength of the concrete is largely influenced by the degree of compaction. A small increase in void content due to insufficient compaction could lead to a large decrease in strength.

The primary characteristics of workability are consistency (or fluidity) and cohesiveness. Consistency is used to measure the ease of flow of fresh concrete. And cohesiveness is used to describe the ability of fresh concrete to hold all ingredients together without segregation and excessive bleeding.

Factors affecting workability

1. **Water content**: Except for the absorption by particle surfaces, water must fill the spaces among particles. Additional water "lubricates" the particles by separating them with a water film. Increasing the amount of water will increase the fluidity and make concrete easy to be compacted. Indeed, the total water content is the most important parameter governing consistency. But, too much water reduces cohesiveness, leading to segregation and bleeding. With increasing water content, concrete strength is also reduced.
2. **Aggregate mix proportion**: For a fixed w/c ratio, an increase in the aggregate/cement ratio will decrease the fluidity. (Note that less cement implies less water, as w/c is fixed.) Generally speaking, a higher fine aggregate/coarse aggregate ratio leads to a higher cohesiveness.
3. **Maximum aggregate size**: For a given w/c ratio, as the maximum size of aggregate increases, the fluidity increases. This is generally due to the overall reduction in surface area of the aggregates.
4. **Aggregate properties**: The shape and texture of aggregate particles can also affect the workability. As a general rule, the more nearly spherical and smoother the particles, the more workable the concrete.
5. **Cement**: Increased fineness will reduce fluidity at a given water-cement ratio, but increase cohesiveness. Under the same water-cement ratio, the higher the cement content, the better the workability (as the total water content increases).
6. **Admixtures**: Air entraining agent and super plasticizers can improve the workability.

7. **Temperature and time**: As temperature increases, the workability decreases. Also, workability decreases with time. These effects are related to the progression of chemical reaction.

Workability test

Workability of concrete has never been precisely defined, but for practical purposes it generally implies the ease with which a concrete mix can be handled from the mix to its final compacted shape. The measurement of workability of fresh concrete is important in assessing the practicability of compacting the mixture and also in maintaining consistency throughout the job. In addition, workability tests are often used as an indirect check on the water content and therefore on the water/cement ratio of the concrete (Barnbrook et al., 1979).

The types of workability test are;

a. Slump test.
b. Compaction factor test.
c. Flow test.
d. Vee-Bee consistometer test.
e. Kelly ball test.

Slump test

The concrete slump test or slump cone test is the most common test for workability of freshly mixed concrete which can be performed either at the working site/field or in the laboratory. To maintain the workability and quality of fresh concrete, it is necessary to check batch by batch inspection of the concrete slump. This can be easily done with the concrete slump test. The slump test is the simplest test to determine workability of concrete that involves low cost and provides immediate results. Slump test is done in accordance to BS 1881: 103 :1993.

Three different kinds of possible slumps exist; true slump, shear slump, and collapse slump. Conventionally, when shear or collapse slump occur, the test is considered invalid. However, due to recent development of self-compact concrete, the term of collapse slump has to be used with caution.

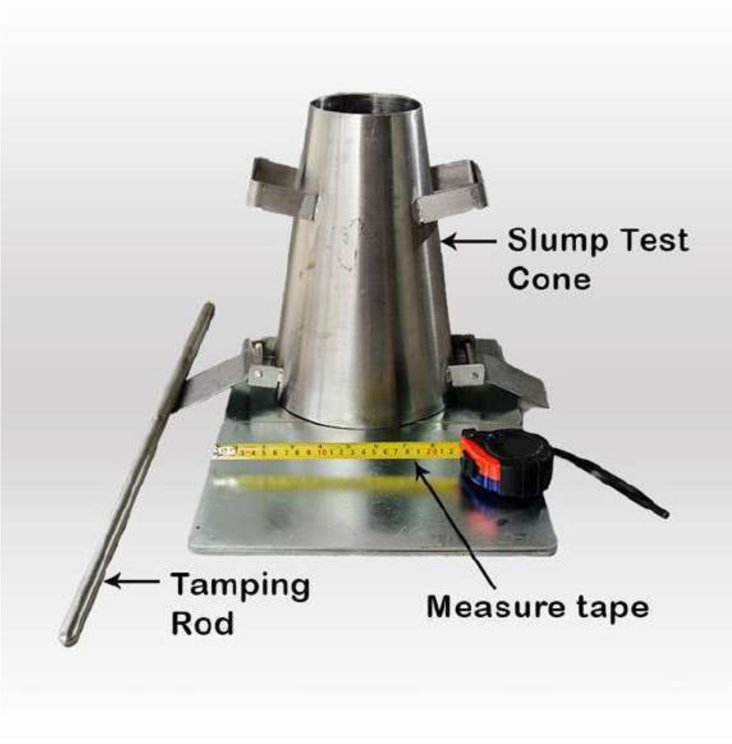

Plate 2.1: Slump Test Apparatus.

Compaction factor test

Compaction factor test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. This is specially designed for laboratory use, but if the circumstances favours, it can also be used on the working site/field.

Compaction factor test of concrete is more precise and sensitive than the concrete slump test; hence it is more favorable and useful for low workable concrete or dry concrete which is generally used when concrete is to be compacted by vibration. Compaction factor test is done in accordance to BS 1881: 103 :1993.

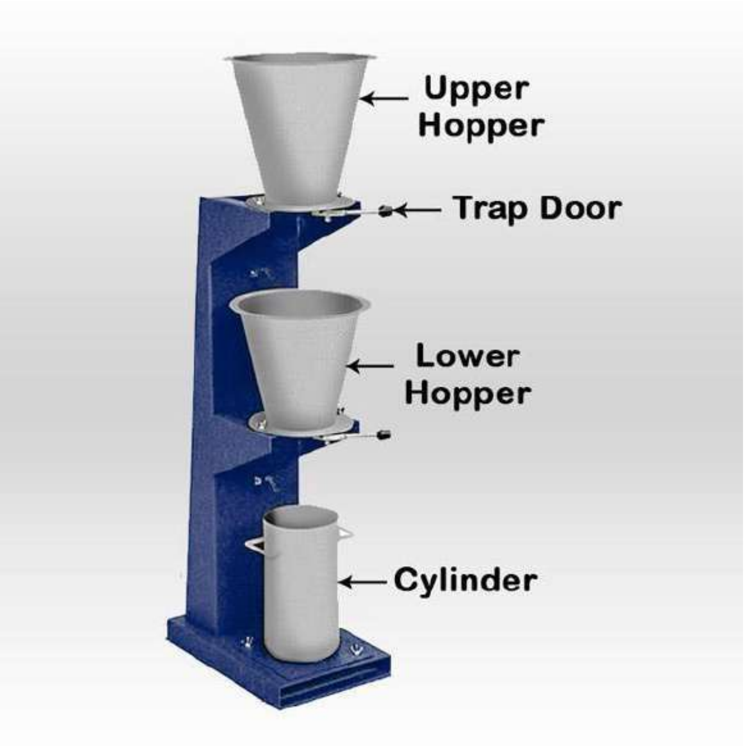

Plate 2.2: Compaction Factor Apparatus

The flow test

The flow test is a laboratory test, which gives an indication of the quality of concrete with respect to consistency or workability and cohesiveness. In the flow test, a standard mass of concrete is subjected to jolting. This test is generally used for high/ very high workability concrete.

Similar laboratory test named ‘Flow Table Test ‘was developed in Germany in1933 and it has been described in ‘BS 1881:105: 1984’. This method is used for the high and very high workable concrete which would exhibit the collapse slump.

Plate 2.3: Flow Test Apparatus

Vee bee consistometer test

Vee bee consistometer test is a good laboratory test on fresh concrete to measure the workability in an indirect way by using a Vee-Bee consistometer. Vee bee test is usually performed on dry concrete and it is not suitable for very wet concrete. Vee bee consistometer test determines the mobility and to some extent compatibility of concrete. In the vee bee consistometer test vibrator is used instead of jolting. Vee bee test determines the time required for the transformation of concrete by the vibration. This test is done in accordance to BS EN 12350-3: 2009.

Plate 2.4: Vee-Bee Apparatus

Kelly ball test

This test is developed by J.W Kelly, hence it’s known as a Kelly ball test. Kelly ball test is a simple and inexpensive field test which measures workability of fresh concrete with the similar to the concrete slump test, but it is more accurate and faster than a slump test. This test uses a device that consist of metal hemisphere (ball) thereby indicating the consistency of fresh concrete by its level of penetration when the metal hemisphere drops. Thus, in this test, depth is determined through metal hemisphere, which sinks under its own weight into fresh concrete. This test is done in accordance to ASTM C360-92 – For ball penetration test

Plate 2.5: Kelly Ball Apparatus

Setting of concrete

Setting is defined as the onset of rigidity in fresh concrete. It is different from hardening, which describes the development of useful and measurable strength. Setting precedes hardening although both are controlled by the continuing hydration of the cement.

2.5 Review Of The Existing Literature

Young and Sam (2008) reported that smooth rounded aggregates was more workable but yielded a lesser compressive strength in the matrix than irregular aggregates with rough surface texture. They were also of the opinion that a fine coating of impurities such as silt on the aggregate surface could hinder the development of a good bond and thus affects the strength of concrete produced with the aggregates.

Chen and Liu (2004) as well as Rao and Prasad (2002) viewed aggregates as the skeleton of concrete and consequently persuaded that all forms of coatings should be avoided in order to achieve a good concrete. When a concrete mass is stressed, failure may originate within the aggregates, the matrix, or at the aggregate-matrix interface. The aggregate-matrix interface is an important factor determining the strength of concrete.

Bloem and Gaynor (1963) studied the effect of shape, surface texture, fine coatings, and maximum size of aggregates on the water requirement and strength of concrete. The study reported that at equal water/cement ratio, irregular shaped smaller sized aggregates without coatings achieved a better strength than smooth rounded large sized aggregates. They also opined that individual properties of aggregates and the magnitude of the size difference may lead to increase or decrease in concrete strength at a fixed cement content.

Aginam et al. (2013) investigated the effect of coarse aggregate types on the compressive strength of concrete on three different types of coarse aggregates, with 20mm maximum size, was employed in the investigation, namely; crushed granite, washed gravel, and unwashed gravel. The grading and relative densities of the aggregates was studied. The mix ratio and water/cement ratio adopted for the study was 1:3:6 and 0.6 respectively. The target mean strength at 28 days was 15N/mm^2. Twelve concrete cubes (150mm x 150mm x 150mm) were cast for each coarse aggregate type of which four were crushed at each maturity age namely; 7, 14, 21, and 28 days. All cubes reached the target mean strength after 7 days of curing. The 28 days strengths of the concretes made with crushed granite, washed gravel, and unwashed gravel were 25.1 N/mm^2, 20.0 N/mm^2, and 16.9 N/mm^2 respectively. Consequently, the authors concluded that the strength of concrete depends greatly on the internal structure, surface nature and shape of aggregates.

According to Bruce and Ndlangamandla (2016), the effect of aggregate size on the compressive strength of concrete. The experiment had three treatments, which were the aggregate sizes (9.5 mm, 13.2 mm and 19.0 mm) and the control. A constant mix of 1: 2: 4 with a water/cement ratio of 0.5 used throughout the experiment. Three cubes (150 mm× 150 mm) were casted from each batch and the compressive strength was determined using a concrete load-testing machine (Pro-Ikon cube press) after 7 days curing. The results reflected that workability (slump) increased with increasing aggregate size. The concrete made from the 9.5 mm, 13.2 mm and 19.0 mm aggregate sizes had workability (slumps) of 10 mm, 13.5 mm and 20 mm, respectively. The mean compressive strength for the 9.5 mm, 13.2 mm, and 19 mm were 15.34 N/mm^2, 18.61 N/mm^2 and 19.48 N/mm^2, respectively. They concluded that concrete workability was directly proportional to aggregate size. The mean concrete compressive strength increased with increasing aggregates size.

Abdullahi (2012) investigated the effect of aggregate type on compressive strength of concrete for a nominal mix (1:2:4), 75 cubes (150x150mm) were cast to allow the compressive strength to be monitored at 3, 7, 14, 21, and 28 days. Test result showed that concrete made from river gravel has the highest workability followed by crushed quartzite and crushed granite aggregates. Highest compressive strength at all ages with concrete made from quartzite aggregate followed by river gravel and then granite aggregate. The author proposed compressive strength models as a function of age at curing. In addition, where concrete practitioners have options, aggregate made from quartzite is advisable for concrete works.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Materials

3.1.1 Cement

The Portland-Limestone cement with the brand name of Dangote cement was purchased at Agu-Awka in Anambra state. It was stored in a dry environment to protect it from moisture to avoid the occurrence of lumps before the experiment.

3.1.2 Fine Aggregates

Fine aggregate used was dry river sand sourced locally from Ezu River in Anambra state and bought from the retailers in Agu-Awka. The sand was sun-dried before sieve analysis was carried out to rid it of impurities such as crushed stones and twigs. It was sieved to a particle size range between 0.15 -2.36mm which is within the range specified by BS112 (1971).

Plate 3.1: Sharp Sand

3.1.3 Coarse Aggregates

The type of coarse aggregate used throughout this investigation was washed granite. The effects of three different sizes of coarse aggregates were investigated in this research these sizes are 20mm, 16mm, and 12mm. These sizes were sourced from the quarries of Abakaliki and were bought from the local retailers in Agu-Awka in Anambra state. Sieve analysis tests were also conducted on the coarse aggregates for adequate confirmation of the sizes of the samples after they have been washed and dried.

Plate 3.2: Coarse aggregates

3.1.4 Water

Portable water at the Nnamdi Azikiwe University was used throughout this investigation and the tests were carried out at the Civil Engineering laboratory of the same University.

3.2 Methodology

The concrete mix proportions were batched by weight and the casting, curing and crushing were done in accordance with the guidelines specified by BS1881; Part108 (1983), BS8110; Part1, (1985), and BS1881; Part3 (1992).

150x150x150mm cubes were casted and the compressive strengths were investigated at 7, 14, 21 and 28 days of curing.

Each concrete mix proportion was the same except the variation in aggregate size. Eight cubes were cast for each aggregate size, two cubes for each curing age. The hardened concrete cubes are retrieved from the steel molds 24hours after casting and are placed in curing tanks. The concrete cubes are withdrawn from water in the curing tanks and allowed to dry for some hours before crushing. The average compressive strength is taken from the two cubes in each curing age

3.2.1 Mix Proportion

A nominal mix ratio of 1:2:4 (cement: fine aggregates: coarse aggregates) was adopted for the purpose of this work and water-cement ratio of 0.55 was used throughout the investigation. The mix composition was computed using the weight method and the batch compositions are shown below. To calculate the quality of materials required to cast 1 concrete cube at a mix ratio of 1:2:4by batching by weight.

Parameters

i. Density of concrete = 2400kg/m^3
ii. Size of cubes =150mm x 150mm
iii. Converting to meters = 0.15m by 0.15m

iv. Volume of cube = 0.15m × 0.15m × 0.15m = $0.00375m^3$

v. Weight of cube = $2400kg/m^3$ x $0.153m^3$= 8.1kg.

To determine the weight of the individual components

1:2:4 = cement: sand: aggregates; 1:2:4 = 7

Cement: 1/7 × 8.1 = 1.157kg

Sand: 2/7 × 8.1 = 2.314kg

Coarse aggregates: 4/7 × 8.1 = 4.629kg

Provide additional 10% on all concrete components to take care of wastage;

Cement = 1.157 + (10/100 × 1.157) = 1.157 + 0.1157 =1.2727kg

Sand = 2.314 + (10/100 × 2.314) = 2.314 + 0.2314 = 2.5454kg

Aggregate = 4.629 + (10/100 × 4.629) = 4.629 + 0.4629= 5.0919kg

To estimate the weight of water for one concrete cube using the chosen water-cement ratio of 0.55;

1.2727 x 0.55 = 0.6999kg

Converting water in kg to liters

1kg of water is approximately 1liter of water therefore for each concrete cube

0.6999liters of water must be maintained.

Table 3.1: Mix design for one concrete cube

CEMENT (Kg)	SAND (Kg)	COARSE AGGREGATE (Kg)	WATER (Kg)
1.2727	2.5454	5.0919	0.6999

3.2.2 Preliminary Test

In controlling the quality of aggregates, it is important to ensure that the aggregate is clean and does not contain any organic impurities which might retard or prevent the setting of the cement and that the proportions of the different sizes of the particles within a graded material remain uniform. Sometimes excessive silt and clay contained in the fine and coarse aggregates may result in increased shrinkage or increased permeability in addition to poor bond characteristics. It may also necessitate greater water requirement for workability.

Accurate tests for determining the proportions of clay, silt and dust in fine or coarse aggregates are given in clause 12 and 13 of BS 812 (Barnbrook et al., 1979), but these tests are suitable only for the laboratory. On site cleanness can be assessed visually, though for natural sands the field settling tests will give an approximate guide to the amount of clay or silt. Cleanness tests on the coarse aggregates was not considered as the coarse aggregate was visibly clean from silt and clayey components as the aggregates used were washed crushed quarry stones.

Sieve Analysis

Sieve analysis is referred to as the simple operation of separating a sample of aggregates into factions (groups) each consisting of particles of the same size. The main aim is to determine various sizes of particles present in aggregates and appropriately grading the aggregates.

Apparatus

a. Standard B.S test sieve
b. A weighing scale
c. Container used in the weighing.

Procedure for the sieve analysis

i. The aggregate specimen to be used (fine aggregate) is dried for 24 hours to rid specimen of any traces of moisture.
ii. Sieves are arranged from top to bottom in descending order.
iii. Weight of the container to be used in the specimen measurements is ascertained.
iv. Before the sample is used, they are sieved through a 4.75mm sieve for uniform sample; and the portion retained in the sieve was discarded while those passing were used to perform the particle size analysis.
v. A considerable measured quantity of the aggregate is placed in the sieves from the top.
vi. Sieving is done for about 5 hours manually.

For the coarse aggregate used, the aggregate was sieved through the 1inch sieve (25mm sieve) and those passing the sieve aperture and retained in the (20 mm) sieve were used to obtain that particular size of aggregate as those not passing the 1 inch sieve were discarded. This was to bring about uniformity in the aggregate used. The same procedure was repeated for sieve sizes 16mm, 12mm. Aggregates subsequently retained in sieve sizes 6.3mm, 5mm, 3.35mm and the pan were discarded.

Testing on fresh concrete

Slump Test

Workability of concrete has never been precisely defined, but for practical purposes it generally implies the ease with which a concrete mix can be handled from the mix to its final compacted shape. The measurement of workability of fresh concrete is important in assessing the practicability of compacting the mix and also in maintaining consistency throughout the job. The slump test was carried out on the fresh concrete after the mixing of each batch, the slump value is taken down and the used concrete is poured back into the mix and reblended. The slump test was carried according to specifications on BS EN 12350-2: 2009.

Determination of workability of concrete is as follows;

Apparatuses Used

a. A truncated slump cone (Truncated conical mold)
b. A tampering rod (16mm diameter and 600mm long)
c. Metallic rule
d. Flat tray (metallic)
e. Trowel
f. Spirit level

Procedure of the Test

i. Concrete is mixed with a water/cement ratio of 0.55 for 12mm, 16mm and 20mm aggregate size for uniformity throughout the project research.
ii. The inside of the mold should be cleaned before each testing and mold applied with lubricant (diesel oil) to prevent concrete from sticking to mold surface. The mold is then placed on the flat hard tray such that the wider surface is on the flat form or tray.

iii. The mold (height 300mm, top diameter 100mm and bottom diameter 200mm) is then filled with concrete in 3 layers of equal height with the use of a trowel. Compacting or rodding is carried on each layer with a minimum of 25 strokes with the tampering rod. After the top layer has been rodded, the surface of the concrete is struck off level with the top of the mold with a trowel.

iv. After leveling and smoothing top of the concrete with the mold/cone height, any spillage around the mold is cleaned away from around the base of the mold, and the mold is the lifted vertically from the concrete.

v. The slump is the difference between the height of the concrete before and after the removal of the mold. The tampering rod is placed on top of the cone to span across the concrete slump. The metallic rule is the used to measure the difference in height between the top of the cone and the top of the cone and the top of the slumped concrete.

Testing on hardened Concrete

Compressive test cubes

For aggregates with nominal size of 20mm (¾ inch) or less can be done in 100mm (4 inches) cubes. The 150mm cube was used in this investigation.

$$\text{Compressive strength} = \frac{Compressive\ Load, P\ (KN)}{Surface\ Area, A\ (mm^2)} \tag{3.1}$$

Details of the testing cubes, beams and cores as stated before are given in part 4 of BS 1881. The testing procedure is as follows;

Apparatuses Used

a. Steel molds (150 x150x150) mm^3 with base plates.

b. Tampering rods

c. Shovels for the concrete mixing
d. Hand trowels
e. Weighing balance

Procedure for the Manufacturing of the Test Cubes

i. The molds for the testing would be properly assembled, cleaned up and lubricated to prevent concrete from sticking to the molds surfaces or sides.
ii. Freshly prepared concrete mix is then placed in the molds in 3 layers, with each layer being effectively rammed with the tampering/ramming rod. The ramming of the concrete is carried out methodically, the strokes being evenly distributed over the surface of the concrete in regular pattern and not concentrated in one particular spot.
iii. The test specimens are kept in conditions of constant room temperature and allowed to set for 24hrs of which they are subsequently demolded and marked before putting them in curing tanks until time of testing.
iv. Cube is removed from the curing tank and dimensions and weight of the cube is duly noted.
v. The bearing surface of the testing machine is wiped clean and the cube placed in the compression machine in such a way that the load is applied to the surface of the cube. The axis of the cube must be carefully aligned with the center thrust of the machine.
vi. The load from the machine is applied to the cube by pulling on the machine level handle repeatedly until such a point when the concrete cube show signs of failure or crushing.
vii. The compressive strength is then recorded.

Batching

Generally, the components of concrete in various proportions can be batched by weight or volume. The batching process was done by weight as this is preferable in most cases because of its degree of accuracy. All the concrete constituents were weighed out, from calculations of required mix quantities using the bulk densities of the constituents as well as the volume of mix required to obtain the weights required. The mixing was performed on the floor of the laboratory premises by hand mixing using a shovel and a trowel.

The mixing process was done with measured amount of water, measured amount of fine aggregate, and a well measured amount of coarse aggregate (which could be of 20mm, 16mm, 12mm size) and was mixed together with a mix design ratio of 1:2:4 before it was poured into a concrete cube of 150mm by 150mm.

The coarse aggregates used were of approximately uniform grading at each size and water/cement ratio was also constant throughout the mixing as effectively calculated. This is because it is a well-known fact that concrete strengths vary with aggregate (coarse) grade or sizes as well as water/cement ratio. These were all done to provide for a uniform basis for clearly distinguishing the effects of the coarse aggregate sizes on the compressive strength of concrete.

Mixing Procedure

As obtained from the mix calculations by weight, 1.2727kg of cement, 2.5454kg of sand and5.0919kg of coarse aggregate was the quantity of components adequate for one concrete cube. Subsequently for 8 cubes 10.1816kg was weigh out and mixed with20.3632kg of fine aggregate (sand) until an even mix was obtained. Thereafter, 40.7352kg of gravel was weighed out and added to the cement and sand mixture and water of 5.5992kg in conformity with a 0.55 water-cement ratio was gradually added to the mixture. The mixture was gradually stirred with a shovel as the water was added to bring about an even concrete paste.

Plate 3.3: Hand mixing of concrete

Details of the testing of cubes, beams and cones as stated before are given in part 4 of BS 1881.The testing procedure is as follows. Cube is removed from the curing tank and dimensions and weight of then cube duly noted. The Bearing surface of the testing machine is wiped clean and the cube placed in the compression machine in such a way that the load is applied to the surface of the cube. The axis of the cube must be carefully aligned with the center thrust of the machine. The load from the machine is applied to the cube by pulling on the machine lever handle repeatedly until such a point when the concrete cube show signs of failure or crushing. The compressive strength is then recorded.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Sieve Analysis For Fine Aggregates

Weight of container used for measurements – 110.42 grams

Weight of sample plus the container - 410.42 grams

Weight of test sample used - 300 grams

Table 4.1: Sieve analysis results for fine aggregates

Sieve Size (mm)	**Weight Retained (g)**	**% Weight Retained**	**Cumulative % Retained (g)**	**Cumulative % Passing (g)**
2.00	6.03	2.01	2.00	97.99
1.60	1.61	0.54	2.50	97.45
1.40	49.03	16.34	18.90	81.11
0.80	140.03	45.67	65.60	34.44
0.40	77.52	25.84	91.40	8.60
0.25	23.23	7.74	99.00	0.86
Sieve Pan	2.55	0.85	100	0.00
Total	**300**	**100**		

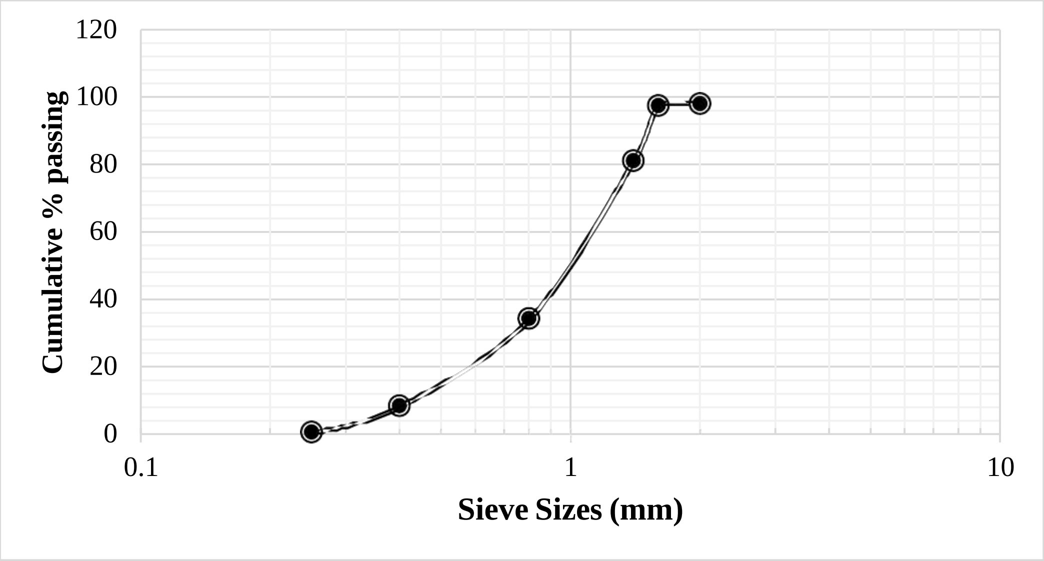

Figure 4.1: Sieve analysis for fine aggregate

4.2 Sieve Analysis for Coarse Aggregates

Table 4.2: Sieve analysis results for coarse aggregate (20mm)

Sieve Size (mm)	**Weight Retained (g)**	**% Weight Retained**	**Cumulative % Retained (g)**	**Cumulative % Passing (g)**
31.50	0.0	0.00	0.00	100.00
26.50	175.0	8.75	8.75	91.25
20.00	561.5	28.08	36.83	63.17
14.00	112.3	56.15	92.98	7.02
10.00	140.5	7.02	100.00	0.00
4.75	0.0	0.00	100.00	0.00
Tray	0.0	0.00	0.00	0.00
Total	**2000.00**	**100.00**		

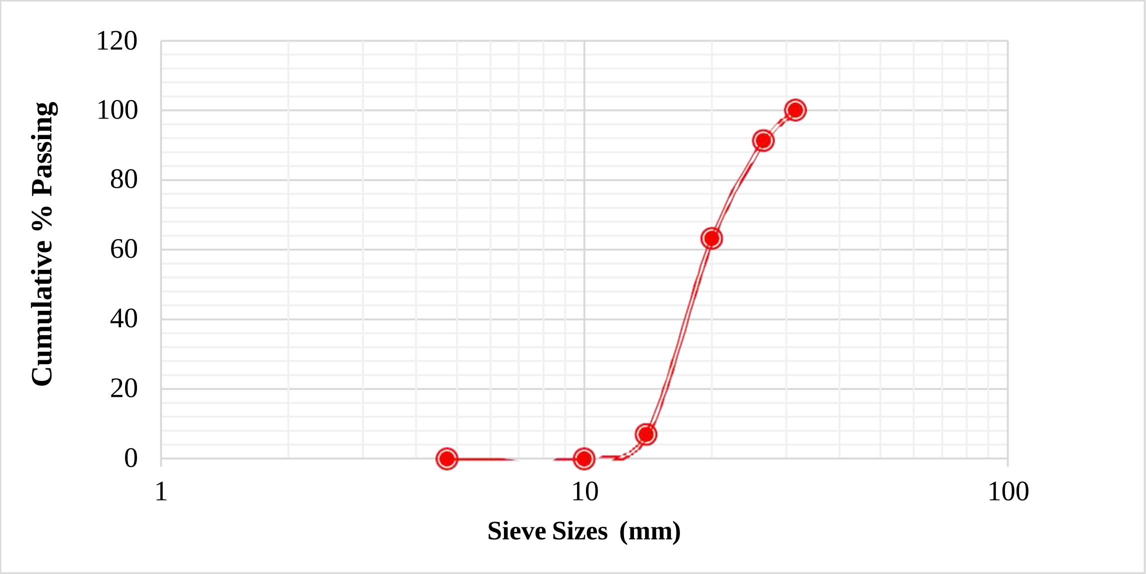

Figure 4.2: Sieve analysis graph for 20mm coarse aggregates

Table 4.3: Sieve analysis results for coarse aggregate (16mm)

Sieve Size (mm)	Weight Retained (g)	% Weight Retained	Cumulative % Retained (g)	Cumulative % Passing (g)
31.50	0	0.00	0.00	100
26.50	250	12.50	12.50	87.50
20.00	450	22.50	35.00	65.00
14.00	1000	50.00	85.00	15.00
10.00	200	10.00	95.00	5.00
4.75	100	5.00	100.00	0.00
Tray	0	0.00	0.00	0.00
Total	**2000**	**100.00**		

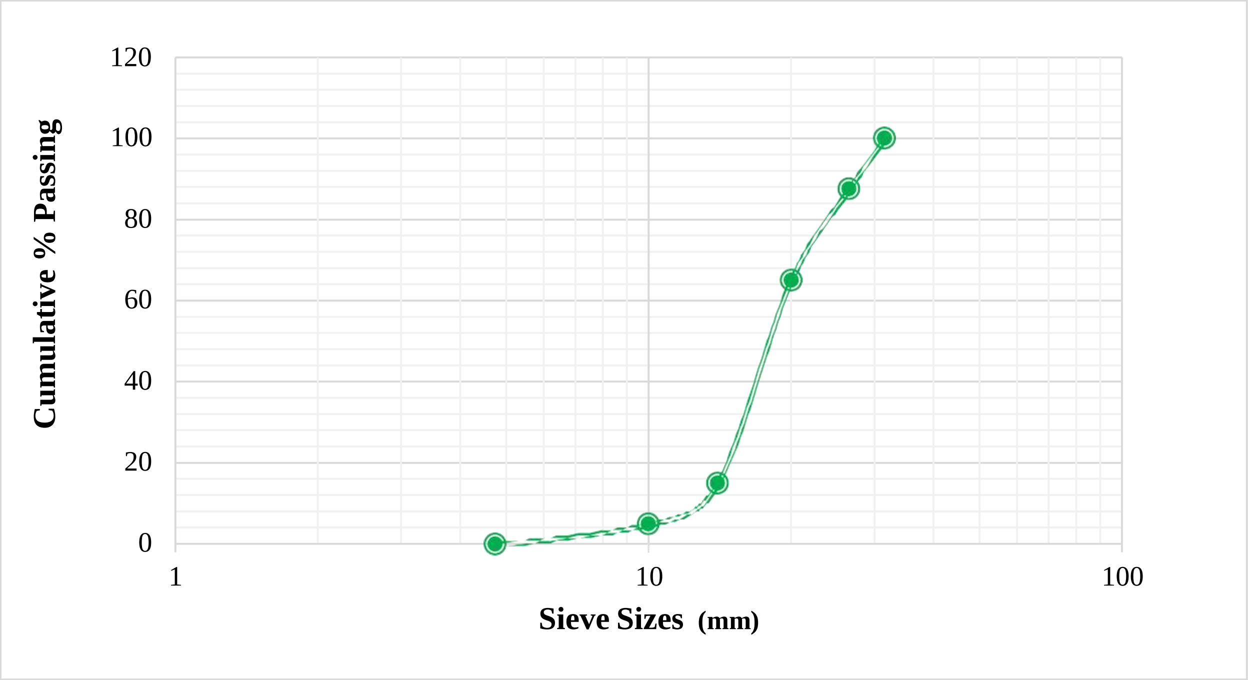

Figure 4.3: Sieve analysis results for 16mm coarse aggregate

Table 4.4: Sieve analysis results for coarse aggregate (12mm)

Sieve Size (mm)	**Weight Retained (g)**	**% Weight Retained**	**Cumulative % Retained (g)**	**Cumulative % Passing (g)**
31.50	0	0	0	100
26.50	0	0	0	100
20.00	0	0	0	100
14.00	900	45	45	55
10.00	1000	50	95	5
4.75	100	5	100	0
Tray	0	0	0	0
Total	**2000**	**100**		

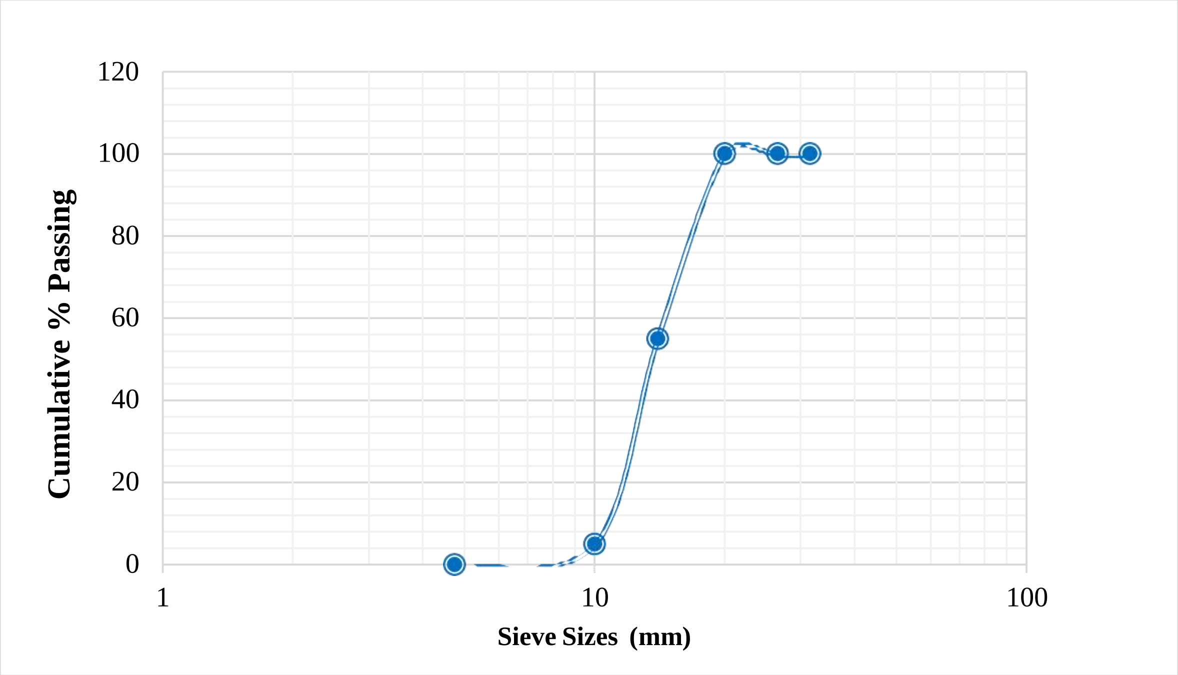

Figure 4.4: Sieve analysis results for 12mm coarse aggregate

The results for sieve analysis test on the aggregates shown in tables 4.1 to 4.4. The grading curve for the aggregates in fig 4.1 to 4.4 falls within the lower and upper limit of grading requirement for aggregate from natural sources BS882 (1992). This implies that the aggregates are suitable for construction work. The following results obtained from graphs for coefficient of uniformity and curvature of each aggregate size

For fine aggregate

$$C_c = \frac{D_{60}}{D_{10}} = \frac{1.10}{0.40} = 2.74$$

$$C_u = \frac{{D_{30}}^2}{D_{60} \times D_{10}} = \frac{0.60^2}{1.10 \times 0.40} = 0.82$$

For 20mm aggregate size;

$$C_c = \frac{D_{60}}{D_{10}} = \frac{10.99}{10.50} = 1.05$$

$$C_u = \frac{{D_{30}}^2}{D_{60} \times D_{10}} = \frac{10.65^2}{10.99 \times 10.50} = 0.98$$

For 16mm aggregate size;

$$C_c = \frac{D_{60}}{D_{10}} = \frac{10.99}{10.40} = 1.06$$

$$C_u = \frac{{D_{30}}^2}{D_{60} \times D_{10}} = \frac{10.80^2}{10.99 \times 10.40} = 1.02$$

For 12mm aggregate size

$$C_c = \frac{D_{60}}{D_{10}} = \frac{10.50}{10.10} = 1.04$$

$$C_u = \frac{{D_{30}}^2}{D_{60} \times D_{10}} = \frac{10.25^2}{10.50 \times 10.10} = 0.99$$

4.3 Slump

The results obtained for the slump test on the 12mm, 16mm and 20mm aggregate size are 97mm, 94mm and 92mm respectively as shown in table 4.5 and figure 4.5 below. Showing an increase in workability as the aggregate size increases which in agreement with Bruce et al, (2016). Findings.

Table 4.5: Slump Test Results

Mix Size (mm)	**Mix Ratio**	**Height of Cone (mm)**	**Height of Slump Concrete (mm)**	**Slump Value**
12	1:2:4	300	203	97
16	1:2:4	300	206	94
20	1:2:4	300	208	92

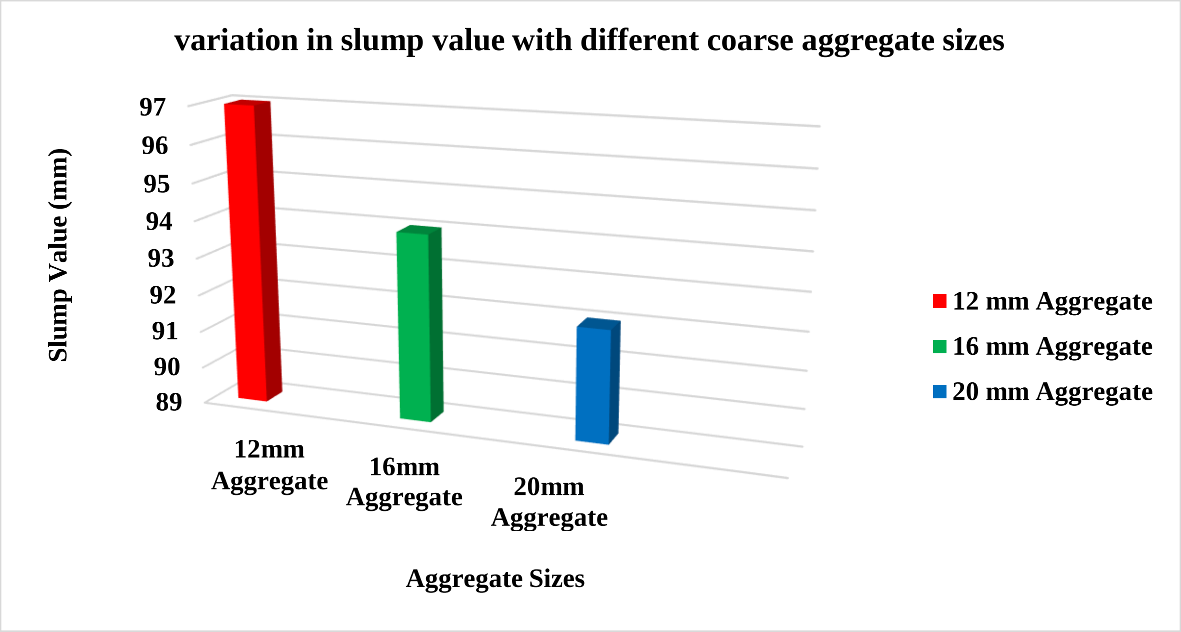

Figure 4.5: Variation in Slump with Different Coarse Aggregate

4.4 Compressive Strength

Table 4.6 to 4.8 and figure 4.6 and 4.7 shows the variation in the compressive strength of concrete using aggregate sizes of 12mm, 16mm and 20mm for 7, 14, 21 and 28 curing days at a water cement ratio of 0.55 and a mix ratio of 1:2:4 throughout the work.

For the 7 curing day been the first shows an increase in compressive strength as the aggregate size increases. With compressive strength of 15.53, 17.55 and 19.34 N/mm^2 for 12mm, 16mm and 20mm aggregate sizes respectively.

For the 28 curing day been the first shows an increase in compressive strength as the aggregate size increases. With compressive strength of 22.03, 24.02 and 26.20 N/mm^2 for 12mm, 16mm and 20mm aggregate sizes respectively.

All through the test 20mm showed the highest compressive strength followed by 16mm then 12mm in this order for each of the curing days showing that the compressive strength of concrete increases with increase in curing days and aggregate size as represented in figure 4.6 and 4.7. this increase in strength as the curing age increases is in agreement with the findings of James et al, (2011) and Joseph et al, (2012)

Table 4.6: Compressive strength of concrete test results for coarse aggregate of 12mm

Specimen	Curing Age (Days)	Area of Specimen (150mm×150mm)	Average Weight of Specimen (kg)	Average Crushing load (N/mm^2)	Average Compressive Strength (N/mm^2)
A12	7	22,500	8.30	349.38	15.53
A12	14	22,500	8.25	393.00	17.47
A12	21	22,500	8.40	426.68	18.17
A12	28	22,500	8.40	495.65	22.03

Table 4.7: Compressive strength of concrete test results for coarse aggregate of 16mm

Specimen	**Curing Age (Days)**	**Area of Specimen (150mm×150mm)**	**Average Weight of Specimen (kg)**	**Average Crushing load (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
A16	7	22,500	8.45	394.50	17.55
A16	14	22,500	8.55	450.67	20.03
A16	21	22,500	8.40	492.69	21.85
A16	28	22,500	8.45	540.54	24.02

Table 4.8: Compressive strength of concrete test results for coarse aggregate of 20mm

Specimen	**Curing Age (Days)**	**Area of Specimen (150mm×150mm)**	**Average Weight of Specimen (kg)**	**Average Crushing Load (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
A20	7	22,500	8.70	435.84	19.34
A20	14	22,500	8.60	478.15	21.24
A20	21	22,500	8.65	530.86	23.23
A20	28	22,500	8.60	589.73	26.20

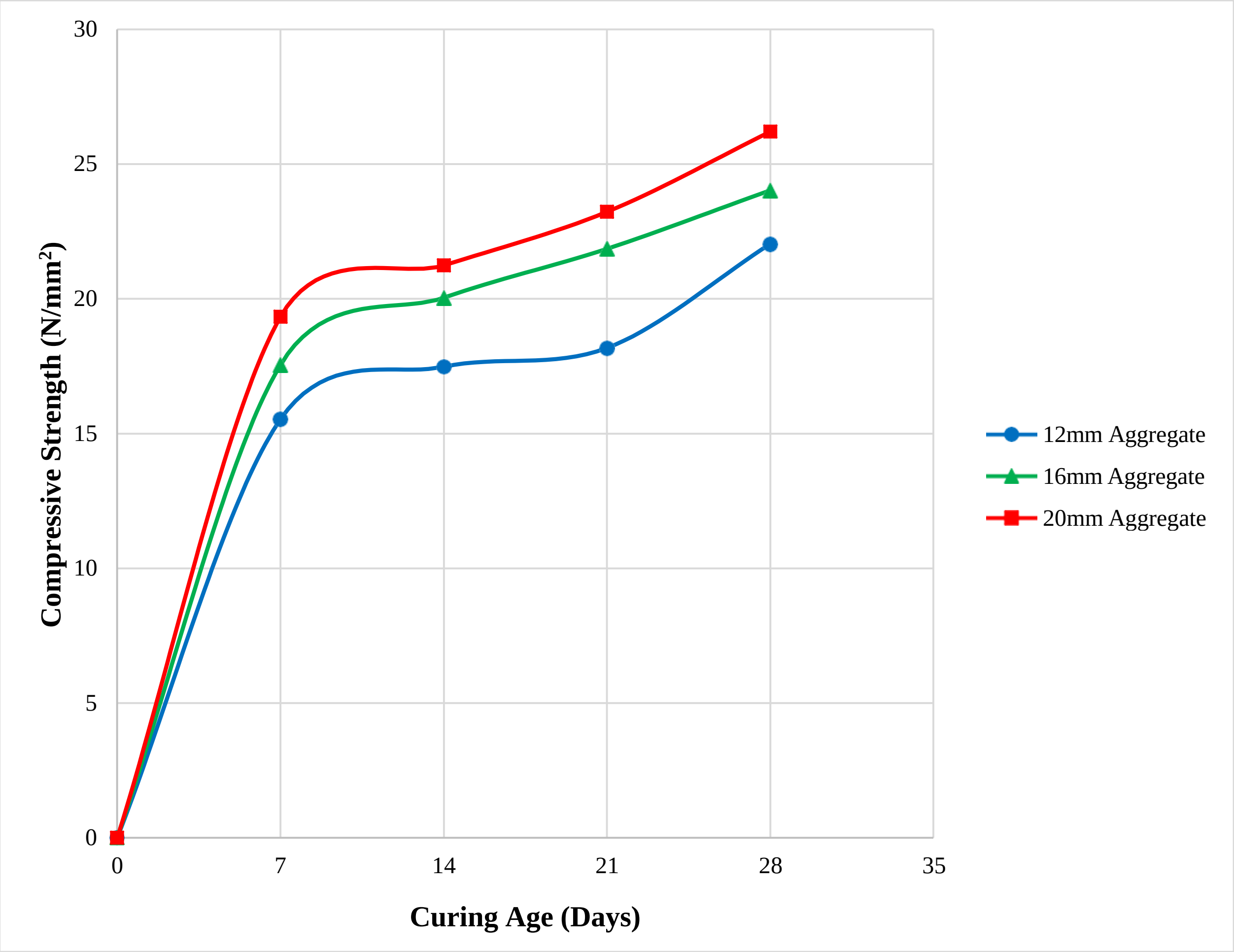

Figure 4.6: Graph of compressive strength against curing age

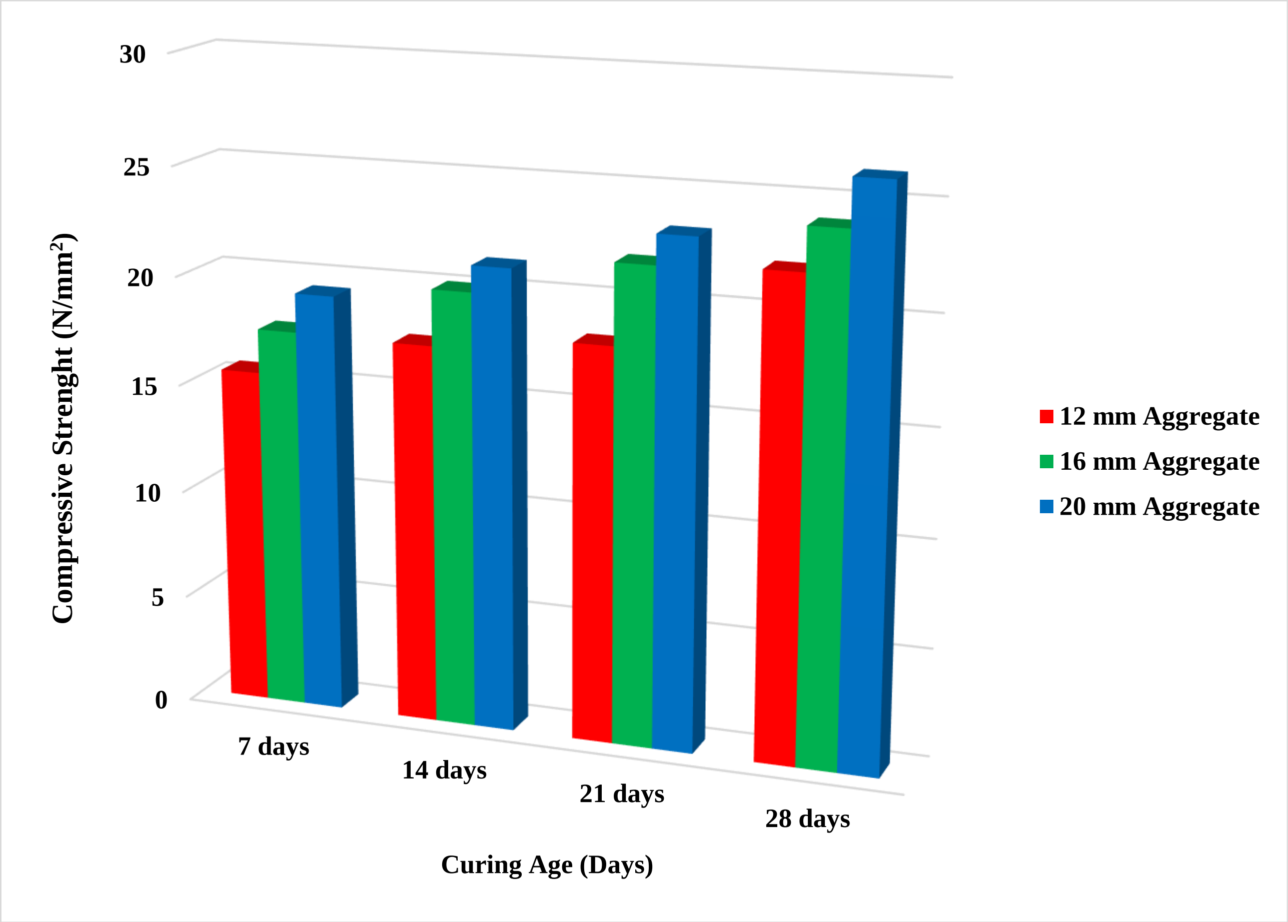

Figure 4.7: Effects of different coarse aggregate sizes on the compressive strength of concrete

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the results obtained and discussed, the following conclusions were drawn:

1. Concrete made with 20mm showed the highest workability for mix ratio of 1:2:4 and a water cement ratio of 0.55 used throughout the research and therefore it is the bet in terms of workability.
2. Concrete made with 12mm aggregate showed the less workability as compared to 16mm and 20mm for the same condition all through.
3. Concretes made with 20mm aggregates performed best in compression than that of 16mm and 16mm better than 12mm in this descending order.
4. Compressive strength of the different sizes of aggregates also increase as the curing days increases.
5. Concrete with 12mm showed the least compressive strength value throughout the project for each of the curing days.
6. 20mm aggregate showed the highest average compressive strength of 26.20N/mm^2 at 28 curing days as seen in figure 4.5 and 4.6. Which makes it more suitable and the best for compressive structural element.
7. 20mm aggregate showed higher compressive strength on each of the curing days as compared to 16mm and 12mm. shown in figure 4.5 and 4.6 graphically.

8. Bigger sizes of aggregates should be used (notwithstanding the cost) in high rise buildings and other massive structures in which high factors of safety for the strength of concrete is required.

5.2 Recommendation

1. The investigation should be extended to the effect of different shape of coarse aggregates on the compressive strength of concrete.
2. The flexural and tensile strength of concrete with aggregate size should be studied so as to draw a general conclusion on the strength of concrete.
3. The effect of water cement ratio of each aggregate size should be studied to see the effect on compressive strength.
4. More studies can be done on the effect different brands of cement produced in Nigeria on compressive strength of concrete.

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APPENDICE

Plate 1: Sieve Analysis on Coarse Aggregate**.**

Plate 2: Sieve Analysis on 20mm Coarse Aggregate**.**

Plate 3: Batching of Concrete**.**

Plate 4: Removal of Cubes from Metallic Molds

Plate 5: Getting Cubes Ready for Curing.

AN INVESTIGATIVE STUDY ON THE COMPRESSIVE STRENGTH OF CONCRETE USING GRAVEL, GRANITE AND LOCAL STONES WITH THE SAME GRADATION

BY

NWAFOR CHIMEZIE EMMANUEL

NAU/2016224069

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD

BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN CIVIL ENGINEERING

SUBMITTED TO THE

DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING

NNAMDI AZIKIWE UNIVERSITY, AWKA

SUPERVISOR: ENGR. EZENWAMMA A.A

FEBRAURY 2022

CERTIFICATION

This is to certify that I, Nwafor Chimezie Emmanuel with registration number 2016224069 personally carried out this project till completion for the award of Bachelor's degree in Engineering (B.Eng.), Department of Civil Engineering, Nnamdi Azikiwe University Awka. This work to the best of my knowledge has not been to any form submitted for same purpose in the field of Civil Engineering.

………………………… ……………………….

Nwafor Chimezie Emmanuel **Date**

APPROVAL

This research work has been assessed and approved by the Department of Civil Engineering, Nnamdi Azikiwe University, Awka.

Engr. A.A Ezenwamma
Supervisor

Date

Engr. Dr. C.A. Ezeagu
Head of Department

Date

Engr. Prof. D.O. Onwuka
External Supervisor

Date

DEDICATION

This project is dedicated to God Almighty whom his infinite grace and mercy has accompanied me to the successful completion of this project. I equally dedicate this work to my mother Mrs. Evelyn Nwafor and my lovely siblings for their immense prayers and support shown towards the success of this project work.

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Finally, I wish to thank my friends and course mates for all the support and company all the way long, I pray that God will in his infinite goodness bless you all in Jesus Mighty Name, Amen.

ABSTRACT

This project work contains a comprehensive details of the test done to investigate and compare the Compressive strength of concrete using local stones, gravel, and granite with the same gradation. The three different aggregate were collected from the same quarry site in Awka, Anambah State. Within the period of this study, it was discovered that the strength and workability of this aggregates differs due to the composition of the parent material, texture and other environmental factors. Based on BS and ASTM, some tests were carried out on this different samples which includes: Gradation test (Sieve Analysis), Slump Test, Compressive Strength Test. Sieve analysis test was carried out on the fine aggregate that was to be as a constituent in the overall concrete. Moreover, Slump Test and Compressive Strength Test was carried out on the coarse aggregates. The sieve Analysis carried out on the fine aggregates shows that it has a coefficient of uniformity of 3.0 and coefficient of curvature of 1.0 which defines the soil to be a uniformly graded soil. The slump Test carried out on the Local stones with water cement ratio of 0.6 resulted to a slump value of 10mm, while that of gravel gave a slump value of 25mm, while that of granite gave a slump value of 58mm. From this, it shows that Gravel and Granite are more preferable as regards the gradation size of 19mm in Construction works where consistency and workability over a significant distance is required before placing. The mix ratio used for the Compressive Strength Test is 1:2:4 and the results shows that granite produced the highest strength of 22.69N/mm^2 followed by that of gravel with a Compressive Strength of 20N/mm^2 then Local stone with the least Compressive Strength of 19.04N/mm^2. These values obtained by these aggregates is attributed to the size of the aggregate used, mode of formation and surface texture. By comparing the Compressive Strength produced by this aggregates, it was advised that gravel and granite of 19mm size can be used for medium load Construction work as it shows a medium resistance to load while that of local stones is preferable in low load Construction work.

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CHAPTER ONE

INTRODUCTION

1.1 Background

In the past, Engineers in Nigeria have not been much interested in recommending aggregates sizes for particular purposes in structural design. This lapse is believed to have contributed to high rate of structural failure in Nigeria. This is because aggregates account for 60 to 80 percent of the volume and 70 to 80 percent of the weight of concrete. Although aggregate is considered inert filler, it is a necessary component that defines the concrete's thermal and elastic properties and dimensional stability (Aginam et Al, 2013).

Aggregates is a broad category of coarse to medium grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates has been known to be the most mined material in the world. It has component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material. Aggregate can occur naturally or artificially. Naturally occurring aggregates are particles resulting from the weathering of rocks. They can be gotten from rivers, such as gravels and sand stone or crushed rock called chippings.

The mere fact that aggregate occupy 70-80 percent of the volume of concrete and 40 percent of asphalt concrete, has an impact on various characteristics and properties of concrete and asphalt. It is important that one should know more about aggregate, which constitute the major volume. Due the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation and French drain, roadside edge drains, septic drain fields and retaining wall drains etc. Aggregates can also be used as a base material under foundations, road and railroads.

In Nigeria, the basic sources of aggregate either for concrete work or road construction are from those occurring naturally which are cheaper and readily available. The most widely used aggregate is crushed rock. Aggregates are also used in construction to provide drainage, fill voids, protect pipes, and to provide hard surfaces. They are also used in water filtration and sewage treatment processes.

Concrete is a mixture of water, cement, or binder and aggregate (fine and coarse aggregate) and is a commonly used material for construction (Barrett, 1984). The most dominant construction material is concrete and the most collapse structures are concrete structures. A number of researches (Ayininuola and Olalusi, 2004; Ede, 2010 and 2011) have identified the use of substandard materials, particularly concrete as the leading cause of building collapse in Nigeria. Concrete failure still occurs despite adequate design and mix ratio. This advocates the existence of a breach in requirement for production of quality concrete. Previous works confirm the use of inferior concrete aggregates materials as among the causative elements of structural concrete failure in buildings. Gollu et al. (2016) mentioned unsuitable materials, unsound aggregate, reactive aggregate, and contaminated aggregate as part of the sources of concrete failure in buildings.

Concrete will only become a quality material for construction when its constituents are properly sourced. The quality of aggregate can vary significantly due to the geographic location and environmental condition (Ajagbe et al., 2018). Fowler and Quiroga (2003) reported that aggregates are expected to have important effects on the properties of concrete since they occupy 70-80% of it.

Concrete aggregates and paste are the major factors that affect the strength of concrete (Shetty, 2005), the properties of aggregate greatly affect the durability and structural performance of concrete as aggregate with undesirable properties cannot produce strong concrete (Neville, 2011). It is not necessarily true that aggregate whose properties all appear satisfactory will always make good concrete, and this is why the criterion of performance in concrete has to be used. According to Mehta and Monteiro (2001), the aggregates exercise a significant influence on strength, dimensional stability, and durability of concrete. Ajagbe and Tijani (2015) stated that assessment of concrete aggregate is vital to overcome the problem of structure collapse due to concrete failure in a certain environment. De Garrard (1999) and Dewar (1999) agreed that the source has an impact on concrete strength. Concrete strength is govern by aggregate size, type and source (Hassan,2014: Aginam et al., 2013; Jimoh and Awe, 2007; Abdullahi, 2012).

Compressive strength is the criterion for the determination of the quality of concrete (Troxel et al. 1968). Infact one of the characteristics of concrete that has made it to be widely used is its high compressive strength, which is the maximum compressive load it can carry per unit area. Compressive strength of concrete depends on the water cement ratio, degrees of compaction, aggregate grading, shape, strength and size of the aggregates (Rocco and Elides, 2009).

Since seventy five percent of concrete is made up of aggregates, its types, quality and general properties determine the quality of concrete(Nevile,1995). At present, the most commonly used coarse aggregate for concrete production are obtained from crushed aggregate of different sizes. There is controversy, however, on the effects of coarse aggregate sizes on the compressive strength of concrete. Ruiz (1966) found that the compressive strength of concrete increases with an increase in coarse aggregate content until a critical volume is reached, while Bayesi and Zhou (1993) found little correlation between compressive strength and coarse aggregate content.

In this light, this research is aimed at investigating the compressive strength of concrete using granite, gravel and local stones of the same gradation gotten from a prominent location in Anambah State.

1.2 Scope Of The Study

This project work is concerned with determining the compressive strength of concrete prepared with different coarse aggregates (Local Stones, Gravel and Granite) of size 19mm.The fine and coarse aggregates and cement used was sourced from Awka, Anambra State. Also, the water was sourced from the Concrete Laboratory, Unizik, Awka.

Gradation Test, Slump Test and Compressive Strength Test was to be performed. M20 grade of concrete of mix ratio of 1:2:4 and water-cement ratio of 0.6 was used to carry out the tests.

1.3 Significance Of The Study

The importance of the project work is to guide young engineers that are practicing civil engineering work to know the type of the coarse aggregate to be used when carrying out concrete works, especially those in construction firms where concrete is done often. Also, it will be helpful to also to expand their knowledge of coarse aggregate as it relates to civil engineering works.

1.4 Aim Of The Study

The aim of this project work is the investigative study of the compressive strength of concrete using granite, gravel and local stones having the same gradation.

1.5 Objectives Of The Study

1. To compare the compressive strength of concrete produced from coarse crushed rock aggregate granite, gravel and local stones with the same gradation.
2. To study the effect of these coarse aggregate on the workability of the concrete.

1.6 Limitations Of The Study

Some problems were encountered during the course of undergoing my project study and practical which includes:

1. One of the limitation is that the time expected to carry out this project is very minute due to the voluminous nature of the study.
2. The second limitation is the sourcing of materials needed to carry out my project work.
3. The third limitation is that of finances to embark on this project work. The expenses for the project is quite high mainly because of the hike in market price of materials.

CHAPTER TWO

LITERATURE REVIEW

2.1 Aggregates

Aggregates are inert granular material such as sand, gravel, crushed stone, crushed hydraulic-cement concrete, or iron blast-furnace slag, used with a hydraulic cementing medium to produce either concrete or mortar (Haseeb, 2017).

Aggregates can also be stated as inert materials that are dispersed through-out the cement paste whose strength depends majorly on its shape, surface texture, and cleanliness (Neville, 1981).

2.2 Classification of Aggregate

The classification of aggregates are based on the following:

2.2.1 According to Production methods

i. **Natural Aggregates:** It is take from native deposit without any change in their natural states during production except for crushing, grading or washing. Examples are: sand, gravel, crushed stone, lime rock.

ii. **Processed Aggregates:** It is a heat treated, expanded materials with lightweight characteristics. Examples are: Perlite, burnt Clays, shale's, processed fly ash.

iii. **Colored Aggregates**: This includes glass, ceramics, manufactured marble for decorative and architectural purposes (Neil and Ravindra ,1996)

2.2.2 According to Petrologic Characteristics

i. **Igneous Rocks**: This is formed from the solidification of molten lava of igneous Rocks. Examples are: Quartz, basalt, granite, pumice and tuff.

ii. **Sedimentary Rocks**: Obtained by the deposition of weathered and transported pre-existing Examples are: Sandstone, limestone, shale etc.

iii. **Metamorphic Rocks**: Formed at a depth under high heat and pressure by the alteration of either igneous rocks or sedimentary Rocks. Examples: Marble, Slate, Schist (Neil and Ravindra.1996)

2.2.3 According to Particle Size

i. **Fine Aggregate (sand):** Fine aggregate includes particles that all passes through the 4.75mm sieve and retained on 0.075mm sieve. Natural sand is generally used as fine aggregate, silt and clay also come under this category. The soft deposit consisting of sand, silt, and clay is termed as loam. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

Table 2.1: Table showing fine aggregates at different size variation

Fine Aggregate	Size Variation
Coarse Sand	2.0mm-0.5mm
Medium sand	0.5mm-0.25mm
Fine sand	0.25mm-0.06mm
Silt	0.06mm-0.002mm
Clay	<0.002

ii. **Coarse Aggregate (gravel)**: Coarse aggregates are particles that are predominantly retained on the 4.75mm (No 4) sieve and will pass through 3-inch screen. The coarser the aggregate, the more economical the mix. Larger pieces offer less surface area of the particles than an equivalent volume of small pieces. Use of the largest permissible maximum size of coarse aggregate permits a reduction in cement and water requirements. Using aggregates larger than the maximum size of coarse aggregates permitted can result in interlock and form arches or obstruction with a concrete form. That allows the area to become a void, or at best, to become filled with finer particles of sand and cement only and results in a weakened area (Haseeb, 2017).

The size range of various coarse aggregates given below.

Table 2.2: Table showing coarse aggregates at different size variation

Coarse Aggregate	Size
Fine gravel	4mm-8mm
Medium gravel	8mm-16mm
Cobbles	64mm-256mm
Boulders	>256mm

2.2.4 According to Their Unit Weight

i. **Normal Weight of Aggregates:** This includes sand, gravel and crushed stone. The weight of concrete produced by this aggregates ranges from 2200kg/m3 to 2400kg/m3.

ii. **Light Weight Aggregates**: This includes slate, slag and other light stone. The structural weight of concrete produced by this aggregates ranges from 1350kg/m3 to 1850kg/m3. This concrete is mainly used for Insulation purposes. The weight of lightweight insulating concrete ranges from 250kg/m3 to 1450kg/m3.

iii. **Heavy Weight Aggregates:** This includes Magnetite, Limonite, Barite, steel, Hematite and iron punching and the weight of concrete produced by this aggregates ranges from 2800kg/m3 to 6400kg/m3 (Neil and Ravindra, 1996).This type of aggregate is used for radiation shielding.

2.2.5 According to shape

i. **Rounded Aggregates-** Natural aggregates smoothed by weathering, erosion and attrition. Rocks, stone, sand and gravel found in riverbeds are the most common rounded aggregates. Rounded aggregates are the main factor behind workability.

ii. **Angular Aggregates-** Angular aggregates have a higher specific surface area than the **s**mooth rounded aggregate. With a greater specific surface area, the angular aggregate may show higher bond strength than rounded aggregates. Also, angular aggregates exhibit a better interlocking effect in concrete that contributes to the strength of concrete.

iii. **Flaky Aggregates-** an aggregate is termed flaky when its least dimension (thickness) is less than three-fifths of its mean dimension. The mean dimension of aggregate is the average of the sieve sizes through which the particles pass and are required, respectively.

iv. **Irregular Aggregates-** These are also shaped by attrition but are not fully rounded. These consist of small stones and gravel and offer reduced workability to rounded aggregates**.**

2.3 Properties of Aggregates

There are basically three properties of aggregates which includes the chemical, mechanical and physical properties.

2.3.1 Physical Properties of Aggregates:

The physical properties of aggregates are those that refer to the physical structure of the particles that make up the aggregate.

They include:

a. **Porosity, Water absorption and Permeability**

The internal pore characteristics are very important properties of aggregates. The size, the number, and the continuity of the pores through an aggregate particle may affect the strength of the aggregate, abrasion resistance, surface texture, specific gravity, bonding capabilities, and resistance to freezing and thawing action. Absorption relates to the particle's ability to take in a liquid. Porosity is a ratio of the volume of the pores to the total volume of the particle. Permeability refers to the particle's ability to allow liquids to pass through. If the rock pores are not connected, a rock may have high porosity and low permeability.

b. **Moisture content:** Moisture content is the water in excess of that saturated surface dry state. Total water content of a moist aggregate is equal to the sum of absorption and moisture content.

c. **Surface texture:** Surface texture is the pattern and the relative roughness or smoothness of the aggregate particle. Surface texture plays a big role in developing the bond between an aggregate particle and a cementing material. A rough surface texture gives the cementing material something to grip, producing a stronger bond, and thus creating a stronger hot mix asphalt or Portland cement concrete. Surface texture also affects the workability of hot mix asphalt, the asphalt requirements of hot mix asphalt, and the water requirements of Portland cement concrete. Some aggregates may initially have good surface texture, but may polish smooth later under traffic. These aggregates are unacceptable for final wearing surfaces. Limestone usually falls into this category. Dolomite does not, in general, when the magnesium content exceeds a minimum quantity of the material.

d. **Specific gravity:** The relative density (specific gravity) of an aggregate is the ratio of its mass to the mass of an equal absolute volume of water. It is used in certain computations for mixture proportioning and control, such as the volume occupied by the aggregate in the absolute volume method of mix design. It is not generally used as a measure of aggregate quality, though some porous aggregates that exhibit accelerated freeze-thaw deterioration do have low specific gravities. Most natural aggregates have relative densities between 2.4 and 2.9 with corresponding particle (mass) densities of 2400 and 2900 kg/m3 (150 and 181 lb./ft3). The relative density of an aggregate may be determined on an oven dry basis or a saturated surface-dry (SSD) basis. Both the oven dry and saturated surface-dry relative densities may be used in concrete mixture proportioning calculations. Oven dry aggregates do not contain any absorbed or free water. They are dried in an oven to constant weight. Saturated surface-dry aggregates are those in the pores in each aggregate particle are filled with water but there is no excess water on the particle surface.

e. **Alkalinity of aggregate:** Reactive forms of silica such as opal may occur in some kinds of rocks, like the siliceous limestone. The reaction takes place between the siliceous minerals present in the aggregate and the alkaline hydroxides gotten from the alkalis (Na_2O, K_20) in the cement. The resulting gel tends to increase in volume in a humid medium and thereby causing cracking of the concrete. In the case, it is recommended to limit the content of alkaline in the cement.

f. **Soundness of aggregate:** The soundness (AASHTO T104) refers to the durability of an aggregate in terms of the resistance to the action of weather and is an indication of the resistance to weathering of fine and coarse aggregates. Items for consideration under weathering action are freezing, thawing, and variation in moisture content, and temperature changes.

2.3.2 Chemical Properties of Aggregates

i. **Chemical composition of aggregate:** The main chemical constituent of limestone is $CaCO_3$, which is the main chemical constituent of alkaline aggregate, and the main chemical constituent of granite is SiO_2, which is the main constituent of acidic aggregate.

ii. **Alkali-aggregate reaction:** Alkali–aggregate reaction is a term mainly referring to a reaction which occurs over time in concrete between the highly alkaline cement paste and non-crystalline silicon dioxide, which is found in many common aggregates. This reaction can cause expansion of the altered aggregate, leading to spelling and loss of strength of the concrete

2.3.2 Mechanical properties of Aggregates

i. **Strength of Aggregate**: The crushing strength of aggregate cannot be tested with any direct test. There are some indirect tests to inform us about the crushing strength of aggregate. The test method used is the crushing value test.

ii. **Toughness of Aggregate:** Toughness can be defined as the resistance of aggregate to failure by impact. Toughness of aggregate is determined by aggregate impact value (AIV) test, which is similar to the ACV test with only difference that the load applied is impact. The impact is provided by a standard hammer falling 15 times under its own weight upon the aggregate in a cylindrical container.

iii. **Hardness of Aggregate:** Hardness, or resistance to wear, is an important property of concrete used in roads and floor surfaces subjected to heavy traffic. Hardness is expressed in terms of aggregate abrasion value of the bulk aggregate, determined using the Los Angeles test.

iv. **Bond strength of Aggregate:** The bond between the surface of the aggregate particles and cement matrix is a decisive factor for the strength of concrete. Both the shape and surface texture of aggregate influence considerably the bond and therefore the strength of concrete. A rougher texture results in a greater adhesion or bond between the particles and the cement matrix. The larger surface area of a more angular aggregate provides a greater bond. However, workability is reduced. Softer, porous and mineralogical heterogeneous particles, allowing penetration by the paste, possess a better bond than those textures which do not permit the paste penetration. There is no test for determining the quality of bond. However, as a thumb rule, the bond is said to be good if a crushed concrete specimen contain some aggregate particles broken right through.

2.4 Tests on Aggregate

Aggregates are the second major ingredient of concrete that contributes around 60 to 70% of its volume. One of the major contributing factors to the concrete quality is the quality of aggregates used therein.

Aggregate generally are tested for strength, toughness, hardness, shape, and water absorption (Suryakanta, 2015). The test methods of aggregates are done as per IS 2386 part-4 assists in assessing the quality of aggregates. The following are the tests for analyzing the quality of aggregate.

1. Grading Test (Sieve Analysis)
2. Slump test
3. Compression Test

2.4.1 Grading Test (Sieve Analysis)

A sieve analysis (or gradation test) is a practice or procedure used (in civil engineering) to assess the particle size distribution (also called gradation) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sand, crushed rock, clay, granite, feldspar, coal, soil, a wide range of manufactured powder, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common. In order to perform the test, a sufficient sample of the aggregate must be obtained from the source. To prepare the sample, the aggregate should be mixed thoroughly and be reduced to a suitable size for testing. The total mass of the sample is also required.

2.4.1.1 Types of gradation

1. Dense gradation

A dense gradation refers to a sample that is approximately of equal amounts of various sizes of aggregate. By having a dense gradation, most of the air voids between the materials are filled with particles. A dense gradation will result in an even curve on the gradation graph.

2. Narrow gradation

Also known as uniform gradation, a narrow gradation is a sample that has aggregate of approximately the same size. The curve on the gradation graph is very steep, and occupies a small range of the aggregate.

3. Gap gradation

A gap gradation refers to a sample with very little aggregate in the medium size range. This results in only coarse and fine aggregate. The curve is horizontal in the medium size range on the gradation graph.

4. Open gradation

An open gradation refers an aggregate sample with very little fine aggregate particles. This results in many air voids, because there are no fine particles to fill them. On the gradation graph, it appears as a curve that is horizontal in the small size range.

5. Rich gradation

A rich gradation refers to a sample of aggregate with a high proportion of particles of small sizes.

Gradation affects many properties of an aggregate, including bulk density, physical stability and permeability. With careful selection of the gradation, it is possible to achieve high bulk density, high physical stability, and low permeability. This is important because in pavement design, a workable, stable mix with resistance to water is important. With an open gradation, the bulk density is relatively low, due to the lack of fine particles, the physical stability is moderate, and the permeability is quite high. With a rich gradation, the bulk density will also be low, the physical stability is low, and the permeability is also low. The gradation can be affected to achieve the desired properties for the particular engineering application.

2.4.2 Slump Test

Concrete Slump Test is a standard and quick test to determine the proportions of various ingredients for preparing concrete of desired consistency and workability.

The ease with which one can work with concrete is called workability this can be measured using a simple test called the slump test.

2.4.2.1 Types of Slump.

i. **Collapse Slump:** In a collapse slump the concrete collapses completely. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which slump test is not appropriate. It means the water-cement ratio is too high, i.e. concrete mix is too wet or it is a high workability mix, for which a slump test is not appropriate.

ii. **Shear Slump:** In a shear slump the top portion of the concrete shears off and slips sideways or if one-half of the cone slides down an inclined plane, the slump is said to be a shear slump. The shear slump indicates that the result is incomplete, and concrete needs to be retested for valid results. If a shear or collapse slump is achieved, a fresh sample should be taken and the test is repeated. If the shear slump persists, as may the case with harsh mixes, this is an indication of lack of cohesion of the mix.

iii. **True Slump:** In a true slump the concrete simply subsides, keeping more or less to shape. This is the only slump which is used in various tests. Mixes of stiff consistence have a Zero slump, so that in the rather dry range no variation can be detected between mixes of different workability.

However, in a lean mix with a tendency to harshness, a true slump can easily change to the shear slump type or even to collapse, and widely different values of slump can be obtained in different samples from the same mix; thus, the slump test is unreliable for lean mixes.

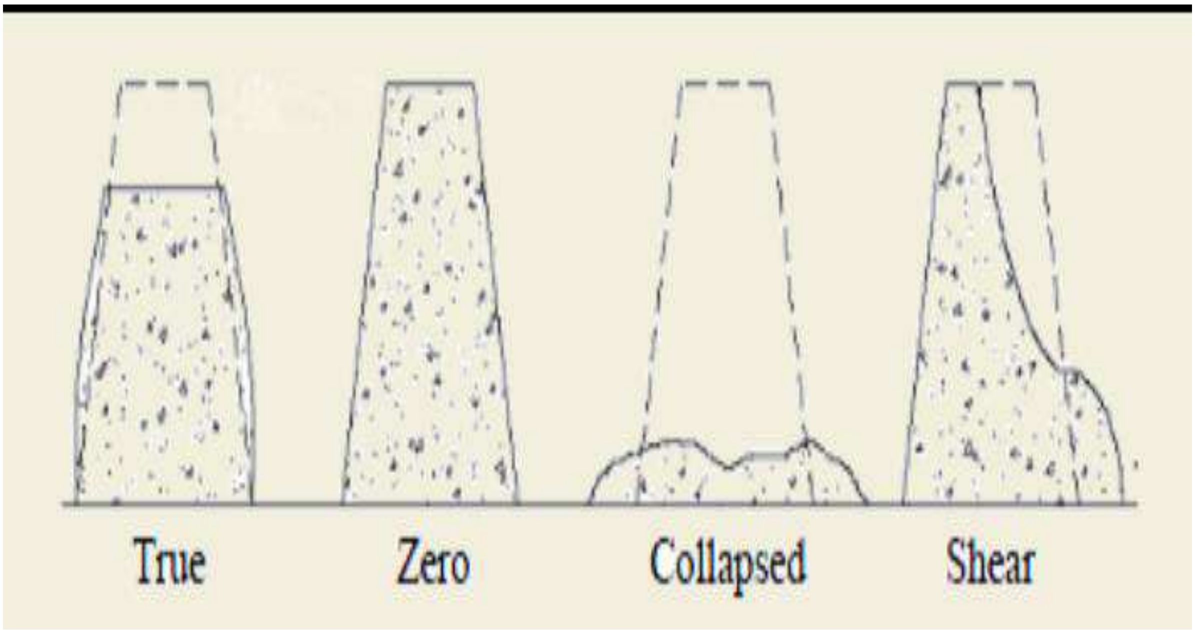

Plate 2.1: Types of slump

2.4.2.2 Applications of Slump Test

The slump test is used to ensure uniformity for different batches of similar concrete under field conditions and to ascertain the effects of plasticizers on their introduction.

This test is very useful on site as a check on the day-to-day or hour- to-hour variation in the materials being fed into the mixer. An increase in slump may mean, for instance, that the moisture content of aggregate has unexpectedly increases. Other cause would be a change in the grading of the aggregate, such as a deficiency of sand.

Too high or too low a slump gives immediate warning and enables the mixer operator to remedy the situation.

2.4.3 Compressive Strength Test

A compressive strength test is any test in which a material experiences opposing forces that push inward upon the specimen that distribute the applied load across the entire surface of the opposite faces of the test sample and then the plates are pushed together by a universal test machine causing the sample to flatten. According to (Bob 1998), A compressed sample is usually shortened in direction of the applied forces and expands in the direction perpendicular to the force. A compression test is essentially the opposite of the more common tension tests.

2.4.3.1 Purpose of compression Strength Test

1. To determine the behavior or response of a material while it experiences a compressive load, by measuring its fundamental variables, which includes this strain, stress and deformation.
2. To determine the yield strength, ultimate strength. Elastic limits and the elastic modulus and other parameters.

With the understanding of these different parameters and the values associated with a specific material it may be determined whether or not the material is suited for specific applications or if it will fail under specific stresses (Bob, 1998).

Table 2.3: Standard Compressive Strength of different grades of concrete at 7 and 28days.

Grade of concrete	Minimum compressive strength (N/mm2) at 7 days	Specified characteristics strength (N/mm2) at 28days
M15	10	15
M20	13.5	20
M25	17	25
M30	20	30
M35	23.5	35
M40	27	40
M45	30	45

2.5 Concrete and its constituents

Concrete is a composite material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens(cures) over time. In the past, lime based cement binders, such as lime putty, were often used but sometimes with other hydraulics cements, such as a calcium aluminate cement or with Portland cement to form Portland cement concrete (named for its visual resemblance to Portland stone). Many other non-cementitious types of concrete exist with other methods of binding aggregate together, including asphalt concrete with a bitumen binder, which is frequently used for road surfaces, and polymer concretes that use polymers as a binder, concrete is distinct from mortar. Whereas concrete is itself a building material, mortar is a bonding agent that typically holds bricks, tiles, and other masonry units together. In simple terms, the addition of cement and water gives cement paste, cement paste and sand gives mortar, mortar and stones gives concrete.

The relative quantities of cement, aggregates and water when mixed together, control the properties of concrete both in the wet and hardened states. These constituents of concrete are mixed with certain proportion to form or make a good concrete (Shetty, 2005).

2.5.1 Cement

A cement is a binder or a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Concrete is the most widely used material in existence and is behind only water as the planet's most-consumed resource. Cements used in construction are usually inorganic, often lime or calcium silicate based, which can be characterized as non-hydraulic or hydraulic respectively, depending on the ability of the cement to set in the presence of water.

The process of manufacturing of cement consist of grinding the raw material, mixing them intimately in certain proportion depending upon their purity and composition and burning them in a kiln at a temperature ,the material singers and partially fuses to form nodular shaped clinker. The clinker is then cooled and grounded to fine powder with addition of about to 5% of gypsum. The product formed by using this procedure is Portland cement (Nick and Kenton, 2006).

2.5.1.1 Chemical composition of Cement.

Portland cement is made up of four main compounds namely:

a. Tricalcium silicate ($3CaO \cdot SiO_2$)

b. Dicalcium silicate ($2CaO \cdot SiO_2$)

c. Tricalcium aluminate ($3CaO \cdot Al_2O_3$) and

d. Tetra calcium aluminoferrite ($4CaO \cdot Al_2O_3Fe_2O_3$).

In an abbreviated notation differing from the normal atomic symbols, these compounds are designated as C_3S, C_2S, C_3A, and C_4AF, where C stands for calcium oxide (lime), S for silica, A for alumina, and F for iron oxide. Small amounts of uncombined lime and magnesia also are present, along with alkalis and minor amounts of other elements.

2.5.2 Water

The amount of water in concrete controls many fresh and hardened properties in concrete including workability, compressive strengths, permeability and water tightness, durability and weathering, drying shrinkage and potential for cracking. These reasons, limiting and controlling the amount of water in concrete is important for both constructability and service.

2.5.3 Binders

A binder or binding agent is any material or substance that holds or draws other materials together to form a cohesive whole mechanically, chemically, by adhesion or cohesion.

In a more narrow sense, binders are liquid or dough-like substances that harden by a chemical or physical process and bind fibers, filler powder and other particles added into it. Examples include glue, adhesive and thickening.

Binders are loosely classified:

i. Organic (bitums, animal and plant glues, polymers) and

ii. Inorganic (lime, cement, gypsum, liquid glass, etc.). These can be either metallic or ceramic as well as polymeric depending on the nature of the main material.

iii. Non hydraulic-gypsum, air-cements, magnesia, hydrated lime

iv. Hydraulic- Roman cement, Portland cement, hydraulic lime.

2.5.4 Aggregates

As explained beforehand, the aggregate stands out as the most significant component in a concrete mix as it gives the concrete the sufficient strength needed. In this project study, we are more concerned about the properties of three different aggregates i.e. gravel, granite and local stones which in turn cannot produce the same strength when subjected to a loading. So we are to carry out the various aggregate test on this three aggregates and afterwards compare the compressive strength produced from the three different aggregates.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Samples And Classification

The samples used for the execution of this project work are as follows:

a. Coarse Aggregates: Gravel, Granite and Local stones.
b. Fine Aggregates
c. Cement (Binder)
d. Water

All the three samples (coarse aggregates) were collected in the South Eastern part of Nigeria from different location. The coarse aggregate sample includes:

- **Sample A (Local stones)**

This sample was collected from a prominent market in Awka, Anambra State. It is reddish brown colored stone with a smooth surface texture. It is made of different sizes but the size needed and obtained for this project work is 19mm as specified.

Plate 3.1: Local stones

- **Sample B: Granite**

This sample was collected from a prominent market in Awka, Anambra State. They are of crushed granite rocks material blasted from natural deposits, crushed and screened to different standard shapes and sizes. The size needed for this work is 19mm.

Plate 3.2: Granite

- **Sample C: Gravel**

This sample was collected from a prominent market in Awka, Anambra State. They are of crushed gravel rocks material blasted from natural deposits, crushed and screened to different standard shapes and sizes. The size needed for this work is 19mm.

Plate 3.3: Gravel stone

b. Fine Aggregates (Sand): This was collected from a quarry site in Awka, Anambra State but was originally sourced from River Niger, Onitsha, Anambra State.

c. Cement: The cement used was Dangote Cement. It is marketed in most cement dealers in Awka. The cement after being purchased was taken to the laboratory in 50kg bag and was carefully kept away dampness to avoid lumpness.

d. Water: The water used was supplied at the Civil Engineering Concrete Laboratory located at Unizik main Campus. The water was screened and justification was done to be sure it is not turbid.

3.2 Grading Test (Sieve Analysis)

A sieve analysis (or gradation test) is a practice or procedure used (in civil engineering) to assess the particle size distribution (also called gradation) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sand, crushed rock, clay, granite, feldspar, coal, soil, a wide range of manufactured powder, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common. In order to perform the test, a sufficient sample of the aggregate must be obtained from the source. To prepare the sample, the aggregate should be mixed thoroughly and be reduced to a suitable size for testing. The total mass of the sample is also required.

Apparatus

1. Set of sieves (4.75mm,2.00mm,1.00mm,0.600mm,0.300mm,0.150mm,0.075mm)

Plate 3.4: a set of sieves

2. Mechanical sieve shaker

Plate 3.4: Mechanical sieve shaker

3. Round Pan

Plate 3.5: Round pan

4. Weighing Balance with an accuracy to measure 0.1percent of the weight of the test sample

Plate 3.6: Weighing Balance

5. Thermostatically controlled oven.

Plate 3.7: Thermostatically controlled oven.

6. Spatula

Sample Preparation

A sufficient sample of fine aggregates was collected from the source bag and placed on a round pan in order to perform the test as indicated.

Procedures

- The test sample was dried to a constant weight at a temperature of (110+5°c).
- The sample was weighed after being dried.
- A stack of sieves was prepared in the descending aperture size from top to bottom and placed on the mechanical sieve shaker.
- The sample was sieved at a specified duration(10- 25mins)
- On completion of the sieving, the material on each sieve was weighed and recorded.

- The cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.

Plate 3.8: Sieve Analysis test

3.3 Slump Test

Concrete Slump Test is a standard and quick test to determine the proportions of various ingredients for preparing concrete of desired consistency and workability.

The ease with which one can work with concrete is called workability this can be measured using a simple test called the slump test.

Apparatus

1. Slump cone
2. Flat plate
3. Tamping rod
4. Grease
5. Measuring tape
6. Spirit level
7. Hand trowel

Sample Preparation

In order to perform the test, a fresh concrete is prepared of M20 grade with mix ratio of 1:2:4 where the selected coarse aggregate size used is 19mm as this project topic recommends.

Procedures

- Clean the internal surface of the mould carefully and apply oil.
- Place the mould on a clean, smooth horizontal and non-porous base plate.
- Fill the mould with freshly prepared concrete in three layers.
- Tamp each layer 25 times with a steel rod of rounded end. The tamping should be done uniformly. For the subsequent layer, the tamping should penetrate into the underlying layer.
- Remove the excess concrete and level the surface with a trowel.
- Lift the mould gently in vertical direction and then unsupported concrete will slump.
- Measure the slump as the difference between height of the cone and that of highest point of the specimen being tested.

Plate 3.9: Slump Test on-going

3.4 Compressive Strength Test

Compressive strength is the capacity of a material such as aggregate or mainly a structure to resist failure under compression. This test was done mainly to determine the Compressive strength of 19mm size of different aggregate type in mixture of concrete. The concrete were prepared by casting a concrete cubes. The concrete grade used is grade 20 and mix ratio of 1:2:4.

Apparatus

1. A cubical mould of size 150mm×150mm×150mm

Plate 3.10: A set of metallic mould

2. Tray
3. Tamping rod
4. Curing tank

Plate 3.11: Curing Tank

5. Trowel
6. Crushing machine

Plate 3.12; Crushing machine

7. Shovel
8. Knife edge
9. Weighing balance
10. Measuring cylinder 100ml

Sample Preparation

The concrete prepared consists of fine aggregates, coarse aggregates, cement in the ratio of 1:2:4 (M20) and water were mixed as prescribed. The mould of dimension 150mm×150mm×150mm were used in the casting of the concrete. A reasonable quantity of grease or oil was applied to the internal surface of the mould to make the concrete freely come out after drying and also to make the loosening and tightening of the nuts easy.

Procedures

- A given quantity of cement and fine aggregate were place on a tray and mixed thoroughly.
- Another given quantity of coarse aggregate after being sieved to it selected size (19mm) was added to the already mixed fine aggregate and cement and then mixed thoroughly until the coarse aggregate was uniformly distributed throughout the batch.
- A required water-cement ratio was added and then mixed until the concrete appears to be homogeneous and of the desired consistency.
- The concrete cubes mould was cleaned and the internal surface and base was greased uniformly.
- After a thorough mix, the fresh concrete was placed in the cube mould in three layers and tapped with a tamping rod for 25 strokes per layer.
- The tamping of the strokes were done in such a way as to distribute the concrete evenly within the mould and to remove the void spaces that may have been trapped in the concrete mix.
- After tamping was done, the top surface of the concrete was leveled and smoothened by using the trowel or knife edge.
- The concrete was left to set for a duration of 24hours.
- After 24hours setting, the concrete cubes were removed from the mould and placed into the curing tank and cured for 7, 14, 21, 28days respectively.
- After 7 days, three cubes each from the three different samples were removed from the curing tank and dried with sunlight.
- After drying, the cubes were weighed with the weighing balance, then crushed with the crushing machine and the reading was obtained and recorded.
- The same procedure for the crushing will be repeated for the remaining curing days.

Plate 3.13: Concrete with mould

Plate 3.14: Batching of cement with the use of a measuring scale

Plate 3.15: Mixing of concrete constituents together

Plate 3.16: Measuring of water with the measuring cylinder

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF RESULTS

4.1 Presentation of Results

The following test was carried on the samples as indicated:

1. Gradation Test (Particle size distribution test)
2. Slump Test
3. Compressive Strength Test.

4.1.1 Gradation Test (Particle size distribution Test)

Particle size distribution or Gradation test was done to determine the distribution of aggregate particle by size within a given sample and to equally ensure compliance with design and production requirements as well as performance for it intended use.

This test was carried out using a given sizable amount of fine aggregate obtained from Onitsha. This test is done in accordance with IS: 1498-1970

The possible apparatus and procedure for this test has been stated on the chapter three of this work.

Nnamdi Azikiwe University, Awka

Soil Laboratory Project Report

Test carried out: Gradation Test

Source: Onitsha

Material: Fine Aggregate

Tested by: Nwafor Chimezie Emmanuel

Total Weight of Sample: 500g

Calculations

Cumulative weight retained %= $\frac{Cumulative\ weight\ retained}{Total\ weight\ of\ sample} \times 100\%$

Cumulative weight passing %= 100% - Cumulative weight retained

Table 4.1: Particle size distribution results

S/N	SIEVE SIZE (MM)	WEIGHT RETAINED (G)	CUMULATIVE WEIGHT RETAINED	CUMULATIVE WEIGHT RETAINED %	CUMULATIVE WEIGHT PASSING%
1	4.75	1.06	1.06	0.212	99.8
2	2.00	24.46	25.52	5.104	94.9
3	1.00	69.61	95.13	19.062	75.6
4	0.600	93.87	189.0	37.800	62.2
5	0.300	176.89	365.89	73.180	26.8
6	0.150	118.06	483.95	96.790	3.2
7	0.075	13.40	497.35	99.470	0.5
8	Pan	1.82	499.17	99.800	0

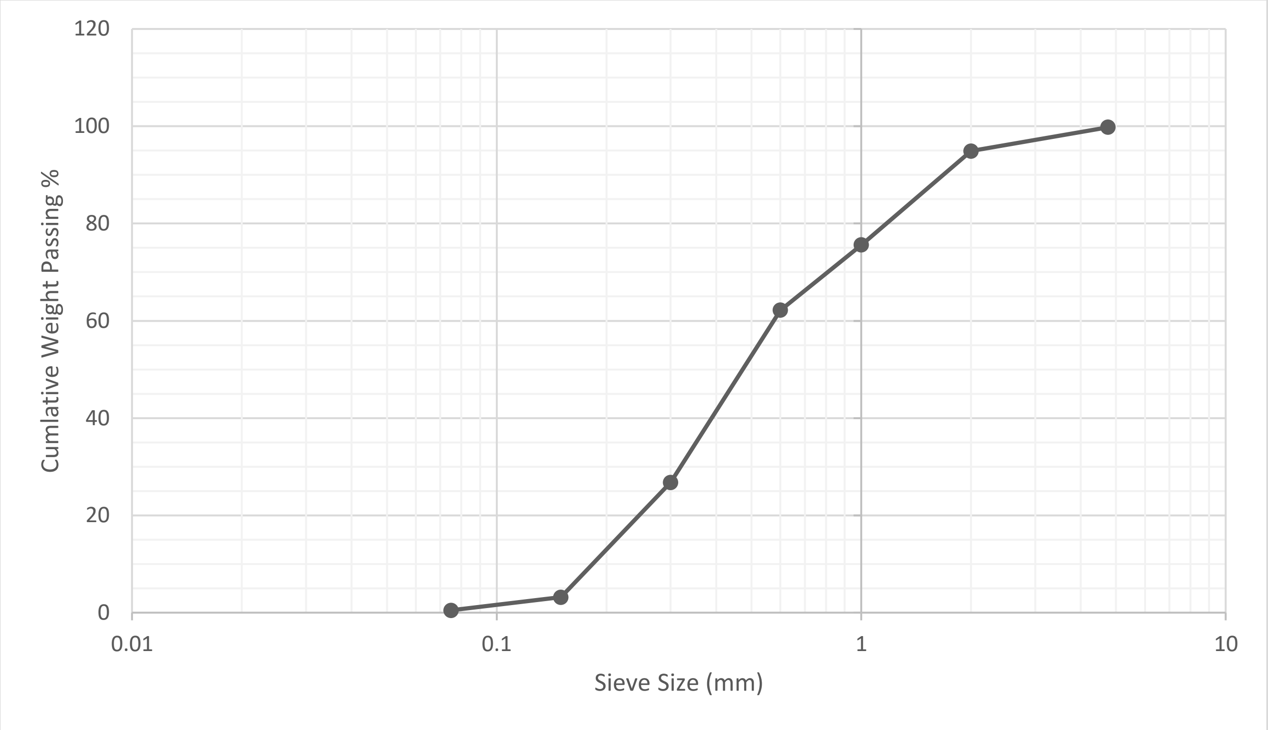

Figure 4.1: A graph of particle size distribution of fine aggregate

Coefficient of uniformity=$\frac{D60}{D10}$

D_{60}= particle size at which 60% of the particles are finer.

D_{30}= particle size at which 30% of the particles are finer.

D_{10}= Particle size at which 10% of the particles are finer.

Where D_{60}=0.58, D_{10}=0.18, D_{30}=0.32

Therefore Cu=$\frac{0.58}{0.18}$

Cu =3.0

Coefficient of curvature=$\frac{(D30)^2}{D60\times D10}$

$$Cc = \frac{(0.32)^2}{0.58\times 0.18}$$

$$Cc = \frac{0.102}{0.10}$$

Cc =1.0

4.1.2 Slump Test

This test was carried out in other to determine the workability of the three different aggregates the following results was obtained.

Mix Ratio; 1:2:4

Concrete Grade: M20

Water Cement Ratio: 0.6

Table 4.2: Table of slump test values

S/N	Coarse Aggregate Type	Slump Value[mm]
1	Local Stones	10mm
2	Gravel	25mm
3	Granite	58mm

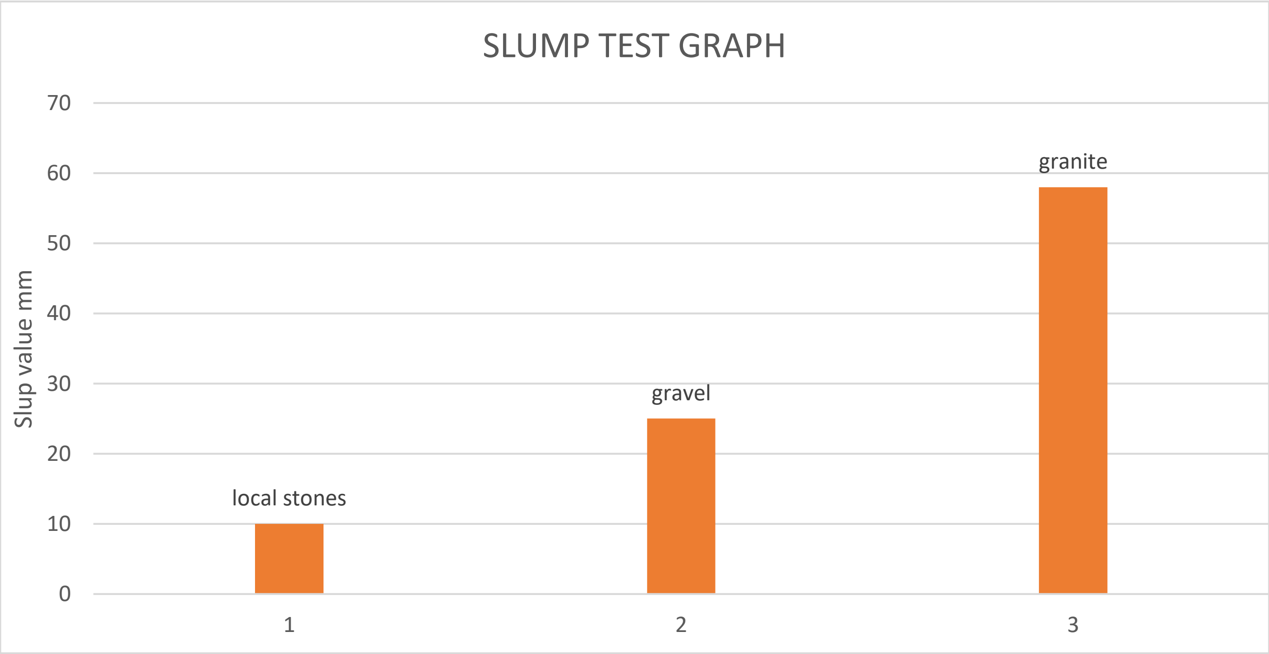

Figure 4.2: A bar chart of the slump test results

Table 4.3: Table showing the degree of workability at different slump value and its uses

Degree of workability	**Slump value in mm**	**Use for which concrete is suitable**
Very Low	0-25	Very dry mixes; used in road making. Roads vibrated by power operated machines.
Low	25-50	Low workability mixes; used for foundations with light reinforcement. Roads vibrated by hand operated machines.
Medium	50-100	Medium workability mixes; manually compacted flat slabs using crushed aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections with vibrations.
High	100-175	High workability mixes; for sections with congested reinforcement. Not normally suitable for vibrations.

4.1.3 Compressive Strength Test

This test was carried out to determine the Compressive strength of the coarse aggregates in concrete in concrete mix of ages 7days, 14days, 21days and 28days respectively. The procedure for this test is stated in chapter three of this project work.

The Mix Design used for the Compressive Strength Test

Mix ratio is 1:2:4

This indicates 1 part of cement, 2 parts of fine aggregate (sand) and 4 parts of coarse aggregates

Size of aggregates used for the three aggregate type =19mm

Volume of concrete cube used=150mm×150mm×150mm

$$=3375000\text{mm}^3$$

$$=3.375\times10^3\text{mm}^3$$

Standard density of Concrete=2400kg/m^3

Water cement ratio=0.6

But Density $= \frac{\text{Mass}}{volume}$

: Mass = Density ×Volume

Mass of concrete produced per cube=2400kg/m^3 × 0.003375m^3

=8.1kg

Mass produced=8.1kg

Mass of individual constituent in concrete produced from design mix of 1:2:4= 1+2+4=7

For cement

$\frac{1}{7}$×8.1kg=1.157kg

The required mass for 3 cubes = 3× 1.157= 3.471kg

For fine aggregate

$\frac{2}{7}$×8.1kg= 2.314kg

The required mass of fine aggregate for 3 cubes = 3× 2.314kg=6.942kg

For coarse aggregates

$\frac{4}{7}$×8.1kg= 4.629kg

The required mass of coarse aggregate for 3 cubes= 3×4.629= 13.887kg

Water-Cement ratio= 0.6

Mass of water=0.6× mass of concrete

=0.6×1.157

=0.6942kg

The required mass of water for 3 cubes =3×0.6942=2.0826 kg

Compressive Strength = $\frac{Maximum\ Compressive\ Load}{Cross\ Sectional\ Area}$ in N/mm^2

Cross Sectional Area= $150mm^2 \times 150mm^2 \times 150mm^2 = 22500mm^2$

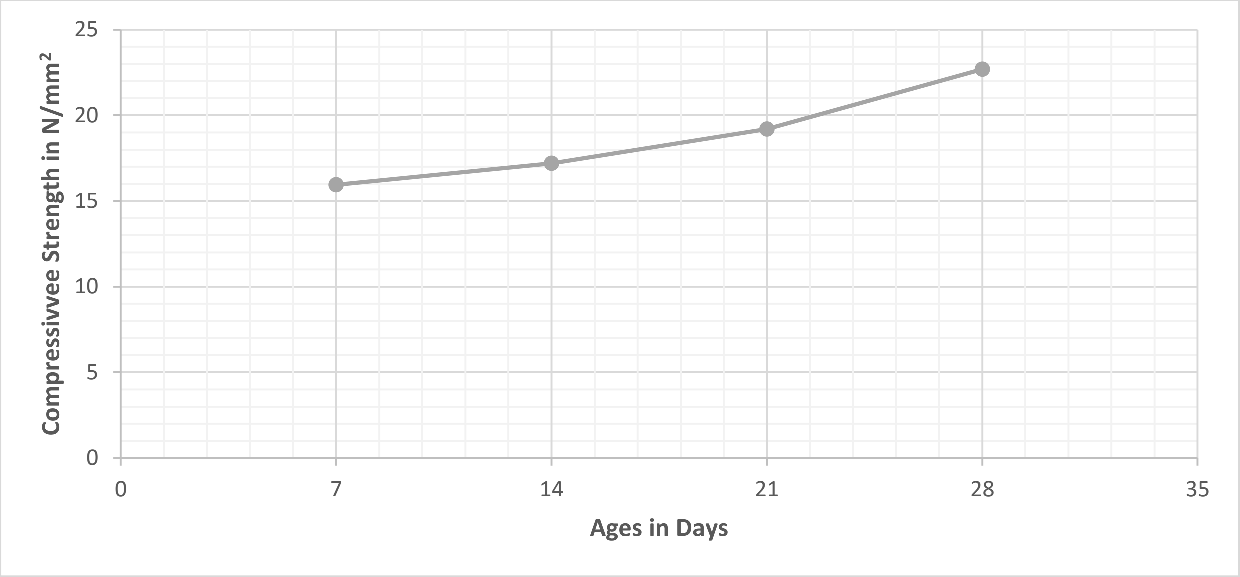

Figure 4.3: A graph of Compressive Strength in N/mm2 against age in days for granite sample

Refer to Appendix I: Table 9-12 for granite

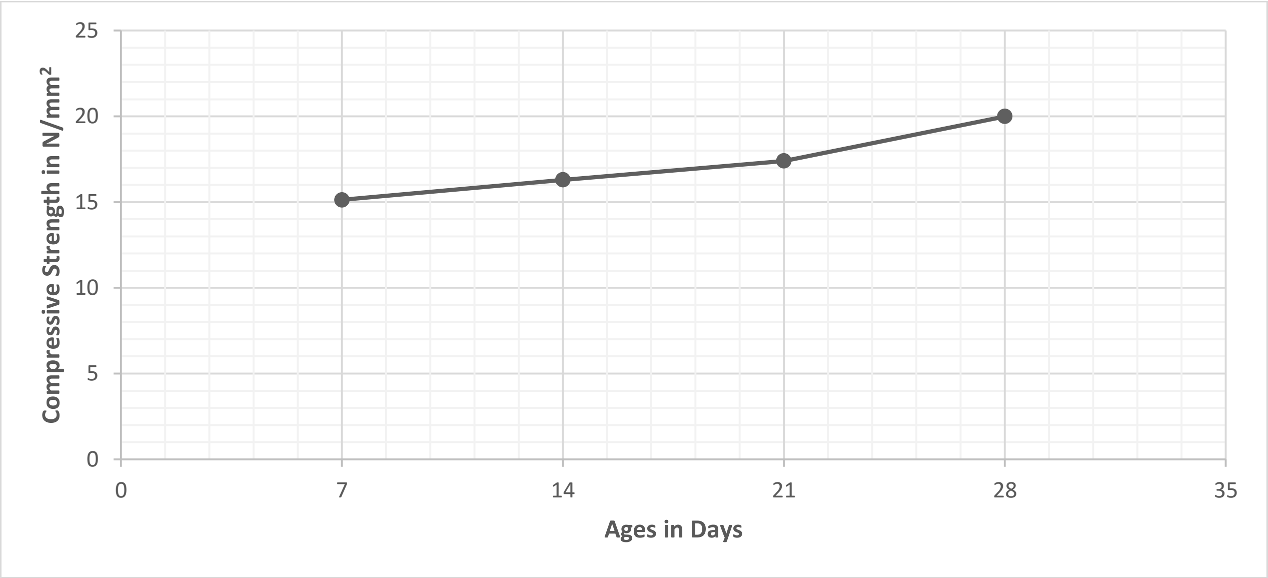

Figure 4.4: A graph of Compressive Strength in N/mm2 against age in days for gravel sample

Refer to Appendix I: Table 5-8 for gravel

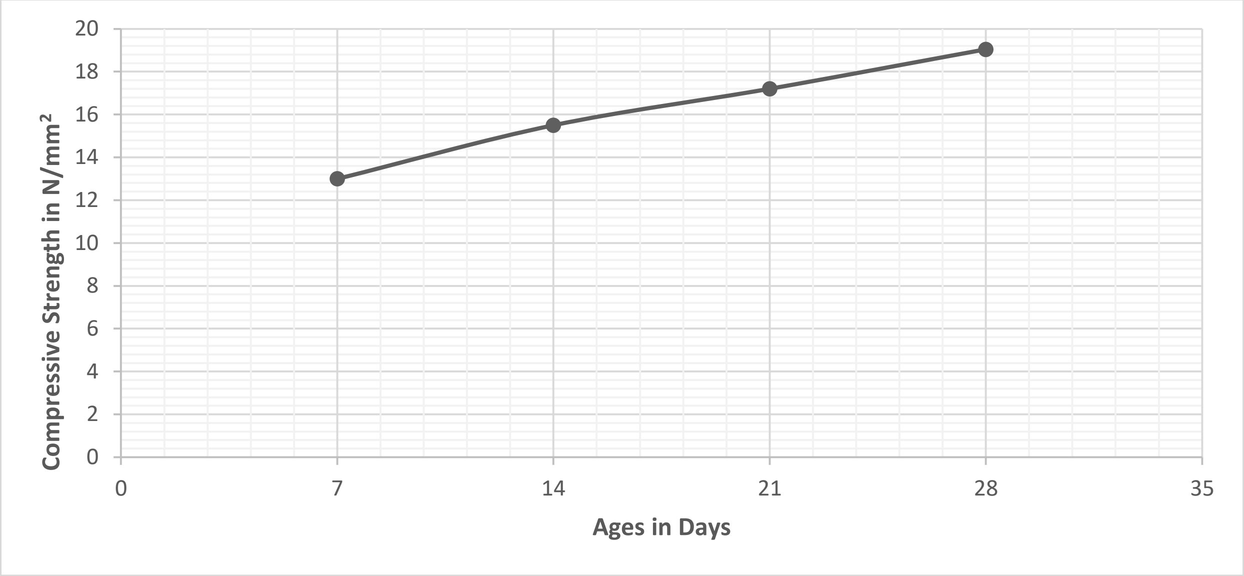

Figure 4.5: A graph of Compressive Strength in N/mm2 against age in days for local stones sample

Refer to Appendix I: Table 1-4 for Local stones

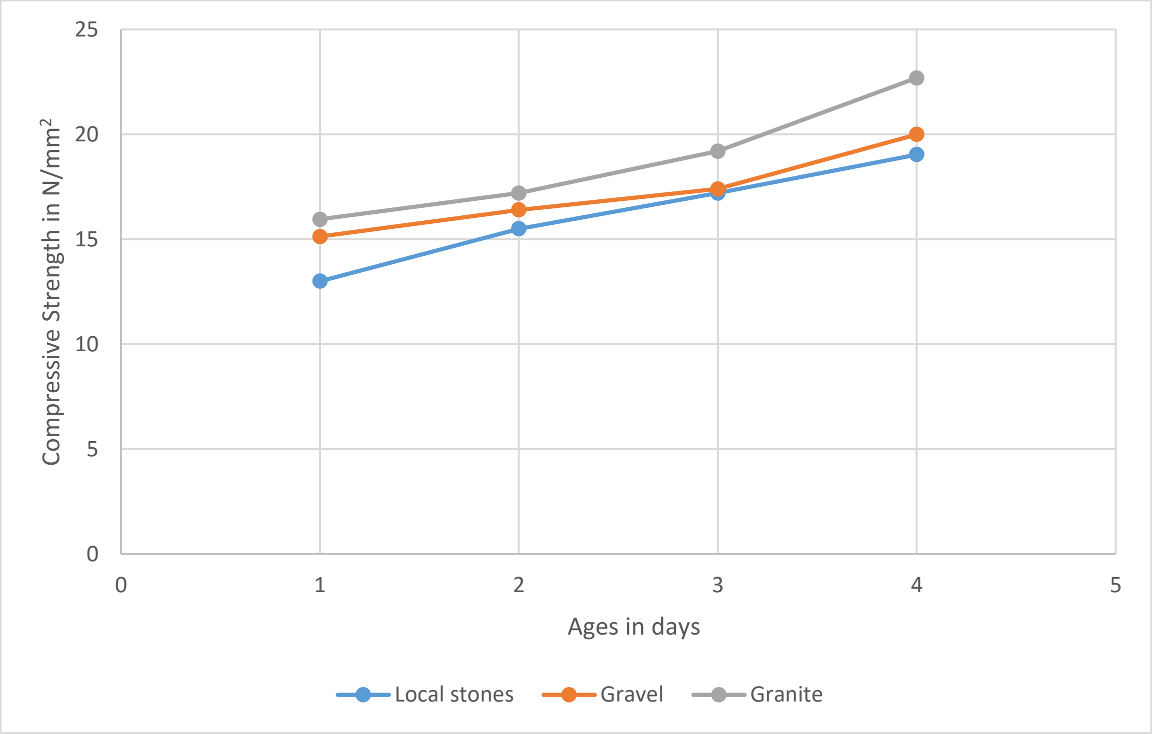

Figure 4.6: A graph of Compressive Strength of the three aggregate sample

4.2 Analysis of Results

4.2.1 Particle Size Distribution (Gradation Test)

The value of Cu and Cc are used to classify whether the soil is well graded or not. When the values of Cu is between 2 and 3, the soil is said to be poorly graded and when the value of Cc is between 1 and 3, the soil is said to be well graded. Therefore, from the results with the value of Cu to be 3.0 and Cc to be 1.0, it is said that the soil is a uniformly graded soil.

4.2.2 Slump Test

The results shown above shows that local stone is of a very low workability of slump value of 10mm which is suitable for road making vibrated by power operated machines as indicated. Gravel is of a low workability of slump value of 25mm used for foundations with light reinforcement and granite is of a medium workability of a slump value of 58mm which is suitable for sections with congested reinforcement and normally suitable for vibrations.

4.2.3 Compressive Strength Test

The Compressive Strength test has shown that coarse aggregate play a significant role in the overall strength of the concrete. Concrete strength is influenced by aggregate size, type and source (Hassan,2014: Aginam et al., 2013; Jimoh and Awe, 2007; Abdullahi, 2012). From the results gotten (Refer to Appendix I & II), it is seen that granite aggregate produced the highest compressive strength as compared to the others (Gravel and Local Stones). Though at the 28th day, there was a little difference in strength obtained from the three aggregates since the same size were used. This clearly indicates also that materials of the same size but of different composition and nature cannot produce the same strength.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

After all the test was conducted, the following deductions were made from the test which includes:

Grading Test (Particle Size Distribution): The fine aggregates produced a coefficient of uniformity of 3.0 and coefficient of curvature of 1.0. This implies that the soil is uniformly graded which is necessary to fill up void spaces.

Slump Test: From the result obtained, comparing the slump value of the three type of aggregate, it was found that gravel produced the best slump value of 25mm suitable in terms of workability and test standards when comparing it with slump value produced from the other two aggregates.

Compressive Strength Test: Compressive Strength of concrete is one of the most important properties of concrete and is used in design and construction works. Also, it is said that concrete attains its maximum strength at the 28th day curing age or more. From the results, at the 28th day curing age, Granite attained the highest compressive strength of 22.69N/mm^2 while gravel attained a compressive strength of 20.0 N/mm^2 and Local Stones attained the least compressive strength of 19.04N/mm^2. From this results, it can deduced that composition, physical quality and nature of aggregates affects the strength of concrete irrespective of size.

5.2 Recommendations

This research work has helped to stimulate further research works on other aspects of concrete technology for the purpose of establishing safe, healthy and sustainable structures. For this study, I recommend the following:

i. Since the use of local stones of 19mm size results in weaker strength and is readily available in some rural areas when compared with gravel and granite of same size, it is recommended that adequate reinforcement be provided and cement content increased to improve the strength of concrete.

ii. For concrete that requires a larger or a significant distance before placing, 19mm granite aggregate can be used because it produced a very wet mix compared to local stone and gravel aggregate of 19mm size.
iii. For shorter distant concrete placing, 19mm local stone and gravel is suitable.
iv. For heavy load construction, gravel and granite aggregates of 19mm or more can be used.
v. For low load construction, local stones can be used due to its poor strength.

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APPENDICES

APPENDIX I

TABLES OF VALUES FOR COMPRESSIVE STRENGTH TEST OF THE THREE AGGREGATES AT DIFFERENT CURING AGES

<u>Local Stone Aggregates Represented As Sample A</u>

Table 1: Weight and Compressive Strength of Sample A at day 7

S/N	WEIGHT kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	7.0	320.12	12.44	13.0
2	7.1	315.02	12.89	
3	6.9	310.8	13.77	

Table 2: Weight and Compressive Strength of Sample A at day 14

S/N	WEIGHT kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	7.2	340	15.11	15.2
2	7.15	350.9	15.60	
3	7.01	355.1	15.78	

Table 3: Weight and Compressive Strength of Sample A at day 21

S/N	WEIGHT Kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	7.2	380.6	16.92	17.2
2	7.25	385.1	17.12	
3	7.3	391.9	17.42	

Table 4: Weight and Compressive Strength of Sample A at day 28

S/N	WEIGHT kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	7.35	420.05	17.82	19.04
2	7.39	430.1	19.1	
3	7.43	450.5	20.0	

Gravel Represented As Sample B

Table 5: Weight and Compressive Strength of Sample B at day 7

S/N	W1EIGHT kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	7.99	334.8	14.8	15.13
2	8.11	341.0	15.2	
3	8.17	345.9	15.4	

Table 6: Weight and Compressive Strength of Sample B at day 14

S/N	WEIGHT kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	8.19	360.8	16.04	16.3
2	8.20	370.6	16.5	
3	8.23	365.0	16.2	

Table 7: Weight and Compressive Strength of Sample B at day 21

S/N	WEIGHT kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	8.26	385.1	17.1	17.4
2	8.30	391.2	17.4	
3	8.33	400.7	17.8	

Table 8: Weight and Compressive Strength of Sample B at day 28

S/N	WEIGHT kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	8.4	435.9	19.4	20
2	8.35	451.1	20	
3	8.39	455.6	20.5	

Granite Represented As Sample C

Table 9: Weight and Compressive Strength of Sample C at day 7

S/N	WEIGHT kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	7.99	354.8	15.6	15.9
2	8.15	365.3	16.24	
3	8.22	360.02	16	

Table 10: Weight and Compressive Strength of Sample C at day 14

S/N	WEIGHT kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	8.25	379.9	17.0	17.2
2	8.23	380.7	16,92	
3	8.3	400.8	17.7	

Table 11: Weight and Compressive Strength of Sample C at day 21

S/N	WEIGHT kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	8.34	421.8	18.7	19.2
2	8.38	440.6	19.6	
3	8.4	436.9	19.4	

Table 12: Weight and Compressive Strength of Sample Cat day 28

S/N	WEIGHT kg	STRENGTH KN	COMPRESSIVE SRENGTH N/mm^2	AVERAGE N/mm^2
1	8.5	489.9	21.77	22.69
2	8.49	500.7	22.3	
3	8.5	535.3	24	

APPENDIX II

Nnamdi Azikiwe University

Concrete Laboratory Project Report

Test: Compressive Strength

Location: Awka

Material: Coarse Aggregate

Tested by: Nwafor Chimezie Emmanuel

Area of cube: 22,500mm^2

Table 13: Ages of Compressive Strength of the three aggregate samples.

Cube Identity	**Mix Ratio**	**W/C Ratio**	**Date Of Cast**	**Ages In Days**	**Density of concrete Kg/m^3**	**Weight kg**	**Strength KN**	**Compressive Strength N/mm^2**	**Average N/mm^2**
EN L1	1:2:4	0.6	9/12/21	7	2400	7.0	280.12	12.44	13.0
					2400	7.1	290.02	12.89	
					2400	6.9	310.8	13.77	
EN L2	1:2:4	0.6	9/12/21	14	2400	7.2	340	15.11	15.5
					2400	7.15	350.9	15.60	
					2400	7.01	355.1	15.78	
EN L3	1:2:4	0.6	10/12/21	21	2400	7.2	380.6	16.92	17.2
					2400	7.25	385.1	17.12	
					2400	7.3	391.9	17.42	
EN L4	1:2:4	0.6	10/12/21	28	2400	7.35	420.05	17.82	19.04
					2400	7.39	430.1	19.1	
					2400	7.43	450.5	20.0	

EN GR1	1:2:4	0.6	9/12/21	7	2400	7.99	334.8	14.8	15.13
					2400	8.11	341.0	15.2	
					2400	8.17	345.9	15.4	
EN GR2	1:2:4	0.6	9/12/21	14	2400	8.19	360.8	16.04	16.3
					2400	8.20	370.6	16.5	
					2400	8.23	365.0	16.2	
EN GR3	1:2:4	0.6	10/12/21	21	2400	8.26	385.1	17.1	17.4
					2400	8.30	391.2	17.4	
					2400	8.33	400.7	17.8	
EN GR4	1:2:4	0.6	10/12/21	28	2400	8.4	435.9	19.4	20
					2400	8.35	451.1	20	
					2400	8.39	455.6	20.5	
EN GN1	1:2:4	0.6	9/12/21	7	2400	7.99	354.8	15.6	15.95
					2400	8.15	365.3	16.24	
					2400	8.22	360.02	16	
EN GN2	1:2:4	0.6	9/12/21	14	2400	8.25	379.9	17.0	17.2
					2400	8.23	380.7	16,92	
					2400	8.3	400.8	17.7	
EN GN3	1:2:4	0.6	10/12/21	21	2400	8.34	421.8	18.7	19.2
					2400	8.38	440.6	19.6	
					2400	8.4	436.9	19.4	
EN GN4	1:2:4	0.6	10/12/21	28	2400	8.5	489.9	21.77	22.69
					2400	8.49	500.7	22.3	
						8.5	535.3	24	

EFFECT OF COCONUT FIBRE ASH ON THE STRENGTH OF CONCRETE

BY

NWALI THANKGOD NNAEMEKA

(NAU/2016224047)

FINAL YEAR PROJECT

SUBMITTED TO

THE DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING

NNAMDI AZIKIWE UNIVERSITY AWKA.

IN PARTIAL FUFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN CIVIL ENGINEERING

FEBRUARY, 2022

DECLARATION

This is to declare that this research work "Effect of Coconut Fibre Ash on the strength of concrete" was carried out by Nwali Thankgod Nnaemeka with the registration number (NAU/2016224047) and that all the information used as contained in the work is a reflection of my personal research. All other sources of information obtained from other literary publication have been duly acknowledged.

______________________________	_______________
NWANLI THANKGOD NNAEMEKA	**Date**

APPROVAL PAGE

This is to certify that this project is the original research work of Nwali Thankgod Nnaemeka and was undertaken and submitted in partial fulfilment of the requirement for the award of Bachelor of Engineering Degree (B.ENG) in the Department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka.

Engr. Dr. Adinna Boniface Okafor Supervisor	Date
Engr. Dr. Ezeagu Akaolisa Celestine Head of Department	Date
Engr. Prof. D.O. Onwuka External Examiner	Date

DEDICATION

This project work is dedicated to Almighty God for his infinite mercy and kindness over my life. I equally dedicate this work to my lovely parent, who serve as a real source of inspiration towards my academic pursuit and my siblings for their immense contribution.

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ABSTRACT

The urgent need to reduce excessive greenhouse emission from the manufacturing process of Ordinary Portland Cement (OPC) has led to an increasing interest in the use of agricultural waste in producing quality construction materials. This study presents an experimental investigation on the strength performance of Coconut Fibre Ash (CFA) with varying dosage. Concrete specimens were cast at 10%, 20% and 30%CFA replacement of OPC in concrete. The oxide composition of the coconut fibre ash was analyzed to determine its pozzolanic properties and also the strength performance of Coconut fibre ash based concrete specimens was evaluated by measuring the compressive strength up to 28 days. The outcome of all test properties indicated that the mixtures prepared with 0% CFA in concrete was optimum seconded by that of 10% CFA dosage.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Government and groups of different levels all over the world find it difficult to provide shelter for its citizenry, shelter has remained a basic necessity of man and the provision of decent shelter at a very reasonable cost is really a major problem all over the world. This problem is caused by unavailability and overall high cost of construction materials.

The construction industry has been faced with ongoing and sophisticated demands, which calls for the most efficient use of available resources. Different parts of the structure of the modern facilities are now so technically specialized that they have to design by many experts.

In Europe after the end of the Second World War, cement was scarce and not enough for the rebuilding the war-turn countries of Europe. This led to the use of fly ash as a partial substitute for cement in concrete production to cope with the problem of scarcity of cement at that time (Faber, 1987 ;). It was then

Discovered that fly ash contained pozzolana and has potentials of other valuable properties for good concrete practice.

Research indicates that most materials that are rich in amorphous silica can be used in partial replacement of cement (Ngbonkwo, 1982 ;). It has also been established that amorphous silica found in some pozzolanic materials reacts with lime more readily than those of crystalline form. Use of such pozzolanas can lead to increased compressive and flexural strengths. The American society of testing materials (ASTM) defines Pozzolans as siliceous or aluminous materials which possess little or no cementitious properties but will, in the presence of moisture, react with lime [$Ca\ (OH)_2$] at ordinary temperature to form compounds with cementitious properties. Examples of pozzolans include class C fly ash, silica fume and rice husk ash. Pozzolans contain some percentages of CaO, blast furnace slag and silica fumes. ASTM C 618 – 78 specifies that any pozzolana that will be used as a cement as binder in concrete requires a minimum of 70 % silica, alumina and ferric oxides. BS 3892: 1965 parts 1 and 2 specify a maximum loss on ignition of 12%, maximum MgO content of 4% and SO_3 of 2.5% respectively.

The use of coconut husk ash in cement concrete can help in waste reduction and pollution control. if, it is proven that it can improve concrete properties. This paper provides an experiment study to evaluate the improvement of concrete using coconut husk ash.

1.2 Statement of the Problem

Pollution associated with cement production, has compelled a search for an alternative binder which can be used sorely or in partial replacement of cement in concrete production. More so, disposal of agricultural waste materials such as rice husk, corn cob, groundnut husk, and coconut fibre have constituted an environmental challenge, hence the need to convert them into useful materials to reduce their negative effect on the environment. Cost of building material such as cement, needs to be reduced to make housing affordable for teeming population of people on earth; hence the need for this research.

1.3 Aim and Objectives

1.3.1 Aim

The aim of this work is to evaluate the strength improvement of concrete using coconut husk ash as an admixture.

1.3.2 Objective

The objective of this study is to:

(i) prepares concrete cubes containing 0, 10, 20, and 30% cement replacements by coconut husk ash to be tested for compressive strength at 7, 14, 21- and 28-days water curing.

(ii) Analyze the results with tables and graph to determine the rate of hydration and strength gain for the various replacement quantities.

(iii) Obtain the oxide composition of the coconut husk ash to analyze its pozzolanic property.

1.4 Scope of the Work

Scope of this work involves production of concrete cubes of 150 x 150 x 150mm containing various percentages of coconut husk ash as partial replacements, and testing them for strength with the help of universal testing equipment for the purpose of determining its effect on concrete strength. No other agricultural waste will be used except coconut husk. Oxide composition of the ash will also be studied for its pozzolanic properties. Other properties of concrete such as flexural strength, tensile strength, creep, water absorption, etc. will not be tested.

This study will help Civil engineers to have a better understanding on the use of coconut husk which is an agro-waste product, as an admixture to improve the strength properties of concrete and also, the use of coconut husk as an alternative admixture in concrete will help reduce the cost of other admixtures since it is readily available and can be obtained at a cheaper rate.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The high cost of construction materials like cement and reinforcement has led to increased cost of construction (Aho and Utsev, 2008). This, coupled with air pollution associated with cement production, has necessitated a search for an alternative binder which can be used sorely or in partial replacement of cement in Construction Industry (Asasutjarit et al., 2007). More so, disposal of agricultural waste materials such as rice husk, groundnut husk, corn cob and coconut fiber have constituted an environmental challenge, hence the need to convert the waste to useful materials to minimize their negative effect on the environment. Research indicates that most materials that are rich in amorphous silica can be used in partial replacement of cement (Aho and Utsev 2008). It has also been established that amorphous silica found in some pozzolanic materials reacts with lime more readily than those of crystalized form (Ede et al., 2014). The use of such pozzolanas can lead to increased strength in concrete. (Aziz et al., 1984).

The American Society of Testing Materials (ASTM) defines pozzolans as siliceous or aluminous materials which possess little or no Cementous properties but will, in the presence of moisture, react with lime at ordinary temperature to form a compound with pozzolanic properties.

Examples of pozzolans include class fly ash in general which contains more than 70% Silica, blast furnace slag and silica fumes (Okere 2013). Also, a pozzolan is a siliceous or siliceous and aluminous material which, in itself, possess little or no cementitious value but which will, in finely divided form and in presence of water, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing Cementous properties (Munawar et al.,2007). The broad definition of pozzolan imparts no bearing on the origin of the material, only on its capability of reacting with calcium hydroxide and water. A quantification of this capability is comprised in the term pozzolanic activity. Mixtures of calcined lime and finely ground reactive (alumino-) silicate materials were pioneered and developed as inorganic binders in the Antique world. Architectural remains of the Minoan civilization on Crete have shown evidence of the combined use of slaked lime and additions of finely ground potsherds for water proof renderings in baths, cisterns and aqueducts. Evidence of the deliberate use of volcanic materials such as volcanic ashes or tuffs by the ancient Greeks dates back to at least 500-400 BC, as uncovered at the ancient city of Kameiros, Rhoodes (Ede, 2014). In subsequent centuries the practice spread to the mainland and was eventually adopted and further developed by the Romans. The Romans used volcanic pumices and tuffs found in neighboring territories, the famous ones found in Pozzuoli (Naples), hence the name pozzolan, and in Sengi (Latium). Preference was given to natural pozzolan sources such as German trass, but crushed ceramic waste was frequently used when natural deposits were not locally available. The exceptional lifetime and preservation conditions of some of the most famous Roman buildings such as Pantheon or Pont du Gard constructed using pozzolan-lime mortars and concrete testify to both the excellent workmanship reached by the Roman engineers and to the durable properties of the utilized binders. Coconut fibre are agricultural waste products obtained in the processing of coconut oil and are available in large quantities in the tropical regions of the world, most especially in Africa, Asia and America. Coconut fibre are not commonly used in the construction industry but are often dumped as agricultural wastes. However, with the quest for affordable housing system for both the rural and urban population in the developing countries, various schemes focusing on cutting down conventional building material costs have been put forward. One of the suggestions in the forefront has been the sourcing, development and use of alternative, non-conventional local construction materials including the possibility of using some agricultural wastes and residues as partial or full replacement of conventional construction materials. In countries where abundant agricultural wastes are discharged, these wastes can be used as potential material or replacement material in construction industry (Parveen et al., 2013). One such alternative is coconut fibre, produced in abundance has the potential to be used as substitute coarse aggregate in concrete (Munawar, 2007). The current waste disposal practice of incineration within the industry is normally done in an uncontrolled manner and contributes significantly to atmospheric pollution. Thus, these residues are becoming expensive to dispose by satisfying the requirements of environmental regulations. In such a situation, efforts are going on to improve the use of these by-products' through the development of value-added products. One of the ways of disposing these wastes would be the utilization of coconut fibre into constructive building materials. Oil Palm Shell (OPS) are the hard endocarp that surrounds the palm kernel. Extensive research and development in the understanding and applications of fibre concrete materials are still taking place all over the world. These activities include, amongst other things, the development of new, stronger fibres, better fibre reinforced composites and new substitutes (Ede et al., 2014). Mechanical properties of coconut fibres reinforced polyester composites was conducted by Aziz and kumar (1984). In this work, chemical modification of the coconut fibres by alkaline treatment was determined in order to use them as reinforcement in polyester resin. The mechanical properties were evaluated by tensile and fatigue tests. The surfaces of the fractured specimens were examined in order to assess the fracture mechanisms. The test results presented a decrease in fatigue life of composites when applied greater tension, due to bonding interfacial, which was not adequate. Ede and Ige (2014) have investigated the possibilities of using coconut shell as aggregate in concrete. The findings indicated that water absorption of the coconut shell aggregate was high about 24% but the crushing value and impact value was comparable to that of other lightweight aggregates. They found that the average fresh concrete density and 28-day cube compressive strength of the concrete using coconut shell aggregate were 1975 kg/m3 and 19.1 N/mm^2, respectively. It is concluded that crushed coconut shells are suitable when it is used as substitute for conventional aggregates in lightweight concrete production.

Previous study by Visconti (1975) has shown that coconut shell is suitable as substitute for conventional aggregates in the structural concrete production. The results also indicated cost reduction of 30% for concrete produced from coconut shells. Apart from its use in production of fibre-roofing material, the other possibility of using coconut fibre as an aggregate in concrete production has not been given any serious attention. However, Adeyemi (2019) carried out for one mix ratio (1:2:4) the suitability of coconut fibre as substitute for either fine or coarse aggregate in concrete production. It is examined that the coconut fibres were more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production. However, no research has been done on the improvement of concrete strength and pozzolanic capability of the residue obtain from the burning of coconut husk ash. This study seeks to close this knowledge gap.

2.2 Cement

Cement is a finely ground powdered product which has the potentials of reacting with water, mixed with it, to turn into a hard-binding matrix for aggregates. Modern cement is accredited to Joseph Aspdin, a leads builder and bricklayer, who ground limestone and finely divided clay into a slurry and burnt the mixture in a kiln until CO_2 was expelled.

The product so formed was ground into powder with gypsum added. Isaac Charles Johnson in 1845 also burnt a mixture of clay and chalk to a clinkering stage to make a better Portland cement. By 1851 factory production of cement had started.

Today, Portland cement are produced in different types and brands with standardized specification all over the world. Aside from Portland cement other types of cements are also produced today; among these are high alumina cement, blast furnace slag cement and Pozzolanic cement.

2.2.1 Physical Properties of Cement

Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement, good cement is supposed to have the following physical properties;

I. Soundness of Cement

Soundness refers to the ability of cement to not shrink upon hardening good quality cement retains its volume after setting without delayed expansion, which is caused by excessive free lime and magnesia

II. Consistency of Cement.

The ability of cement paste to flow is consistency. It is measured by vicat test.

III. Strength of Cement

There are three types of strength of cement are measured. Compressive, tensile and flexural. Various factors affect the strength, such as water-water ratio, cement – fine aggregate ratio, curing conditions size and shape of a specimen, manner of molding and mixing, loading conditions and age.

IV. Setting Time

Cement sets and hardens when water is added. This setting time can vary depending on multiple factors such as factors, such as admixtures, chemical content, cement –water ratio and fineness of cement.

Cement used in construction should have an initial setting time that is not too low & a final setting time not too high.

V. Loss of Ignition

Heating a cement sample at 900°c – 1000°c (i.e., until a constant weight is obtained) causes weight loss. This loss of weight upon heating is calculated as loss of ignition.

Improper and prolonged storage or during transport or transfer may lead to pre-hydration and carbonation, both of which might be indicated by increased loss of ignition.

VI. Bulk Density

When cement is mixed with water, the water replaces areas where there would normally be air. Because of that, the bulk density of cement is not very important. Cement has a varying range of density depending on the cement composition percentage.

VII. Heat of Hydration

When water is added to cement, the reaction that takes place is called Hydration. Hydration generates heat, which can affect the quality of the cement and also beneficial in maintaining curing temperature during cold weather. On the other hand, when heat generation is high, especially in large structures, it may cause undesired stress. The heat of hydration is affected most by C_3S and C_3A present in cement and also by water-cement ratio, fineness and curing temperature. Calculation of heat of hydration of Portland cement is to determine the difference between the dry and partially hydrated cement.

VIII. Fineness of Cement

The size of the particles of the cement is its fineness. The required fineness of geed cement is achieved through grinding the clinker in the last step of cement production process. As hydration rate of cement is directly related to the cement particle size, fineness of cement is very important.

2.2.2 Chemical Properties

The raw materials for cement production are limestone (Calcium) sand or clay. (Silica) bauxite and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate. Chemical analysis of cement raw materials provides insight into the chemical properties of cement.

I. Tricalcium Aluminate (C_3A)

Low content C_3A makes the cement sulfate resistant. Gypsum reduces the hydration of C3A, which liberates a lot of heat in the early stages of hydration. C_3A does not provide any more than a little amount of strength.

II. Magnesiz (MgO)

The manufacturing process of Portland cement uses mangnesia as a raw material in dry process plants. An excess amount of magnesia may make the cement unsound and expansive, but a little amount of it can add strength to the cement. Production of MgO – based cement also causes less CO^2 emission. All cement is to a content of 6% MgO

III. Sulphur Trioxide

Sulfur trioxide in excess amount can make cement unsound.

IV. Iron Oxide/Ferric Oxide

Aside from adding strength and hardness, iron oxide or ferric oxide is mainly responsible for the color of the cement.

V. Free Lime

Free lime, which is sometimes present in cement, may cause expansion.

VI. Silica fumes

This is added to cement concrete in order to improve a variety of properties especially compressive strength, abrasion resistance and bond strength. Though setting time is prolonged by the addition of silica fume. It can grant exception high strength. Hence, Portland cement containing 5 – 20% silica – fume is usually produced for Portland cement projects that require high strength.

VII. Alumina

Cement containing high alumina has the ability to withstand frigid temperatures since alumina is chemical – resistant. It also quickens the setting but weakness the cement.

2.3 Water

Water is a substance composed of the chemical elements' hydrogen and oxygen and existing in gaseous, liquid and solid states. It is one of the most plentiful and essential of compounds. A tasteless and odorless liquid at room temperature, it has the important ability to dissolve many other substances.

In small quantities water appears colorless, but water actually has an intrinsic blue color caused by slight absorption of light at red wavelengths. Water is so vital for all known forms of life, even though it provides no calories or organic nutrients.

Water, ice and snow are also central to many sports and other forms of entertainment, such as swimming, pleasure boating, boat racing, surfing sport fishing, diving, ice skating and skiing. Water is the key ingredient, which when mixed with cement, forms a paste that binds the aggregate together.

The water causes the hardening of concrete through a process called hydration. The role of water is important because the water to cement ratio is the most critical factor in the production of perfect concrete.

2.4 Aggregates

These are the inert materials that are mixed in fixed proportions with a binding material to produce concrete. These act as fillers or volume increasing components on the one hand and are responsible for the strength, hardness, and durability of the concrete on the other hand. Aggregate takes up 60%~90% of total volume of concrete. Thus, concrete properties are highly affected by physical properties of its aggregate such as aggregate size distribution. Shape and grading of aggregates can significantly influence concrete workability. Poorly shaped and poorly graded aggregates generally show a lower packing density than well shaped and well graded aggregates, as a result more paste being required to fill the voids between aggregates. As the more paste volume needed to fill the voids is reduced, the fluidity of the paste must be increased to maintain a given workability level. As, poorly shaped aggregates show increased inter particle friction, resulting in reduced workability. The concrete mixtures having poorly shaped and poorly graded aggregates often require higher water and cementations materials requirements than those with well-shaped and well graded aggregates to maintain the same workability. The right selection of aggregates can minimize the increased water and cementations materials contents needed to ensure adequate workability.

2.4.1 Qualities of Aggregates

I. It should be chemically inert. i.e. they should not react with cement or any other aggregate or admixture.
II. It should possess sufficient toughness to bear impact and vibratory loads
III. It should be capable of producing an easily workable plastic mixture on combining with cement and water.
IV. It should be free from impurities inorganic or organic in nature, which will affect adversely on its quality.
V. It should be strong enough to bear compressive and normal tensile loads in the ordinary mixture.
VI. It should possess sufficient hardness to resist scratching and abrasion in the hardened state.

2.4.2 Types of Aggregates

This is classified on the basis of their grain size, origin and density.

2.4.2.1 Classification based on grain Size:

I. Fine aggregates: The grain – size lies between 4.75mm and 0.15mm. They pass-through from sieve with the mesh size of 4.75mm and are retained on a sieve of 0.15 mesh size. Sand is the most universally available natural fine aggregate.

II. Coarse: They are those that are retained on the sieve of mesh size. 4.75mm. their upper size is generally around 7.5mm gravels from river bed are the best coarse aggregates in the making of common concrete. Situations, may require suitable rock types to be crushed to the desired particle sizes for making coarse aggregates.

2.4.2.2 Classification based on the origin:

I. Natural: They are those types of fine and coarse aggregates, that are available in almost ready to use form, from natural resources. Examples are sand from river beds, pits and beaches, and gravels from river banks.

II. Bye Product: They are materials obtained as wastes from some industrial and metallurgical engineering operations which possess suitable properties for being used as aggregate examples are cinder obtained from burning of coal in locomotives and kilns and also slag is obtained from blast furnaces as scum is the best example from this category.

III. Processed: These form a special class in aggregates. Examples include, burnt clay, Shale, vermiculites and perlite. They are essential ingredients of lightweight concrete.

2.4.2.3 Classification based on density:

I. Standard or normal: these types of aggregates give strength and weighting to the concrete of around 2300 to 2500kg/m^3.

II. High Density: These ones are used in standard proportions yield in heavy weight concretes. Such concretes are especially useful as shields against x-rays and radiations in the atomic power plant. Examples are Baryle – a natural mineral with a specific gravity of 4.3 is an example.

III. Light Weight: They are natural and artificial materials of very low density so that the resulting concrete is also quite light in weight, generally within a range of 350 to 750kg /m^3. They are specially used in sound proofing and fire proofing constructions. They are also used extensively in the manufacture of light weight pre-cast concrete blocks.

2.5 Concrete

Concrete in construction, structural material consisting of a hard, chemically inert particulate substance, known as aggregate (usually said and gravel), that is bonded together by cement and water. Among the ancient Assyrians and Babylonians, the bonding substance most often used was clay. The Egyptians developed a substance more closely resembling modern concrete by using lime and gypsum as binders. Lime (Calcium oxide), derived from limestone, chalk or Oyster shells, continued to be the primary Pozzolanic, or cement – forming agent until the early 1800s. in 1824 an English inventor, Joseph Aspdin, burned and ground together a mixture of limestone and clay. This mixture, called Portland cement, has remained the dominant cementing agent used in concrete production.

Concrete is characterized by the type of aggregate or cement used, by the specific qualities it manifests, or by the methods used to produce. Many other non-cementitious types of concrete exist with other methods of binding aggregate together, including asphalt concrete with a bitumen binder, which is frequently used for road surfaces, and polymer concretes that use polymers as a binder. Concrete is distinct from mortar. Whereas concrete is itself a building material, mortar is a bonding agent that typically holds bricks, tiles and other masonry units together. When aggregates are mixed with dry Portland cement and water, the mixture forms a fluid slurry that is easily poured and mold into shape.

Concrete is one of the most frequently used building materials. Its usage worldwide is twice that of steel, wood, plastics and aluminum combined.

Concrete is a brittle material, which exhibit low resistance to tensile stress. The failure of concrete at very low tensile force is attributed to the spreading of micro cracks, which are inherent in concrete due to heat formations in cement hydration. The compressive strength of concrete is generally dependent on the water to cement ratio, degree of compaction, ratio of cement to aggregate, bond between mortar and aggregate, and grading, shape, strength and size of the aggregate (Ahmed et al., 2019). Concrete can be classified as a multi-phase composite material made up of three phases; namely the mortar, mortar/aggregate interface, and the coarse aggregate phase. The cause of failure is manifested by crack growth in the concrete. For normal concrete the crack growth is mainly near the cement paste or at the aggregate/cement paste interfacial zone. The strength of concrete at the interfacial zone mostly depends on the integrity of the cement paste and the nature of the coarse aggregate.

2.6 Admixture

An admixture is a substance which can be added to concrete to achieve or modify its properties. Admixtures are added to the concrete, in addition to cement, water and aggregate, typically immediately before or during the mixing process. Admixtures are used to improve the behavior of concrete under a variety of conditions. The properties commonly modified using admixtures are setting time, workability, air –entrainment, dispersion etc. The admixture is generally added in relatively small quantity ranging from 0.005% to 2% by weight of cement. Over use of admixtures have detrimental effects on the properties of concrete.

Admixtures are natural or manufactured chemicals added to concrete before or after mixing. They're used to mitigate difficult construction situations or to give fresh or set concrete certain properties. Admixtures can augment the workability, durability and strength of concrete, and resolve challenges presented by hot and cold temperatures, early-strength requirements or low water-to-cement specifications. Admixtures are of two main types: Chemical and Mineral. Some classifications of chemical admixtures: air-entraining, water-reducing, retarding, accelerating and plasticizers (super plasticizers) etc and that of minerals: Pozzolana admixtures, Grouting admixtures, Bonding admixtures, Corrosion inhibiting admixtures and Coloring admixtures etc.

2.6.1 Chemical Admixtures

Chemical admixture reduces the cost of construction, modify properties of hardened concrete, ensure quality of concrete during mixing, transporting, placing, curing and overcome certain emergencies during concrete operations.

2.6.1.1 Accelerating Admixtures:

These admixtures when added to concrete, mortar or grout Increases the rate of hydration of hydraulic cement, shortens the time of set, and accelerates the hardening or development of strength of concrete / mortar. These admixtures function by interaction with C_3S (Tri-calcium silicate) component of the cement thus increasing the reaction between cement and water.

2.6.1.2 Retarding Admixtures:

This type of chemical admixtures decreases the initial rate of reaction between cement and water and there by retards the setting of concrete. It functions by coating the surface of C_3S (Tri calcium silicate) components, thus, delaying this reaction with the water. Reaction products are slow to form as such the setting and hardening of concrete are delayed reducing early compressive strengths. Since the rate of stiffening of concrete can be too fast in certain tropical climatic conditions, sufficient time for the concrete is required for transportation and placement before setting. In such conditions retarding admixtures can be very useful. Retardation in setting time up to 8-10 hours is possible by suitable use of retarders. The delay in hardening caused by the retarders can be exploited to obtain an architectural finish of exposed aggregate: the retarder is applied to the interior surface of the formwork so that the hardening of the adjacent cement is delayed. This cement can be brushed off after the formwork has been struck so that an exposed aggregate surface is obtained.

2.6.1.3 Plasticizers (Water Reducer) Admixtures:

A material, which either increases workability of freshly mixed concrete without increasing water cement ratio or maintains workability with a reduced amount of water, is termed as water reducing admixture.

As their name implies, the function of water reducing admixture is to reduce the water content of the mix, usually by 5 to 10%, sometimes (in concrete of very high workability) up to 15%. Thus, the purpose of using a water reducing admixture in a concrete mix is to allow a reduction in the water cement ratio while retaining the desired workability or, alternatively, to improve its workability at a given water cement ratio. The actual reduction in water depends on dose of admixtures, cement content, type of aggregate used, ratio of cement, fine and coarse aggregate etc. Therefore, the trial mixes containing an actual material to be used on the job are essential to achieve optimum properties.

2.6.2 Mineral admixtures

2.6.2.1 Pozzolana admixtures:

The pozzolanic materials are essentially a siliceous or aluminous material which itself possessing cementitious properties, which will in finely divided form and in the presence of water, react with calcium hydroxide liberated in the hydration process to form compounds possessing cementitious properties. The pozzolanas can be replaced with cement by 10 to 35 %. The substitution produces cement that is more permeable but more resistant to the action of salt, sulphate, or acid water. Strength gain is usually slower than normal concrete. The pozzolanic materials used as admixtures are: Natural pozzolana which are Clay, Shale, Diatomaceous earth, Volcanic tuffs and Opaline cherts etc. while Artificial pozzolana are Fly ash, Surk,, Blast furnace slag, Silica fume, Rice husk ash and Metakaolin etc.

2.6.2.2 Grouting admixtures:

Under different conditions grout mixtures of different qualities are required. Sometimes grout mixtures will be required to set quickly and sometime will have to be in a fluid form for a longer period. Various admixtures used for grouting purposes are: Accelerators, Retarders, Plasticizers, Gas forming agents and Workability agents.

2.6.2.3 Bonding admixtures:

Bonding admixtures are usually water emulsions of organic materials including rubber, polyvinyl chloride, polyvinyl acetate, acrylics, styrene butadiene copolymers, and other polymers. They are added to Portland cement increase the bond strength between old and new concrete.

Flexural strength and resistance to chloride-ion ingress are also improved. They are added in proportions equivalent to 5% to 20% by mass of the cementing materials; the actual quantity depending on job conditions and type of admixture used. Some bonding admixtures may increase the air content of mixtures. Non re-emulsifiable types are resistant to water, better suited to exterior application, and used in places where moisture is present.

The ultimate result obtained with a bonding admixture will be only as good as the surface to which the concrete is applied. The surface must be dry, clean, sound, free of dirt, dust, paint, and grease, and at the proper temperature. Bonding agents should not be confused with bonding admixtures. Admixtures are an ingredient in the concrete; bonding agents are applied to existing concrete surfaces immediately before the new concrete is placed. Bonding agents help “glue” the existing and the new materials together. Bonding agents are often used in restoration and repair work; they consist of Portland cement or latex modified portland cement grout or polymers such as epoxy resins.

2.6.2.4 Colouring admixtures

Natural and synthetic materials are used to colour concrete for aesthetic and safety reasons. Red concrete is used around buried electrical or gas lines as a warning to anyone near these facilities. Yellow concrete safety curbs are used in paving applications. Generally, the amount of pigments used in concrete should not exceed 10% by weight of the cement. Pigments used in amounts less than 6% generally do not affect concrete properties.

2.6.2.5 Corrosion inhibiting admixtures

These admixtures work for many years after the concrete has set, increasing the corrosion resistance of reinforcing steel to reduce the risk of rusting steel causing the concrete to crack and scale. The commonly used corrosion inhibiting admixtures are sodium benzonite and sodium nitrate.

CHAPTER THREE

EXPERIMENT AND METHOD

3.1 Materials

3.1.1 Cement

Cement is a finely ground powdered product which has the potentials of reacting with water, to turn into a hard-binding matrix for aggregates. 50kg(1bag) of 42.5R BUA cement was used and it was purchased at Eke-Awka market, Anambra State from there it was conveyed to the school laboratory and was stored properly.

Plate 3.1 Picture of a bag of BUA cement

3.1.2 Coconut Fibre

Coconut fibre commonly known as coir is a natural fibre extracted from the outer husk of coconut and it is mostly used in products such as floor mats, doormats brushes and mattresses etc. This material was obtained locally from Agulu in Anaocha Local Government Area, Anambra State. It was properly kept in a store before it was burnt to ash.

Plate 3.2 Picture of coconut fibre.

3.1.3 Water

The water used was fetched from a water tank, which is in Nnamdi Azikiwe University civil engineering workshop. The water was used both for the mixing of concrete as well as in curing of the cubes.

3.1.4 Coarse Aggregate

Coarse aggregates are irregular broken stone or naturally occurring rounded gravel used for making concrete. It consists of broken stones of hard rock like granite and limestone or river gravels. The coarse aggregate used was bought in bags from Agu-Awka building materials market, Anambra state after which 12mm aggregate was sieved out for the practical.

Plate 3.3 Picture of coarse aggregate.

3.1.5 Fine Aggregate

Fine aggregates are small size filler materials in concrete. Fine aggregates are the particles that pass through 4.75mm sieve and retain on 0.075mm sieve. The fine aggregate used was purchased in bags from Agu-Awka building materials market, Anambra state. It was spread in the laboratory to air dry.

Plate 3.4 Picture of fine aggregate.

3.2 Equipment

The equipment used were:

3.2.1 Universal testing machine

A universal testing machine (UTM) is a test machine used to test the mechanical properties of a sample by applying a tensile, compressive or transverse load. A universal test machine is designed to meet a wide range of tests by simply switching out different grips and fixtures.

Plate 3.5 Picture of universal testing machine.

3.2.2 Measuring cylinder.

A graduated cylinder, also known as a measuring cylinder or mixing cylinder is a common piece of laboratory equipment used to measure the volume of a liquid. It has a narrow cylindrical shape. Each marked line on the graduated cylinder represents the amount of liquid that has been measured.

3.2.3 Wire gauze.

A wire gauze or wire mesh is a sheet of thin metal that has net-like patterns.it is used to provide support for items being held over flame.

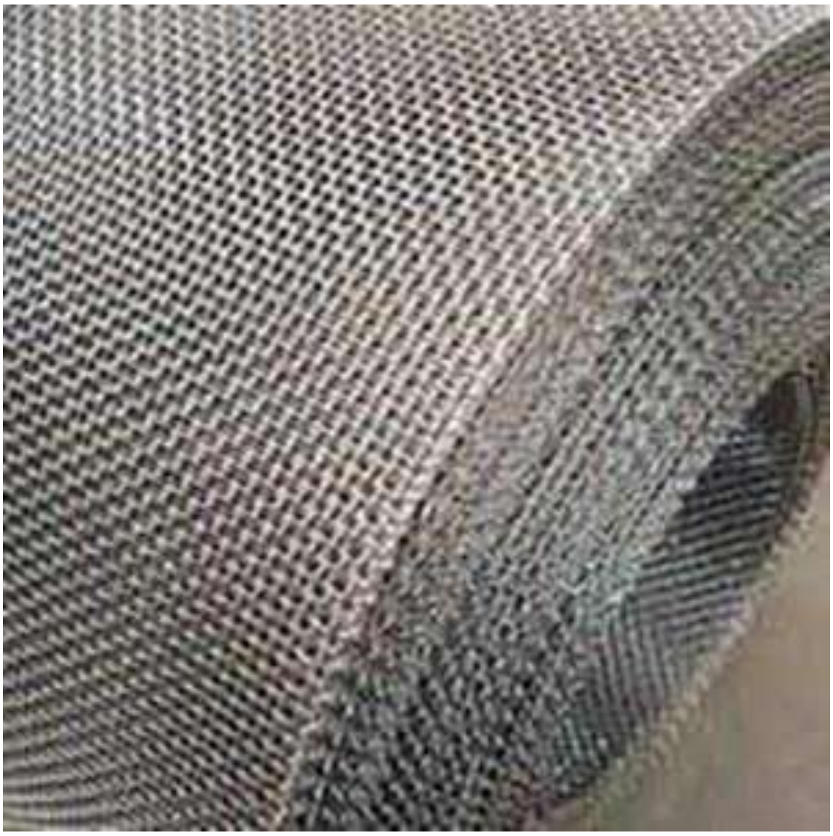

Plate 3.6 Picture of wire gauze

3.2.4 Burn barrel

Burn barrel means a metal container used to hold combustible of flammable waste materials so that they can be ignited outdoors for the purpose of disposal.

Plate 3.7 Picture of a burn barrel.

3.2.5 Concrete cube mold.

A concrete cube mold hold concrete during the curing process and can be easily dismantled so the molded concrete cube can then be either lab tested or kept in curing tank for quality control purposes.

Plate 3.8 Picture of concrete cube mould.

3.2.6 Curing tank.

The concrete curing tanks are constructed of galvanized steel or heavy plastic. They are used for lab or field curing of concrete beams, cylinders, or other concrete specimens.

Plate 3.9 Picture of concrete cube curing tank.

3.2.7 Tamping rod.

Tamping rods are dimensionally accurate rods used to tamp fresh concrete into concrete cylinder molds and grout sample boxes to eliminate voids and excess air. it is used for compacting concrete into cube molds.

3.2.8 Weighing balance.

A weighing balance is an instrument which is used to determine the weight or mass of an object. These are also known as mass scales, weight scales, mass balance and weight balance.

Plate 3.10 Picture of weighing balance.

3.2.9 Shovel.

Shovel is a tool used to dig as well as move loose, granular materials from one spot to another. In concrete work shovel is used to mix material components of the concrete.

3.2.10 Scoop.

Scoops are used for introducing concrete into the cube mold. They are made from 304 S.S and fitted with handle.

3.2.11 Trowel.

Trowel is a small tool with a flat blade that is used to smoothen a surface after the concrete has begun to set.

3.3 Practical Procedure

3.3.1 Burning of coconut fibre:

To obtain coconut fibre ash (CFA), the coconut corb was subjected to uncontrolled combustion in a rolled wire gauze placed inside a metal burn barrel. Burning was continued until the coconut corbs were burnt into ashes. The burnt ash was collected and sieved with 45µm BS sieve.

3.3.2 Mixing and curing of concrete cube:

The required quantities of cement, coconut fibre ash, fine and coarse aggregate were weighed out in a mix ratio of 1:2:4 and the water/cement ratio used was 0.6. Weight batching was adopted in measuring out the materials used for the mix design. The measured coconut fibre ash was mixed thoroughly with cement before the addition of fine aggregate and coarse aggregate. Then after proper mixing, a uniform mix was obtained. The measured water was then added to the mix and properly mixed with hand shovel. Cube molds to be used were prepared and well oiled. The concrete sample were filled into the cube molds in 3layers and each layer was approximately 5cm deep. In placing each scoopful of concrete, the scoop was moved around the top edge of the mold as the concrete slide from it. Each layer of the concrete filled in the mold was compacted by not less than 35 strokes using a tamping bar. The strokes were ensured to penetrate into the underlying layer. After tamping the third layer, excess concrete was removed and the top surface was smoothed. The casted cubes were stored under shed at a place free from vibration and at a temperature 22˚C to 33˚C for 24hours. Immediately after initial curing of the cubes, they were clearly marked. The cubes were removed from the molds and immersed in clean water at a temperature 24˚C to 30˚C till 7 or 28-days age of testing. The cubes were tested in saturated and surface dry condition.

3.3.3 Crushing of concrete cubes:

Compressive strength of the casted cubes was tested at 7, 14, 21 and 28days age of curing. The cubes to be crushed was air dried before been placed on the universal testing machine. weight of the cubes was noted. The cube to be test was placed in the space between bearing surfaces. Care was taken to prevent the existence of any loose material or grit on the metal plates of machine. The cube placed on bearing plate was aligned properly with the center of thrust in the testing machine plates. The loading was applied axially on the specimen without any shock and was increased at the rate of 140kg/sq. cm/min. till the specimen collapse. Due to constant application of load, the specimen cracked at a point and the breakdown of the specimen was noted.


Plate 3.11 practical picture 1


Plate 3.12 practical picture 2

Plate 3.13 Practical picture 3

Plate 3.14 Practical picture 4


Plate 3.15 Practical picture 5


Plate 3.16 Practical picture 6

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Preamble.

In this chapter, various tests conducted on the specimen will be looked into. The present study aims to investigate the oxide composition of coconut fibre ash used, compressive strength of coconut fibre ash as a partial ordinary Portland cement replacement in concrete.

This chapter show the results of oxide composition of coconut fibre ash and the compressive strength test performed on 32 concrete cube specimens. The specimen was cured and results were collected for 7, 14, 21 and 28 days with 2 specimens crushed for each day and the average of the two values taken. The mix ratio of the concrete is 1:2:4 and the size of aggregate used is 12mm with a water cement ratio of 0.6 maintained throughout the experiment. All the tests were done as described in the chapter three of this thesis.

4.2 Chemical composition of coconut fibre ash (CFA)

The result of the chemical analysis carried out on the coconut fibre ash shows that its chemical composition constituted some metallic and nonmetallic oxides in different proportions. The various constituents were analyzed in accordance with ASTM C 618 -78.

Table 4.1 Chemical Composition of Coconut Fibre Ash (CFA)

Oxide	Percentage concentration (%)	
	CFA	OPC
CaO	57.101	64
SiO2	8.035	20.7
Al2O3	2.122	5.75
Fe2O3	1.191	2.5
MgO	7.915	1
SO3	3.32	2.75
K2O	15.101	0.15

Table 4.1 shows the oxide composition of CFA and OPC respectively. From the table, CFA contains 8.035% of SiO_2, 2.122% Al_2O_3 and 1.191% of Fe_2O_3. This gives 11.343% of SiO_2 + Al_2O_3 + Fe_2O_3 which is below the ASTM C 618-78 requirement of 70% minimum for pozzolana. 8.035% of SiO_2 is less than 35% min of SiO_2 per cent by mass required to classify it as a pozzolana. 7.915% of MgO is greater than 5% max required. 3.32% of SO_3 is more than 3% max of SO_3.

It can therefore be said that the CFA used even though it possesses all the oxides composition of a pozzolana but the oxide percentages doesn't tally with ASTM C 618 -78 requirement.

4.3 Compressive strength

Compressive strength was assessed at the ages of 7, 14, 21 and 28 days of curing on 150 mm by 150mm by 150mm cube mortar specimens, as per means of compression testing machine at standard loading rate. The machine automatically stops when failure occurs and then displays the failure load.

The compressive strength development in OPC, 10% CFA, 20% CFA and 30% CFA mortar specimens with curing period is shown in table 4.1.

Table 4.2 compressive strength test result.

Amount of Cement (%)	Amount of CFA (%)	Design strength (N/mm2)			
		7days	14days	21days	28days
100	0	12.64	17.45	18.29	19.18
90	10	10.76	14.4	14.87	16.37
80	20	5.66	8.14	9.46	12.52
70	30	4.87	6.72	7.69	10.5

4.3.1 Effect of curing time on compressive strength.

The compressive strength increases at all percentage replacement with curing time as seen in the figure 4.1. At 0% replacement of coconut fibre ash, compressive strength increased gradually from 12.64N/mm^2 to 19.18N/mm^2 at 28 days. For 10% replacement of coconut fibre ash, the compressive strength increased from 10.76 N/mm^2 at 7 days curing time to 16.37N/mm^2 at 28days.

At 20% replacement of coconut fiber ash, the compressive strength increased from 5.66N/mm^2 to 12.52N/mm^2 at 28 days. For 30% replacement of CFA Compressive strength increased from 4.87N/mm^2 at 7 days to 10.50N/mm^2 at 28 days.

It can therefore be said conclusively that giving more time for curing concrete cubes the compressive strength increases.

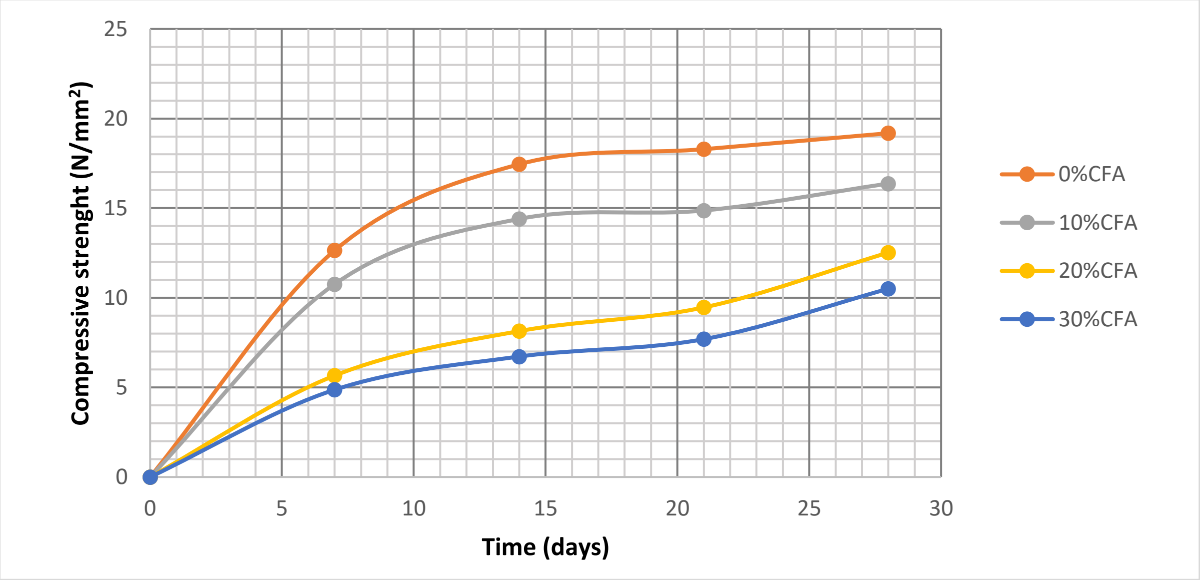

Figure 4.1 Effect of curing time on compressive strength.

4.3.2 Effect of coconut fibre ash as Partial replacement for cement on compressive Strength.

The compressive strength decreases with increase in the percentage replacement of coconut fibre ash for all the curing time as seen in Figure 4.2. For 7 days curing period, compressive strength decreased from 12.64N/mm^2 to 4.87N/mm^2 at 30% replacement of coconut fibre ash. At 14 days curing time, the compressive strength decreased from 17.45N/mm^2 at 0% replacement to 6.72N/mm^2 at 30% replacement of coconut fibre ash. Also, at 21days curing period, compressive strength decreased from 18.92N/mm^2 to 7.69N/mm^2. At 28days curing period compressive strength decreased from 19.18N/mm^2 at 0% replacement to 10.50N/mm^2 at 30% replacement of coconut fiber ash. It is observed that the concrete specimen achieved highest strength at 0%CFA replacement but on addition of 10%CFA, the strength at 28days curing age is observed to have dropped by 14.65% and on addition of subsequent percentages of CFA, decrease in strength are noticed. The research conducted by Anifowoshe and Nwaiwu (2016) on partial replacement of cement with 10%, 30%, 50%, 70% and 100% CFA also affirm that on addition of CFA to cement in concrete will lead to reduction in strength.

It can therefore be said conclusively that compressive strength decreases with increase in the percentage of replacement of coconut fiber ash.

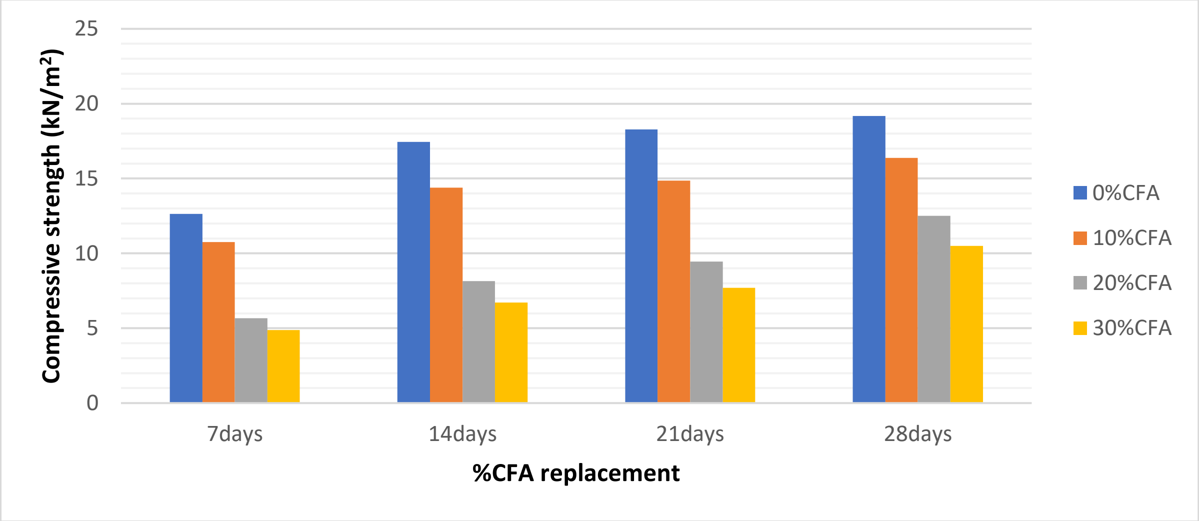

Fig 4.2 Effect of coconut fibre ash as partial replacement for cement on compressive strength.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research investigates the effect of 10%, 20% and 30% of CFA on concrete cured for 7, 14, 21 and 28 days. The oxide composition of CFA and the compressive strength of the concrete were investigated.

From the results and discussions of this research. It can be concluded that:

1. The oxide composition of CFA used doesn't conform to ASTM C 618 -78 requirement. The CFA contains 8.035% of SiO_2, 2.122% Al_2O_3 and 1.191% of Fe_2O_3. This gives 11.343% of $SiO_2 + Al_2O_3 + Fe_2O_3$ which is below the ASTM C 618-78 requirement of 70% minimum for pozzolana. 8.035% of SiO_2 is less than 35% min of SiO_2 per cent by mass required to classify it as a pozzolana. 7.915% of MgO is greater than 5% max required. 3.32% of SO_3 is more than 3% max of SO_3.
2. Concrete strengths increases with curing age and decreases with increasing percentage of CFA replacement in concrete. The concrete strength is highest at 0%CFA replacement and at 10%CFA replacement, the concrete still has an appreciable strength and can be used for load bearing concretes while 20% and 30%CFA replacement are suitable for concrete production in pit latrine construction.
3. The use of CFA will reduce the volume of cement used in light weight concrete, thereby reducing the cost of concrete production.
4. The use of CFA will minimize the environmental issues arising from the disposal of Coconut Fibre Wastes.

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5.1 Recommendation

Further areas of research are recommended. This includes the use of CSA calcined under controlled conditions, since the Calcination temperature and time appears to have a marked effect on the amorphosity of the ash and altering water/cement ratio and curing of concrete cubes more than 28days as we saw that with more curing days compressive strength of cubes increased and also to investigate the rate of water absorption as the percentages of CFA increases.

Finally, high institutions should equip their respective laboratories in order to enable students carry out laboratory test with relative ease and accuracy. This lack of laboratory equipment is a major reason for the abandonment of some laboratory concrete tests that would have otherwise been very relevant in further research work.

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APPENDIX

COMPRESSIVE STRENGHT OF CONCRETE

Two cubes per crush

7days curing

	0% CFA	**10% CFA**	**20% CFA**	**30% CFA**
C1	13.54	11.78	6.04	4.22
C2	11.74	9.74	5.28	5.52
Av.	**12.64**	**10.76**	**5.66**	**4.87**

14days curing

	0% CFA	**10% CFA**	**20% CFA**	**30% CFA**
C1	18.45	15.74	8.78	6.98
C2	16.45	13.06	7.5	6.46
Av.	**17.45**	**14.4**	**8.14**	**6.72**

21days curing

	0% CFA	**10% CFA**	**20% CFA**	**30% CFA**
C1	20.42	15.84	9.24	6.78
C2	16.16	13.9	9.68	8.6
Av.	**18.29**	**14.87**	**9.46**	**7.69**

28days curing

	0% CFA	**10% CFA**	**20% CFA**	**30% CFA**
C1	20.12	17.08	13.48	11.87
C2	18.24	15.66	11.56	9.13
Av.	19.18	16.37	12.52	10.5

OXIDE COMPOSITION OF COCONUT FIBRE ASH

Oxide	Percentage concentration (%)	
	CFA	OPC
CaO	57.101	64
SiO_2	8.035	20.7
Al_2O_3	2.122	5.75
Fe_2O_3	1.191	2.5
MgO	7.915	1
SO_3	3.32	2.75
K_2O	15.101	0.15

EFFECT OF COARSE AGGREGATE GRADING ON PROPERTIES OF CONCRETE

BY

NWOGU CHIDERA PRECIOUS

2016224028

A PROJECT SUBMITTED TO THE DEPARTMENT OF

CIVIL ENGINEERING,

FACULTY OF ENGINEERING,

NNAMDI AZIKIWE UNIVERSITY, AWKA

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN CIVIL ENGINEERING

FEBRUARY, 2022

CERTIFICATION

This is to certify that I am responsible for this work submitted in this project, that the original work is mine except as specified in the acknowledgement and references and that neither the project nor the original work submitted therein has been submitted to this university or any other institution.

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Nwogu Chidera Precious Date

(Student)

APPROVAL PAGE

This project has been read and approved by the undersigned as meeting the requirements of the Department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka for the Award of B.ENG in Civil Engineering.

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Engr. Dr. V. O. Okonkwo	Date
(Supervisor)	
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Engr. Dr. C.A. Ezeagu	Date
Head of Department	
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Engr. Prof. D.O. Onwuka	Date
External Examiner	

DEDICATION

I dedicate this project to God Almighty who is the source of inspiration and who starting from the day I was born till this very day has been blessing, prospering and putting smiles on my face in whatever my very hands found doing.

ACKNOWLEDGEMENT

My thanks and gratitude goes to God Almighty for giving me such an opportunity and for his unprecedented love and blessing upon me.

My profound gratitude goes to my supervisor Engr. Dr. V. O. Okonkwo whose dedication to academic advancement brought me under discipline to work hard to make this research a reality.

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My gratitude also goes to the following darling friends of mine, Chisom, Ruth, Chinenye, Evans and Emeka who had contributed in one way or the other to make this work a success.

ABSTRACT

Coarse aggregates have a great effect on properties of concrete, so gradation of coarse aggregates will always end up giving concretes of different properties. This project is an effort to provide properly detailed information concerning the influence of coarse aggregates grading on properties of concrete. Chippings of sizes 10mm, 20mm and 25mm were selected and used for this work. Preliminary tests like sieve analysis were conducted on the fine aggregate (sand) and also on the three selected coarse aggregates. 10mm and 25mm coarse aggregates were mixed in various proportions to produce five different concretes. Concrete C1 [100% of 10mm + 0% 25mm coarse aggregates], concrete C2 [75% of 10mm + 25% of 25mm coarse aggregates], concrete C3 [50% of 10mm + 50% of 25mm coarse aggregates], concrete C4 [25% of 10mm +75% of 25mmcoarse aggregates], and concrete C5 [0% 10mm + 100% 25mm coarse aggregates], Another concrete, [concrete C6] was casted with only 20mm and used as check, as 20mm coarse aggregate is mostly used in construction. In each mixture, slump test was performed and six cubes casted. The cubes were cured in water, and at 7days and 28days the selected cubes were crushed to obtain their compressive strength. After all the crushing it was found that the compressive strength increases as the percentage of 25mm coarse aggregate increases in a mixture, while workability decreases as the percentage of 25mm increases in each mixture.. Additionally, the sieve analysis graphs of the fine and coarse aggregates, the slump histogram of the three coarse aggregates and the graph of the concretes' compressive strengths, all went a long way in throwing more light on the properties of all the concretes.

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CHAPTER ONE

INTRODUCTION

1.0: BACKGROUND OF STUDY

Concrete is a mixture of water, cement or binder and aggregates is a commonly used material for construction (Barritt, 1984). The strength of concrete depends on aggregate type, size and source (Abdullahi, 2012; Hassan, 2014: Aginam et al 2013; Jimoh and Awe 2007). Aggregates amount to at least three-quarter of the volume of normal weight of concrete (Neville, 2003) and they are cheaper than cement and also confer a considerable better durability in concrete than the ordinary cement paste. The aggregates are divided into two major divisions by size- fine and coarse. The fine aggregates are sizes not larger than 5 mm while the coarse aggregate are sizes of at least 5 mm (Neville, 2003). There has been concern about the best aggregate sizes to be adopted in the manufacturing of concrete in the Nigerian construction industry. Effect of aggregate properties on concrete like grading of aggregates depends on proportions the coarse aggregate is varied or also the proportions of coarse aggregate and fine aggregate. If grading of aggregate is varied, it also changes cement content (cost economy), workability of the mix, density and porosity.

It is an important factor and has a maximum influence on workability. Well graded aggregates result in the least amount of voids in a given volume. Less voids result in excessive paste availability in a unit volume and more lubrication. Hence the mix is cohesive and avoids segregation.

Factors affecting properties of concrete include

- Size of aggregate

- Types of aggregate
- Quantity of aggregates
- Gradation of aggregate
- The amount of mix water
- The age or maturity of the concrete
- The type and quantity of cement and/or supplementary cementitious materials

Of all these factors, “coarse aggregate grading” plays an important role in determining the properties of concrete especially its compressive strength. Coarse aggregate is usually greater than 4.75mm (retained on a No. 4 sieve) which accounts for 60 to 80 percent of the weight of the concrete. There are various types of coarse aggregate like normal aggregates and light-weight aggregates. Normal aggregates like chippings, granite, gravel, limestone and sandstone are mostly used in modern civil engineering projects. Coarse aggregate is a necessary component that defines the concrete’s thermal and elastic properties and dimensional stability. Coarse aggregate used in concrete making contain aggregate of various sizes. This particle size distribution of the coarse aggregates is termed as “Gradation”. The sieve analysis is conducted to determine this particle size distribution. There are three typical range categories of aggregate grading, they are; well graded, poor graded, and gap graded and each type of the gradation has a certain influence on the properties of concrete.

That a particular mix yields an end product of higher economy, higher strength, lower shrinkage and greater durability depends on the type of aggregate grading employed. So it is always advisable for a right choice to be made in selecting a certain size of aggregate that will be suitable for a particular type of concrete work.

Hence, effects of aggregate properties on concrete properties are huge. In fact, most of the properties exhibited by concrete are what it is made up of - aggregates.

1.1: PROBLEM STATEMENT

At times concrete after being produced and cured shrinked and cracked, deformed and creeped under pressure by applied loads. When such happens, it means that the concrete has failed in various ways, which depends on the size of coarse aggregates used for that particular concrete. Mostly in concrete production, best properties are expected to be obtained, so when unsuitable size of coarse aggregate is used, it then means there is bound to be a compromise in the concrete's initial expected properties. In avoiding such a problem, its then imperative that right grading of coarse aggregate is employed during concrete work since a certain category of aggregate grading has a certain effect on concrete's properties.

The proposed research will attempt to determine the suitable grading of coarse aggregate that will bring out the best properties in concrete.

1.2: AIMS

The aim of this project is to determine the effect of coarse aggregate grading on properties of concrete.

OBJECTIVES

The principle aims and objectives of this research study include:

- To learn more about the nature of concrete
- Characterization of sharp sand and coarse aggregates.

- Acquisition of slump value for each concrete grade.
- Obtaining through some laboratory tests the compressive strength and workability of concretes casted by mixing 25mm and 10mm coarse aggregates at different percentages.
- To determine through the study and its experiments which particular sizes of the coarse aggregates that gives a concrete the best properties.

1.3: SIGNIFICANCE OF THE STUDY

This project aims at serving as a guide for people in the construction industries/companies. Contractors and structural Engineers can use the success of this project/research to determine the percentage combinations of 25mm and 10mm coarse aggregate that gives better properties than 20mm coarse aggregate.

1.4: LIMITATION OF STUDY

This research work was done by combining 25mm and 10mm coarse aggregates only, while 20mm coarse aggregate was used as check, though there are other sizes available in the market. Also concerning the properties of concrete, the research was limited to workability and compressive strength.

1.5: SCOPE OF WORK

This research work will be limited to the effect of coarse aggregate when 25mm and 10mm are combined at varying percentages in different concrete mix. This is related to workability and compressive strength properties of the resulting concrete only.

This entails preparing and casting concrete cubes of 150mm x 150mm x 150mm using 1:2:4 mix ratio and 0.55 water-cement ratio. Combining 10mm and 25mm coarse aggregate at varying percentages for different concretes and also casting concrete with only 20mm coarse aggregate as check.

For each of the concrete mix (100% 10mm + 0% 25mm coarse aggregates, 75% of 10mm + 25% of 25mm coarse aggregates, 50% of 10mm + 50% of 25mm coarse aggregates, 25% of 10mm +75% of 25mmcoarse aggregates, and 0% 10mm + 100% 25mm coarse aggregates). six concrete cubes each will be cast and the slump test taken to check for the workability of the concrete and the cubes were cured for a period of 7and 28 days to determine respectively the compressive strength of the concrete cubes.

CHAPTER TWO

LITERATURE REVIEW

A literature review on concrete and the effect of coarse aggregate grading on the qualities of concrete was presented in this chapter.

2.0 Overview of Concrete

Concrete, specifically port land cement concrete, has the qualities of strength, durability, versatility, and economy, and can be placed or molded into virtually any shape and reproduce any surface texture. It is the most widely used construction material in the world.

2.1. Concrete Components and Mixes

Both mass concrete and reinforced concrete are composite materials. Mass or plain concrete is made up of cement or lime, fine and coarse aggregate, and water; and reinforced concrete incorporates steel, although wrought iron was used in the earliest reinforced structures before 1900. The cement or lime is used as an adhesive to bind the coarse and fine aggregates. Water is added after dry mixing, which starts a chemical reaction with the cement or lime, resulting in a fluid mixture that hardens into a solid mass with good compressive strength but poor tensile strength. Steel reinforcing is used to improve the tensile strength of the concrete, allowing it to span considerable distances, and producing a very strong and versatile building material.

2.2 Cement

Natural cement: Natural cements occurred in the form of hydraulic limes3, to which pozzolans were sometimes added. The hydraulic properties of the natural cements varied according to the type of limestone used and whether pozzolanic material was added to increase the hydraulicity. Lime concrete is both weaker and more porous than that made with Portland cement. These natural cements generally have a compressive strength of approximately one-third that of Portland cement. The fineness to which the cement was ground determined the rate and degree of hydration, and also influenced the ultimate strength. Early cements were not as finely ground as modern Portland cement. It is most likely that the earliest imports from Britain, which occurred between 1840 and 1850, were of natural cement, as Portland cement only came into general use in Britain in about the 1860s. It is known that large quantities of Roman cement was being produced in England at this time for use by the plastering trade, but this product was not imported into New Zealand. Lime-based cements were being produced in New Zealand by the late 1860s. Lime concrete was not generally reinforced, as it was not considered strong enough and its porosity meant that any reinforcing would be more likely to corrode: 'For reinforced concrete work cements of doubtful quality should in no case be employed, and for this reason natural cements must be avoided, as their behavior is very uncertain, and they are more likely to be uneven in quality than artificial cements in which the ingredients can be proportioned with exactness' (Marsh, 1905).

Portland cement: Early Portland cements were not equivalent to today's 'ordinary Portland' cement-now more generally known as 'general purpose' cement. They were produced at lower burning temperatures and had weaker hydraulic properties, but were still stronger than natural cements. They were often lighter and greyer in colour (the natural cements tended to range from brown to light brown and paler colours). The exact specifications for Portland cement were gradually refined from its first patent in 1824 through to 1920. In 1909, C.F. Mitchell noted that "the modern method of manufacture is rapidly superseding the old' (Mitchell 1909) and gave a specification issued by the British Engineering Standards Committee for Portland cement that had been revised in June 1907. By then, the product was substantially similar to modern general purpose cement. Further refinements of the burning and grinding processes, and research into hydration and the roles of silica and alumina led to a Portland cement that, by the 1920s, was equivalent to that used today. It is probable; therefore, that concrete structures built in New Zealand prior to 1900 contains natural cements of varying hydraulic properties. Testing and analysis will assist in determining the type and properties of cement used in a historic concrete structure.

2.3 Aggregate

Increasing the maximum size of aggregate will increase durability by decreasing the cement paste content that will be under the physical or chemical attack (Mindess, et al ., 2003).

However, reducing the aggregate size will increase durability when concrete is subjected to freeze-thaw condition (Mindess, et al., 2003).

Aggregates should be unsound to prevent volume change by resisting a high internal stress when water inside the aggregate is frozen. The degree of saturation, porosity, permeability, and size of aggregate determines this stress (Mindess, et al., 2003).

Use of hard, dense and strong aggregate will improve durability by providing good wear resistance (IMCP 2006; Mindess, et al ., 2003; Kosmatka, et al ., 2002; Monteiro, et al ., 1993). In addition, aggregates should be free of reactive silica that causes a chemical reaction between the alkali in the cement paste and silica in the aggregate. Because alkali-silica reaction is very damaging for concrete and it significantly decreases the durability of concrete by causing map cracking, popouts and staining (Mindess, et al ., 2003).

The aggregate (both fine and coarse) makes up about 80% of the volume of the concrete. Shape, grading, size and type of aggregate all affect the final characteristics of the concrete produced; it is not simply inert filler. Before 1900, few researchers had studied the contribution made by the aggregate material to the quality of concrete. Although the importance of using clean aggregate gradually began to be understood in the 1800s, it is unlikely that the use of clean aggregates that were free of clay coatings, organic materials or sea salts was always ensured in early concrete. The consequences of using dirty aggregates include a tendency to attract and retain water, poor setting and curing, and chemical reactions that result in corrosion of the reinforcing and accumulation of efflorescence on the concrete surface.

In modern concrete, aggregate is carefully selected crushed stone. However, in early concrete structures, the choice of aggregate was determined largely by what was readily available. For example, in the supply of material for the construction of Fort Cautley in 1889, the aggregate was specified simply as local sand and scoria (Frankham, 1889, 1890). In other examples, ceramic waste and scoria ash were incorporated in the concrete walls of a cottage in Sinton Road, Hobsonville, and the concrete walls in W.J. Wilson's house at Warkworth contained a broken brick aggregate reinforced with strained wire hawsers. It is possible that the use of such aggregates may have had an inadvertent beneficial effect by increasing the hydraulic properties of the cement and the resultant concrete. The scoria ash and burnt clay would have acted as pozzolanic materials-as the Romans discovered two millennia ago.

For many builders, economic considerations and the reality of working in a country with a rudimentary land-based transport infrastructure would have meant that the most likely sources of aggregate were those that were locally available. The most commonly used aggregates came from streams and gravel pits, and often included sea sand and shells. Grading and size of aggregate both affect the amount of water needed to obtain workability. Generally, about 30% of the volume of well-graded sand is voids, which means that 30% of this volume of cement binder will be required. This explains the commonly used proportion of 1:3 binder to sand ratio often used in mortar specifications. This is a useful guideline for mixes in general, unless the historic mortar is known to have had a different binder: aggregate ratio.

There should be a continuum in the size of grains from small to large smaller grains fill the interstices between the larger grains, keeping the amount of cement paste to a minimum. A well graded aggregate, i.e. one with a range of particle size, improves the workability, as does using the largest possible particle size that can be compacted around and over the reinforcing. The improved workability means that less water is required and a stronger concrete is produced. This in turn limits the amount of shrinkage and deformation that takes place during drying.

The shape of the aggregate will also affect the workability of the concrete. An extremely rough, angular aggregate is less workable and may require more water to be added to the mix to increase its workability, thus reducing strength and producing a more porous concrete. Sharp aggregate can also hinder compaction. It does, however, bond well with the cement paste to produce a stronger concrete. Therefore, a balance between rounded and sharp aggregate is desirable. Ideally, aggregate should have a compressive strength equal to that of the cement paste, should be chemically inert in water, and should be clean, hard, and free from clay coatings and organic materials to ensure a good bond with the cement. However, it is unlikely that the aggregates used in early structures would always have been ideal for the purpose. Testing and analysis, and knowledge of local history and conditions will assist in determining the most likely aggregate that would have been used in a historic structure.

2.3.1 Coarse aggregate effect on concrete

Modern concrete consists of aggregate (fine & coarse), cement, water, admixture and other additives. Several factors are known to influence the strength of concrete. They include their batch ratios, processes, aggregate texture and shape and nature of other constituent materials (Woode, Amoah, Aguba, & Ballow, 2015). Aggregates are mixtures of various sizes of stone or rock particles in contact with each other. They are typically combinations of gravel and crushed materials, such as limestone, basalt and granite, but may also include blast furnace slag, or recycled concrete fragments. Particles with a diameter greater than 4.75 mm are usually classified as coarse aggregate, while smaller particles are called fine aggregate (McNally, 1998). For a long time aggregate was considered to be an inert filler which is added to cement paste simply for economic reasons. The properties of the resulting concrete were thought to be nearly independent of the properties of the aggregate (Stensatter, 1963). Since approximately three-quarters of the volume of concrete are occupied by aggregate, it is not surprising that its quality is of considerable importance. Not only may the aggregate

*Corresponding author: Jeetendra Prajapati Department of Civil Engineering, Khwopa Engineering College, Libali-08, Bhaktapur, Nepal Email: jeeten.prajapati@gmail.com

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limit the strength of concrete, but the aggregate properties JScE Vol.7, November 2019 Jeetendra Prajapati 53 greatly affect the durability and structural performance of concrete. Aggregate was originally viewed as inert, inexpensive material dispersed throughout the cement paste so as to produce a large volume of concrete. In fact, aggregate is not truly inert because its physical, thermal and sometimes, chemical properties influence the performance of concrete (Neville & Brooks, 2010). Many studies have been made to determine the effect of the physical and chemical properties of aggregate on the behavior of concrete. They include investigations into the effects of particle strength, surface texture, shape and alkali reactivity. Significant findings indicate that aggregate plays a more "active role" than was previously believed and a better understanding will result from further research (Stensatter, 1963). The compressive strength of fresh and hardened concrete is greatly affected by the type of coarse aggregate being used in concrete mixing. Since coarse aggregate occupies major volume in concrete, the overall property of coarse aggregates affect the property of concrete produced with different nominal mix. The property of coarse aggregate is governed by their source, size, shape, unit weight, texture, etc. Coarse aggregate properties (geological, physical and mechanical) are greatly influenced by the source from which they have been recovered. The variation on the aggregate properties (either mechanical or physical) also affects the property of concrete strength, workability and durability. There is significant influence of different aggregate types on concrete compressive strength, with stronger aggregate types increasing the overall strength of the concrete (Aitcin & Mehta, 1990; Zhou, Barr, & Lydon, 1995; Larrard & Belloc, 1997). Aggregate characteristics like shape, texture, and grading influence workability, finishability, bleeding, pumpability, and segregation of fresh concrete and affect strength, stiffness, shrinkage, creep, density, permeability, and durability of hardened concrete (Lafrenz, 1997. All these characteristics have an important influence on the properties of both fresh and hardened concrete (Neville & Brooks, 2010; Donza, Cabrera, & Irassar, 2002). The study on effect of content and particle size distribution of coarse aggregate on the compressive strength of concrete revealed that compressive strength is strongly linked to the coarse aggregate parameters (content, proportion of fine to coarse aggregate and grain size distribution) of concrete mixture (Mohammed, Salim, & Said, 2010). In 2003, Sahin et al., also observed that the increase in strength for a given increase in cement content depends on the type of aggregate used and the cement content itself while Ozturan and Cecen (1997) have found that for the same properties of paste, different types of coarse aggregate with different shape, texture, mineralogy and strength may result in different concrete strengths. In research on the effects of aggregate content on the behavior of concrete, Ruiz (1966) found that the compressive strength of concrete increases along with an increase in coarse aggregate content, up to a critical volume of aggregate, and then decreases. The initial increase is due to a reduction in the volume of voids with the addition of aggregate. In 1947, Glanville et al., has expressed the opinion that the shape, texture and porosity of aggregate affect concrete workability. Kaplan (1959) studied the effects of the properties of 13 coarse aggregates on the flexural and compressive strength of high strength and normal-strength concrete.. In the context of Nepal, concrete is being used as an extensive material of civil construction works of buildings, dams, bridges, highways, retaining walls, irrigation canals, etc.

2.3.2 Aggregate gradation

Aggregate gradation determines the void content within the structure of aggregate and consequently the amount of cement paste that is required to fill the void space and ensure a workable concrete. It is desirable to optimize the aggregate gradation in concrete using

Portland cement, as it is the most expensive and high carbon footprint ingredient, to minimize the void content in the aggregate and therefore the volume of cement paste required to achieve a workable, economical and an environmentally sound concrete for a given application.

The optimization of aggregate gradation also improves the rheological, mechanical and durability properties of concrete.

Proper aggregate gradation not only ensure a workable concrete mixture that can be compacted easily, but also reduces problems associated with plastic concrete such as potential for segregation, bleeding and loss of entrained air and plastic shrinkage cracking. Furthermore, most concrete that is used in construction of transportation infrastructure is often vibrated to achieve good compaction in concrete. Segregation in plastic state under vibration particularly is the most vulnerable problem in concrete containing aggregate with poor gradation. Cement paste filling the void space between the aggregate has a tendency to shrink when there is a progressive loss of moisture from concrete, either due to evaporation from surface of concrete or through internal consumption of moisture due to hydration reactions of cement. Aggregates in concrete, being much stiffer than the hardened cement paste, act to resist the shrinkage behaviour of concrete. Aggregate gradation, which determines the relative proportions of aggregate and cement paste in a concrete, therefore dictates the shrinkage behaviour of concrete and hence long-term durability of concrete.

The particle size distribution of an aggregate as determined by sieve analysis is termed as grading of the aggregates. If all the particles of an aggregate are of uniform size, the compacted mass will contain more voids whereas aggregate comprising particles of various sizes will give a mass with lesser voids .The particle size distribution of a mass of aggregate should be such that the smaller particles fill the voids between the larger particles. The proper grading of an aggregate produces dense concrete and needs less quantity of fine aggregate and cement waste, therefore, it is essential that coarse and fine aggregates be well graded to produce quality concrete.

2.3.2.1 Gradation and Its Effects in Compressive Strength of Concrete

Coarse aggregates used in concrete making contain aggregates of various sizes. The sieve analysis was conducted to determine this particle size distribution. Grading pattern is assessed by sieving a sample successively through the entire sieves mounted one over the other in order of size, with larger sieve on the top. The material retained on each sieve after shaking represents the fraction of aggregate coarser than the sieve in question and proper gradation ensures that a sample of aggregate contain all standard fractions of aggregate in required proportion such that the sample contains minimum voids. A sample of the well graded aggregate containing minimum voids will require minimum paste to fill up the voids in the concrete. Mindess, etc (1981) explained that minimum paste means less quantity of cement and less quantity of water leading to increased economy, higher strength, lower shrinkage and greater durability. The workability is improved when there is an excess of paste above that required to fill the voids in the sand, and also when there is enough water to hydrate the concrete. An excess mortar (sand plus cement) will fill the voids in the coarse aggregate because the fine material lubricates the larger particles. Cement-paste or the matrix that links together the coarse aggregates is weaker than the aggregates. It is this matrix that is vulnerable to all ills of concrete. It is more permeable and is susceptible to deterioration by the attack of aggressive chemicals. Therefore lesser the quantity of such weak link in concrete the better will the concrete be.

This objective can be achieved by having well graded aggregates. Variation in coarse aggregates gradation causes change in the workability of concrete (BS 1881, 1983). There are three typical range categories of aggregate grading, they are; Well Graded, Poor Graded, and Gap Graded. Each of the type of grading has a certain type of effect on the compressive strength of concrete. ACI Committee (1991) rightly argued that well-graded aggregate has a gradation of particle size that fairly evenly spans the size from the finest to the coarsest. A slice of a core of Well - Graded aggregate concrete shows a packed field of many different particles sizes. Well - Graded aggregate is characterized by the S - Shaped in gradation curve. Poor-Graded aggregate is characterized by small variation in size. It contains aggregate particles that are almost of the same size. This means that the particles pack together, leaving relatively large voids in the concrete. It is also called "Uniform- Grade". It is characterized by steep curve. Gap-Graded aggregate consists of aggregate particles in which some intermediate size particles are missing. A core slice of Gap-Graded, or skip size, concrete shows a field of small sized-aggregate interspersed with slightly isolated, large aggregate pieces embedded in a small sized aggregate. It is characterized by a gradation curve with a Jump in between. Montgomery (2001) explained that poor graded concrete generally require excessive amounts of cement paste to fill the voids making them uneconomical. Gap-Graded concrete fall in between Well-Graded and poorly graded in terms of performance and economy. Gap Graded is viable gradation, but not optimal. Well-Graded aggregates are tricky in proportion. The goal of aggregate proportioning and sizing is to maximize the volume of aggregate in the concrete while preserving the strength, workability and finishing. This balance the proportions of each so there are just enough of each size to fill all the voids, while preserving workability and Cast-Surface quality. Neville (1995) explained that some experiments have concluded that grading for maximum density gives the highest strength, and that the grading curve of the best mixture resembles a parabola. However such aggregates graded for maximum density give a harsh concrete that is very difficult in ordinary concreting. So the proportioning should be based on the surface area of aggregates that Is to the wetted. Other things remaining same, it can be said that the concrete made from aggregate grading having least surface area will require least water which will consequently be the strongest. Ozturan and Cecen (1997) showed that generally angular aggregate particles have rough texture and round aggregate particles are smooth textured. From the bonding point of view it seems that smooth textured rounded particles form a poor bond with cement paste. But the smooth looking surface of rounded particles is also rough enough at the microscopic level and the cement -gel that forms a bond with aggregate surfaces also has particle sizes in the level of microns. Both, surface and the cement gel reacts at the sub-microscopic level.

Angular aggregates have higher specific surface area than smooth rounded aggregate. With a greater specific surface area the angular aggregate may show higher bond strength than rounded aggregates. Also angular aggregates exhibit better interlocking effect in concrete that contributes in strength of concrete. Higher specific area of angular aggregates with rough texture demands more water for a given workability than rounded aggregates

2.4 Water

Water is another essential ingredient in concrete. It is now understood that mixing water should be kept free from salts and other impurities: generally, if it can be drunk, it is acceptable.

However, this was less well understood by the makers of early concrete, and sea water was often used when available.

On occasion, salt, sugar or glycerine was added to mixing water to prevent freezing during cold weather. Some builders also adopted the practice of adding fine clay to mixing water to improve the waterproofing characteristics of the finished concrete. All of these additions would have ultimately had a detrimental effect.

In one of the standard textbooks on reinforced concrete, Charles Marsh noted that 'for ordinary concrete work sea water does not appear to have any ill effects, it is possible that the contained salts might have an injurious action on the metal' (Marsh 1905). Although he then recommended using fresh water, this indicates that at this time there was still only a vague understanding that salts might be a problem. Salts in the water have an extremely detrimental effect on reinforced concrete, and it is probable that sea water was used in many early structures.

2.4.1 Water-to-Cement Ratio

An important parameter for durability is the w/c (IMCP 2006; Mindess, et al ., 2003; Kosmatka, et al ., 2002; Mehta and Monteiro, 1993). As w/c decreases, the porosity of the paste decreases and concrete becomes less permeable thus reducing passage of water and aggressive compounds such as chlorides and sulfates (IMCP 2006; Dhir, et al ., 2004; Mindess, et al ., 2003; Kosmatka, et al ,. 2002; Monteiro, et al ., 1993).

2.5 Admixture

Admixtures are ingredients other than port land cement, water, and aggregates that are added to the concrete mixture immediately before or during mixing. They are used to modify certain properties of the concrete and can be classified according to their function:

1. Air-entraining admixtures.
2. Water-reducing admixtures.
3. Retarding admixtures.
4. Accelerating admixtures.
5. Cementing agents.
6. Workability agents.
7. Miscellaneous agents such as bonding, damp-proofing, permeability-reducing, grouting, and gas forming agents.

Except for air entrainment, the desired concrete properties can often be obtained more easily and economically by selecting suitable materials rather than resorting to admixtures.

Air-entraining agents are the most commonly used admixtures for agricultural concrete. Air entrainment produces microscopic air bubbles throughout the concrete. Entrained air bubbles dramatically improve the durability of concrete exposed to moisture and freeze/thaw action. The resistance of the concrete surface to scaling is also improved. Scaling may result from the use of chemical deicers or exposure to mild corrosive agents, such as manure or silage. Air-entrainment is recommended for all concrete used for agricultural applications, even though it has slightly lower strength than non-air-entrained concrete.

The workability of fresh concrete is also improved with air-entrainment. Retarding admixtures are used to slow the rate of concrete set or hardening. They are particularly useful for concrete that is placed during hot weather. On the other hand, accelerating admixtures, such as calcium chloride, are used to increase the rate of set-usually during cold weather. In Nebraska, fly ash from coal fired generating plants is used both as a cementing agent and/or workability admixture.

2.6 Properties of Concrete

Concrete is essentially a manufactured material. As mentioned component above, materials, its properties but also are complex by the and varied, and are determined not the only design by of the construction procedures the cement, the structure and the manufacturing process of workmanship and the design of concrete structures are much followed on site. Today, materials, workmanship and the design of concrete structures are much more standardized than they were in the past. Concrete that has been prepared properly and more standardized than they were in placed in a well-designed building is a very durable material with a slow rate of deterioration. However, this was very often far from the case in historic structures. The properties of early concrete structures may vary considerably from each other and from modern, general purpose cement reinforced concrete. The behavior of such structures must, therefore, be individually assessed according to the materials used, and their design and detailing.

Mass or plain concrete, which was produced with hydraulic lime, natural cement or early Portland cement, is an essentially different material from modern reinforced concrete. Each mix has differing strengths and weaknesses, and is exposed to different deterioration processes. Concrete without steel or iron does not have the problems associated with corrosion and exponential deterioration due to rusting steel that reinforced concrete has, but it is far more vulnerable to seismic and tensile forces than reinforced concrete.

2.6.2 Strength

Concrete was initially used as a replacement for or component of masonry because of its adhesion to other materials and good compressive strength. The achievable compressive strength increased as the understanding of cement materials and their hydraulic properties improved. Portland cement concrete rapidly became the predominant material used for engineering and building, due to its compressive strength being approximately three times that of concretes based on hydraulic lime or natural cement. A range of factors affect the ultimate strength of concrete, including the water: cement ratio, compaction, the aggregates used and workmanship. General purpose cement concrete usually has an average compressive strength of about 25 MPa, while that of lime concrete could range from about 5 to 10 MPa (Mitchell, 1909).

As mentioned above, plain concrete was mostly used for its compressive strength, as this was about ten times its tensile strength. The addition of steel reinforcing from the 1900s resulted in a material with combined compressive and tensile strengths, which made it extremely versatile.

2.6.3 Movement

Concrete shrinks when drying (drying shrinkage). A proportion of this initial shrinkage is irreversible, but even fully cured concrete expands when wetted and shrinks as it hardens. Similarly, like most other materials, concrete expands and contracts with changes in temperature.

If the movement exceeds the tensile strength of restrained concrete, it will crack. The likelihood of moisture movement increases with the ratio between water and cement, and between cement and aggregate. 'Carbonation shrinkage' can also occur, where high levels of carbon dioxide from the atmosphere react with the hydrated cement paste. The extent of this shrinkage can be equivalent to that of wetting-drying shrinkage.

Creep is the deformation caused by a constant load. In concrete, there is a gradual increase of deformation due to the first application of a load. Initial creep is rapid at first but approaches a limit after about 5 years. The creep is roughly in proportion to the load, and is greater in weaker and less mature concrete.

2.6.4 Permeability

All concrete is to some extent permeable, particularly to water vapor. Lime concrete, however, is much more permeable than modern, general purpose cement concrete. Well-compacted concrete made with a low water: cement ratio has good resistance to water absorption, but where more water has been used in the mixing, as was often the case in early concrete, the concrete tends to be more porous, and hence more permeable. This characteristic is more pronounced where lime cements and early Portland cements were used. Conversely, poorly compacted or 'bony' concrete may also be porous because of voids between aggregate particles that were not filled with cement paste.

The permeability of early concrete can be a disadvantage where reinforcing was incorporated, as this reinforcing is more likely to corrode. In non-reinforced concrete structures, however, permeability is not necessarily detrimental, although the moist concrete may more readily support organic growths. Lime concrete has a greater ability to absorb and lose water vapor than general purpose cement. Condensation can be a problem with solid concrete walls, so the ability to 'breathe' can be an advantage.

2.6.5 Durability

Many circumstantial external factors will affect the durability of any concrete. The specific effect of these on an individual structure will depend on the nature of the particular concrete and the intensity of the external agent. External factors include frost, chemicals and fire.

2.6.5.1 Frost

Concrete can be damaged by the expansion of ice crystals, which are most likely to occur where water has lodged in pores or cracks in the concrete. A dense concrete will have a high resistance to this type of erosion. In contrast, concrete with voids, cracks or large pores will be more vulnerable to frost damage and, if reinforced, corrosion of the steel will be more likely.

2.6.5.2 Chemicals

As a general principle, the better the compressive strength, the better the chemical resistance. Lime concrete, which is softer and weaker than Portland concrete, is more vulnerable to chemical attack. In concrete that has voids and cracks or is porous, reinforcing steel will be more likely to be affected by chemicals, and this may result in corrosion damage to the structure.

2.6.5.3 Fire

Reinforced concrete is one of the most fire-resistant of common structural materials. However, although the strength of ordinary concrete increases up to temperatures of 120◦C, there is a serious loss of strength at higher temperatures. Flexural strength is more affected than compressive strength because of the effect of heat on steel reinforcing. The fire resistance of non -reinforced concrete is slightly lower than that of brick of the same thickness, although the type of aggregate will affect this. Siliceous aggregates have the poorest fire resistance, while those that include burnt clay products, pumice, well-burnt clinker, crushed limestone and pelleted fly ash have greater fire resistance.

Concrete fails in fire because of the differential expansion of the hot exposed layers over cooler internal layers. The insulation that the concrete provides is an important factor in its fire resistance, and lightweight aggregate concrete performs better in this respect. If steel reinforcing Is exposed, fire resistance and structural strength reduce dramatically as the rapid conduction of heat increases the temperature differential. One of the more destructive forces in a fire is the spontaneous expansion of water into steam, and this may be enough to shatter concrete members, especially older concretes with a high content of free lime.

2.6.6 Appearance

Early concrete structures were often rendered with plaster or clad in a veneer of brick or stone. Where the surface was left untouched after the formwork was removed, the aesthetic effect depended on the inherent color and texture of the concrete, and the quality of the formwork and workmanship.

The final color of concrete depends on the color of the cement as well as that of the aggregate; for example, where scoria was used for aggregate, the color of the concrete tended to have a reddish tinge. Early Portland cements were generally lighter in color than modern grey, general purpose cement.

However, all concrete changes appearance over time, as the initial cement 'laitance' (milkiness, i.e. fine particles in the surface) weathers away from the aggregates at the surface. As the aggregates are revealed, there may be quite dramatic changes in the appearance of the concrete.

2.7 Testing

There is a large variation in the cost, reliability and type of information provided by the different methods of testing available. The extent of testing will depend on the nature of the project, the allocation of funding and the feasibility. This section aims to give those managing the structure a general knowledge of the testing methods that are available to assist in the analysis and evaluation of repairs that may be required. A range of on-site, non-destructive tests can be undertaken. Laboratory testing can also be used to supplement the field condition survey and on-site testing as necessary. Laboratory testing will require samples to be taken on site. These can be in the form of lump, sawn or core samples. However, core samples may be difficult to obtain on remote sites, as a power source and water are necessary for the use of a core drill. It may also be inappropriate and disfiguring to take such samples from a historic structure; thus, discretion and judgment are required. The number and position of sample taken should be designed to give as accurate an assessment of the structure as possible, taking into account that the concrete may not be uniform.

.A well-equipped concrete laboratory can analyze the samples for strength, unit weight, alkalinity, carbonation, porosity, alkali-aggregate reaction, presence of chlorides and past composition. Such tests can determine approximate mix proportions and cement content. Thus, laboratory testing can aid the formulation of a compatible design mix for repair materials to historic concrete.

2.8 Curing

Concrete that has been specified, batched, mixed, placed, and finished "letter-perfect" can still be a failure if improperly or inadequately cured. Curing is usually the last step in a concrete project and, unfortunately, is often neglected even by professionals. Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance to freezing and thawing. Proper concrete curing for agricultural and residential applications involves keeping newly placed concrete moist and avoiding temperature extremes (above 90?F or below 50?F) for at least three days. A seven-day (or longer) curing time is recommended if construction constraints permit. Two general methods of curing can be used:

1. Procedures that keep water on the concrete during the curing period. These include ponding or immersion, spraying or fogging, and saturated wet coverings. Such methods provide some cooling through evaporation, which is beneficial in hot weather.

2. Procedures that prevent the loss of the mixing water from concrete by sealing the surface. This can be done by covering the concrete with impervious paper or plastic sheets, or by applying membrane-forming curing compounds. The best curing method for a particular job depends on cost, application equipment required, materials available, and the size and shape of the concrete surface. Begin the curing as soon as the concrete has hardened sufficiently to avoid erosion or other damage to the freshly finished surface. This is usually within one to two hours after placement and finishing.

2.9 Workability

This can be defined as the ease with which concrete can be compacted hundred percent having regards to mode of compaction and place of deposition. It can also be defined as the property of concrete which determines the amount of useful internal work necessary to produce full compaction. The workability of concrete depends on the quantity of water, grading of aggregates, and the percentage of fine materials in the mix. It is measured in terms of slump test, compacting factor and Vee-Bee degrees. In the test, four results can be expected; zero slump, true slump, shear slump and collapse slump. The desired one is the true slump.

2.10 Rheology

To address the shortcomings of results found in workability tests, researchers have tried to study concrete properties at a more fundamental level. Rheology is the study of the flow of materials including fluids and solids. Consequently, rheological models could be defined to describe the flow of fresh and hardened concrete. Liquids under shear stress will deform continuously. Likewise, fresh concrete will deform continuously, after a minimum shear stress, called the yield stress, has been applied. The objective of concrete rheology is to develop aptly relationships between the applied shear stress and the corresponding shear that allow predicting the behavior of concrete. For the purpose of this test the rheology of concrete will not be used.

2.11 Packing Density

Given a unit volume filled with particles, packing density or packing degree is the volume of solids in this unit volume and is equal to one minus the voids. The packing density gives an indication of how efficiently particles fill a certain volume and for that reason is such an important concept in materials science. If high volume of particles can be packed in a certain volume, the necessity for binder, which usually is much more expensive, to fill the voids and glue particles will be decreased.

The packing density or packing degree not only depends on the aggregate characteristics, but also on the compaction method and on the dimensions of the container. If the sample is just poured, the packing density will be lower than that corresponding to a sample tapped with a rod or a sample vibrated. Unfortunately, a correlation among packing densities obtained using different compaction methods has not been established, as it depends on the size, shape and texture of the particles. In fact, it is possible that a crushed aggregate has a lower loose density than a rounded one, while the vibrated density could be the opposite.

CHAPTER THREE

MATERIALS AND METHODS

3.0: GENERAL:-

Here the utilization of three sizes of commercially available chipping aggregates for concrete work were investigated. Normal concrete were produced from different sizes of aggregates and this imparts different qualities to the resulting concretes. For the purpose of this work, three sizes of aggregate, 25mm, 20mm, and 10mm were used. The selected aggregates were spread out for few days before use, to dry, in order to keep the aggregates at surface dry condition. Other foreign materials such as pebbles present were handpicked.

Normal mix (1:2:4) and water – cement ratio of 0.55 was adopted for this work and mix composition was obtained by weight method. As discussed in literature review, coarse aggregate contributes a lot to the qualities of concrete. Gradation of coarse aggregate in the same hand has great effect also on concrete in the sense that as the sizes of the coarse aggregate differs (along with their physical and mineralogical hardness) so do their qualities in concrete mixture.

3.1: MATERIALS AND METHOD

Cement:-

Commercially available ordinary Portland cement (Bua Portland cement) was used for this purpose.

Fine Aggregate

The fine aggregate used is sharp river sand obtained from a local dealer in Awka.

Coarse Aggregates:

Three sizes of commercially available chippings; 25mm, 20mm, and 10mm were used.

Water:

Clean water obtained from Civil Engineering laboratory, Nnamdi Azikiwe University, Awka was used for this work.

3.2: TEST APPARATUS AND EQUIPMENT

Some laboratory apparatus and equipment which were used in this study include: concrete mould of dimension 150mm×150mm×150mm, rammer/tamping rod, shovel, head pan, hand towel, BS sieve, weighing balance, mechanical sieve shaker, slump cone, universal testing machine and curing tank.

3.3: PRELIMINARY TEST

In order to throw more light on the materials used for this work, sieve analysis was carried out to obtain the range of particle size of the fine aggregate and that of the three selected coarse aggregate so as to ensure that the size of the aggregates was suitable for the study.

3.4: METHODOLOGY:

Here, the workability and compressive strengths of five different concretes made by using two different coarse aggregates (25mm and 10mm) in various mixed proportions were investigated. The third size which is 20mm was used as check.

By using the three different coarse aggregates, a total of six different concretes were casted.

The total six different mixtures were conducted in stages and proportions as shown below:

CALCULATIONS

Parameters

Density of concrete = 2400kg/m

Size of cubes = 150mm × 150mm = 0.15m × 0.15m

Volume of cube = 0.15m × 0.15m × 0.15m

Weight of cube = 2400kg/m ×

Calculating for the individual components using mix ratio 1:2:4 = cement: sand: aggregate

1+2+4 = 7

For cement; 1/7 × 8.1 = 1.157kg

For sand; 2/7 × 8.1 = 2.314kg

For coarse aggregate; 4/7 × 8.1 = 4.629kg

Provide additional 10% on all concrete components to take care of wastage.

Cement = 1.157 + (10/100 × 1.157) = 1.157 + 0.1157 = 1.2727kg

Sand = 2.314 + (10/100 × 2.314) = 2.314 + 0.2314 = 2.545kg

Aggregate = 4.629 + (10/100 × 4.629) = 4.629 + 0.4629 = 5.0919kg

Estimating the weight of water for one cube given that the water cement ratio used is 0.55

Water/cement = 0.55

Therefore weight of water = weight of cement × 0.55 = 1.2727 × 0.55 = 0.7024kg = 0.7024litres

Stage 1 of concrete C1 (100% of 10mm coarse aggregate + 0% of 25mm coarse aggregate)

At this stage 100% of 10mm coarse aggregate was mixed along with sand, cement, and water to form a concrete since 25mm coarse aggregate was at 0%. Slump test was performed and six cubes were casted.

With a mix ratio of 1:2:4, the concrete's constituents appeared as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

Stage 2 of concrete C2 (75% of 10mm coarse aggregate +25% of 25mm coarse aggregate):

At this stage 25% of 25mm coarse aggregate was mixed with the remaining 75% of 10mm coarse aggregate. After the proportioning, the whole aggregates were mixed along with sand, cement, and water to form a concrete. Slump test was performed and six cubes were casted.

With a mix ratio of 1:2:4, the concrete constituents appeared as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

25% of 20mm coarse aggregate = 25/100 × 30.5514 =7.6378kg

Therefore 7.6378kg of 25mm coarse aggregate were used.

75% of 10mm coarse aggregate =75/100× 30.5514kg = 22.9136kg

Therefore 22.9136kg of 10mm coarse aggregate were used.

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

Stage 3 of concrete C3 (50% of 10mm coarse aggregate + 50% of 25mm coarse aggregate):

At this stage 50% of 25mm coarse aggregate was mixed with the remaining 50% of 10mm coarse aggregate. After the proportioning, the whole aggregates were mixed with sand, cement, and water to form a concrete. Slump test was performed and six cubes were casted.

With a mix ratio of 1:2:4, the concrete's constituents appeared as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

50% of 25mm coarse aggregate = 50/100 ×30.5514 = 15.2757kg

Therefore 15.2757kg of 25mm coarse aggregate was used

50% of 10mm coarse aggregate = 50/100 ×30.5514 = 15.2757kg

Therefore 15.2757kg of 10mm coarse aggregate were used

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

Stage 4 of concrete C4 (25% of 10mm coarse aggregate + 75% of 25mm coarse aggregate)

At this stage 75% of 25mm coarse aggregate was mixed with the remaining 25% of 10mm coarse aggregate. After the proportioning, the two aggregates were mixed together along with sand, cement, and water and prepared as concrete. Slump test was performed and six cubes were casted.

With a mix ratio of 1:2:4, the concrete's constituent appeared as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

75% of 25mm coarse aggregate = 75/100 × 30.5514kg = 22.9136kg

Therefore, 22.9136kg of 25mm coarse aggregate were used.

25% of 10mm coarse aggregate = 25/100 × 30.5514 =7.6378kg

Therefore 7.6378kg of 10mm coarse were used.

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

Stage 5 of concrete C5 (0% of 10mm coarse aggregate + 100% of 25mm aggregate)

Here the only coarse aggregate used in concrete mix was 25mm coarse aggregate because 10mm was at 0%. The 25mm coarse aggregate was mixed with sand, cement and water to prepare a concrete. Slump test was performed. Six cubes were casted.

With a mix ratio of 1:2:4, the concrete's materials used were as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

Stage 6 of concrete C6 (100% of 20mm coarse aggregate):

At this stage 100% of 20mm coarse aggregate was mixed along with sand, cement, and water to form a concrete. Slump test was performed and six cubes were casted.

With a mix ratio of 1:2:4, the concrete's constituents appeared as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

3.5: MIXING OF THE CONCRETE

Hand mixing method was employed in mixing all the various concretes. On a hard dry concrete floor, the required volumes of all the concrete's constituents needed for a certain concrete mix were measured out, and by using shovel they were thoroughly mixed together. After mixing slump test was taken and finally the concrete was casted into the cubes.

By following the same mixing method, all the individual concretes were mixed, slump tests taken and were casted into cubes.

3.6: SLUMP TEST

Slump test is conducted to determine the consistency as well as workability of freshly mixed concrete.

Apparatus

- Slump cone (mould)
- Steel tamping rod
- Measuring tape
- Baseplate

Procedure

The mould of the slump test, which is the cone of about 305mm (12 inches) high, is used. It has base diameter 203mm (8inches) and top diameter 102 (4 inches). Moisten the inside of the cone to reduce friction that may influence slump variations. The base is placed on a smooth surface. The cone id then filled with concrete in three layers. Each layer is tamped 25 times with a standard 16mm (5\8 inches) diameter steel rod with rounded end. After filling the three layers, the top surface of the cone is struck off and levelled with a steel rod. Clean the area around base of the cone after levelling. The cone is slowly lifted and the concrete will slump. The lifted cone is placed beside the slumped concrete. place straight edge on top of the cone to cover the slumped concrete. Take the measure between the centre of the concrete and the straight edge with a rule. The height taken is the slump. The slump should be up to 125mm (5 inches). If the slump is more than 125mm the workability has then been failed.

3.7: CASTING OF CONCRETE

The casting of concrete after mixing was done by using a 150mm x 150mm x150mm cube mould. The side plates of the mould were fixed to the base plates and all the nuts tightened. The moulds were properly lubricated before filling the moulds with mixed concrete. The concrete was filled to about one-third of the mould. Then tamping rod was used to compact the concrete inside the mould especially in the corners for 25times. The second layer was filled to about two-third of the mould and also compacted for 25times using the stamping rod. The final layer was overflown and also tamped again for 25 times. The surface of the moulds was then given a smooth finish using the trowel. Hence, the specimens were prepared in accordance with BS 1881.

3.8: CURING OF THE CON CRETE:

The test specimens (the concrete cubes) were stored in the laboratory at a place free from vibration for 24hours after which the specimens were removed from the moulds and immediately submerged in a clean fresh water (curing tank). The specimens were left in the curing tank until taken out just prior to the compression test in range of 7 days and 28 days. For accurate result, the water that contained the specimens was renewed every 7days, while the specimens were not allowed to become dry at any time until they were crushed.

3.9: COMPRESSIVE STRENGTH TEST

This is to determine the comprehensive strength of the concrete specimens prepared in a cube crushing machine shown. The procedure for the cube crushing includes;

1. The specimen was removed from the water after the specified curing time and excess water was wiped from the surface and allowed to dry
2. The bearing surface of the testing machine was cleared
3. The specimen was placed in the machine in such a manner that the load shall be applied to the opposite side of the test cubes.
4. The specimen was aligned centrally on the base plate of the machine.
5. Then the movable portion was rotated gently by hand so that it touches the top surface of the specimen.
6. The load was applied gradually without shock and continuously at the rate of 140kg/cm^2 /minute till the specimen fails.
7. The maximum load was recorded.

By following the depicted procedures mentioned above and also maintaining the standards, the individual concretes made by the three different sized coarse aggregates were worked on and their respective average compressive strengths noted and recorded.

CHAPTER FOUR

ANALYSIS AND DISCUSSION

This study investigated how the sizes (gradations) of a commercially available chippings influence the compressive strength of concrete. Three different sizes 20mm, 10mm and 25mm of the selected chippings were investigated so as to know their effects on the concrete compressive strength.

In order to ensure that high degree of accuracy was achieved, each and every one of the selected gradation was singled out and every phase of the research carried out one after the other. The phases of the experiments were the same for all the gradations.

4.0 ANALYSIS AND RESULTS

Sieve Analysis of Aggregates

The results for the sieve analysis for the fine aggregate grading for the work is shown belowWeight of sample used = 300kg

Table 4.1: Sieve analysis result for fine aggregate

sieve size (mm)	mass retained (g)	cumulative mass retained (g)	Cumulative % retained	cumulative % passing
4.75	1.21	1.21	0.40	99.60
2	7.83	9.04	3.01	96.99
1.18	15.44	24.48	8.16	91.84
0.6	225.21	249.69	83.23	16.77
0.3	40.99	290.68	96.89	3.11
0.15	8.62	299.30	99.77	0.23
0.075	0.34	299.64	99.88	0.12
Tray	0.36	300.00	100.00	0.00
	300			

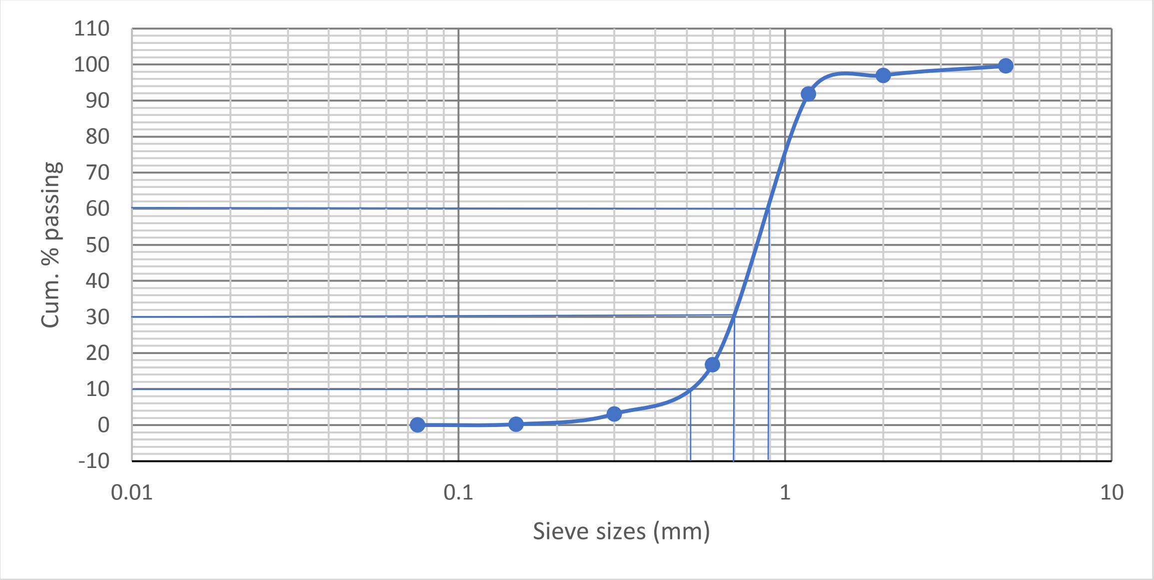

Figure 4.1: Sieve Graph for fine aggregate

Calculating for coefficient of curvature (Cc) = $D30^2/D60 * D10$

$$Cc = 0.7^2/0.9 * 0.52 = 1.05$$

Soil particle with coefficient of curvature between 1 and 3 shows that the particle is well graded and the soil is poorly graded when it is less than 1and uniform at 1. Since the result gotten (1.05) is approximately 1, the particle is uniformly graded.

Coefficient of uniformity (Cu) = D60/D10 = 0.9/0.52 = 1.73

Soil particle with coefficient of uniformity above 4 shows that the particle is well graded and the soil is uniformly graded when it is less than 4. Since the result gotten is 1.73, which is less than 4, the particle is uniformly graded.

SIEVE ANALYSIS FOR 10MM COARSE AGGREGATE

WEIGHT OF SAMPLE USED = 2000g

Table 4.2: Sieve analysis result for 10mm coarse aggregate

Sieve size	Mass retained (g)	% Mass retained	Cumulative % mass retained	Cumulative % passing
26.5	50	2.5	0	100
25	1200	60	60	40
20	500	25	85	15
14	200	10	95	5
10	50	2.5	97.5	2.5
4.7	0	0	97.5	2.5
Tray	0	0	97.5	2.5
Total	2000	100		

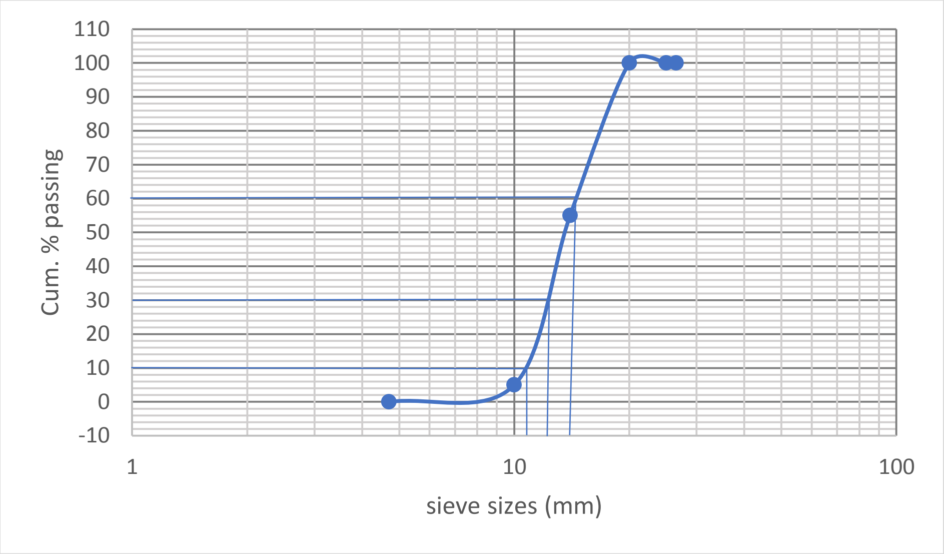

Figure 4.2: Sieve graph for 10mm coarse aggregate

Calculating for coefficient of curvature (Cc) = $D30^2/D60 * D10$

$$Cc = 13^2/15 * 11 = 1.02$$

Coefficient of uniformity (Cu) = D60/D10 = 15/11 = 1.36

The aggregate is uniformly graded.

SIEVE ANALYSIS FOR 20MM COARSE AGGREGATE

WEIGHT OF SAMPLE USED = 2000g

Table 4.3: Sieve analysis result for 20mm coarse aggregate

Sieve size	Mass retained (g)	% Mass retained	Cumulative % mass retained	Cumulative % passing
26.5	50	2.5	0	100
25	1200	60	60	40
20	500	25	85	15
14	200	10	95	5
10	50	2.5	97.5	2.5
4.7	0	0	97.5	2.5
Tray	0	0	97.5	2.5
Total	2000	100		

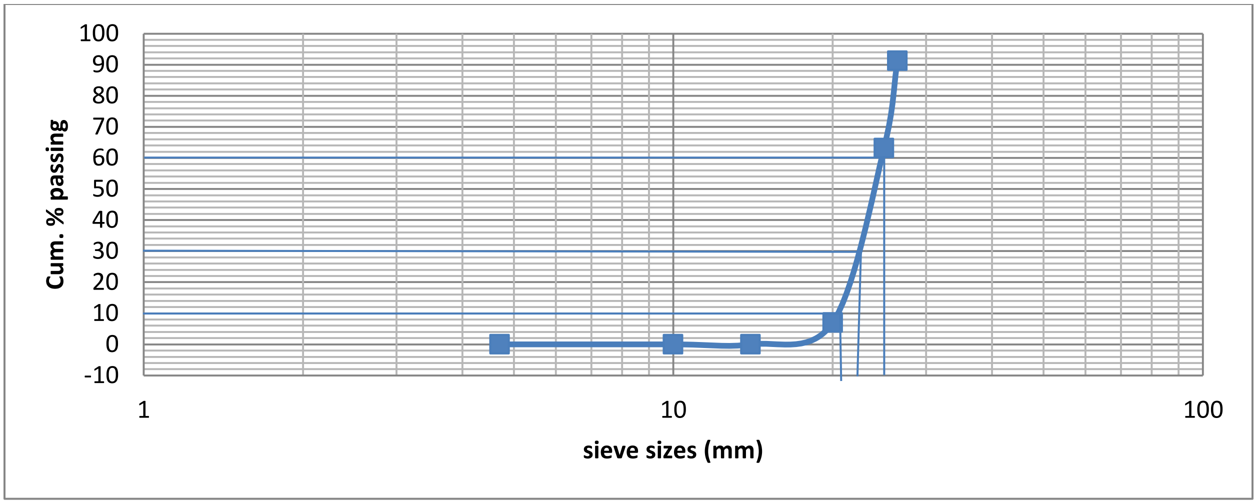

Figure 4.3: Sieve graph for 20mm coarse aggregate

Calculating for coefficient of curvature (Cc) = $D30^2/D60 * D10$

$$Cc = 23^2/20.5 * 25.5 = 1.01$$

Coefficient of uniformity (Cu) = D60/D10 = 25.5/20.5 = 1.24

The aggregate is uniformly graded.

SIEVE ANALYSIS FOR 25MM COARSE AGGREGATE

WEIGHT OF SAMPLE USED = 2000g

Table 4.4: Sieve analysis result for 25mm coarse aggregate

Sieve size	Mass retained (g)	% Mass retained	Cumulative % mass retained	Cumulative % passing
26.5	50	2.5	0	100
25	1200	60	60	40
20	500	25	85	15
14	200	10	95	5
10	50	2.5	97.5	2.5
4.7	0	0	97.5	2.5
Tray	0	0	97.5	2.5
Total	2000	100		

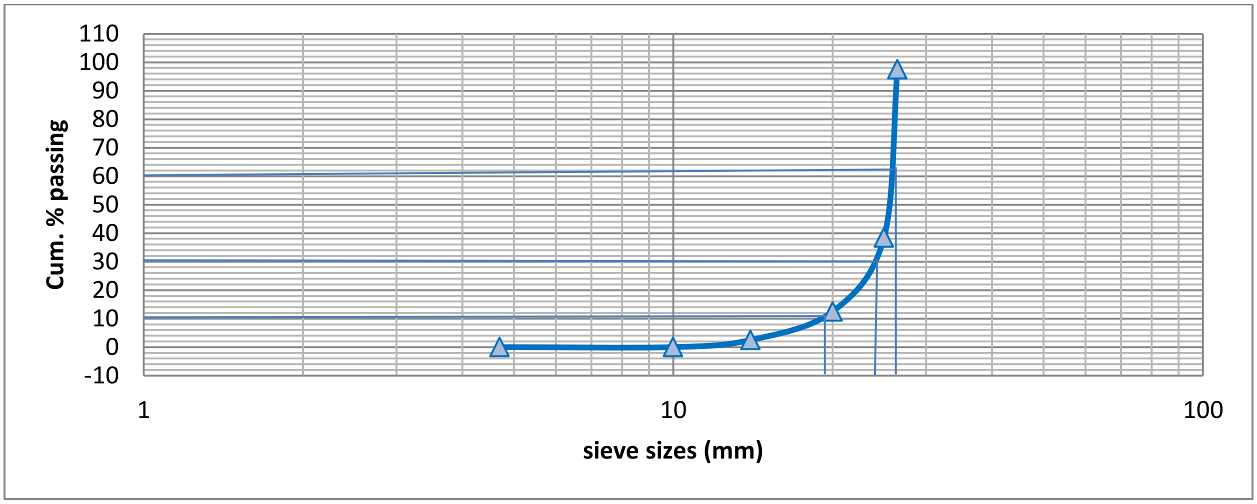

Figure 4.4: Sieve graph for 25mm coarse aggregate

Calculating for coefficient of curvature (Cc) = $D30^2/D60 * D10$

$$Cc = 25^2/27 * 19.5 = 1.19$$

Coefficient of uniformity (Cu) = D60/D10 = 27/19.5 = 1.38

From the results obtained, the aggregate is uniformly graded.

SLUMP

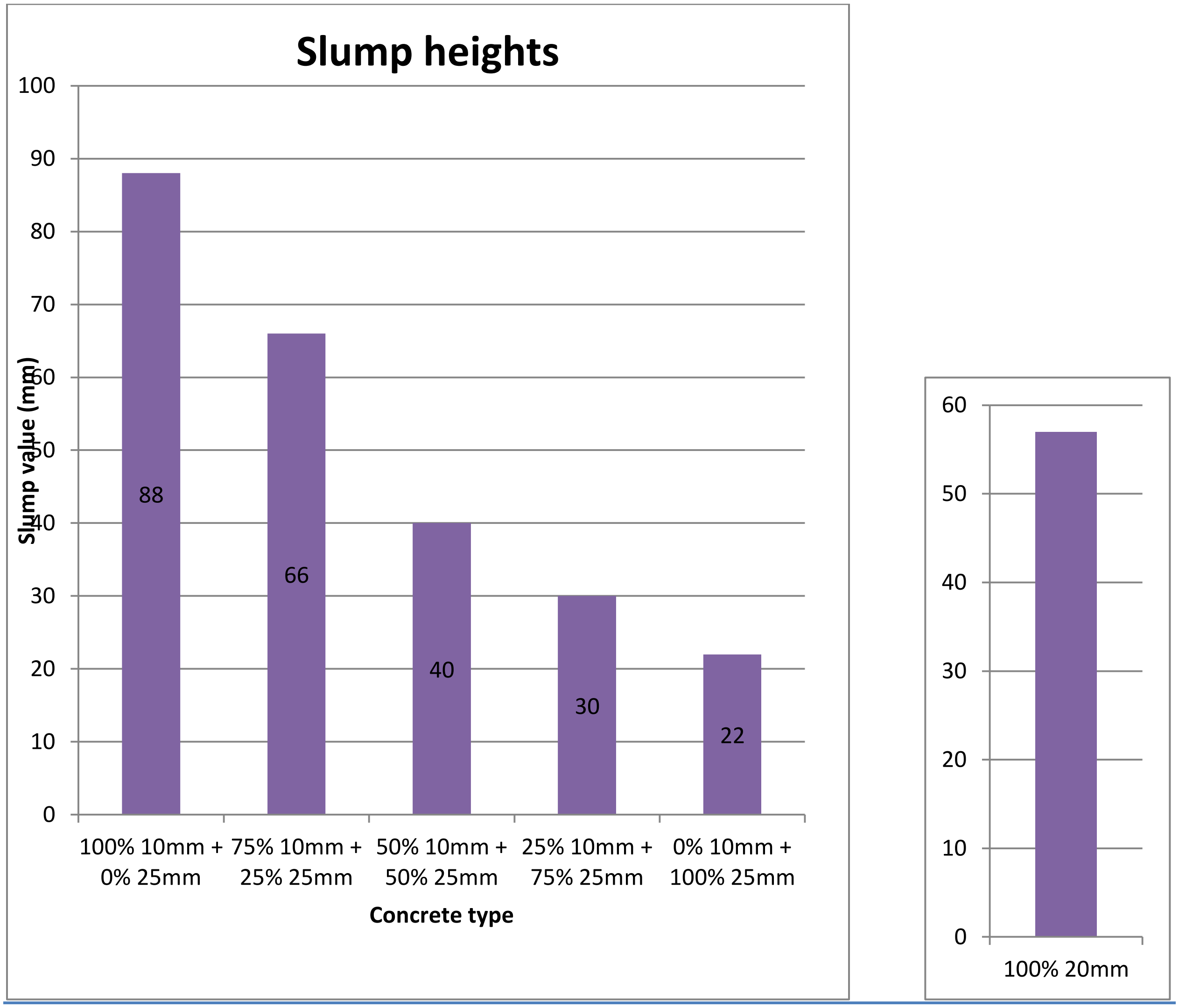

Figure 4.5: Slump values of the concretes

It is known that as sizes of aggregate increases, the workability decreases. From the slump histogram, 100% 10mm is found to be the highest; this shows that it is more workable than others. The workability keeps decreasing as the ratio of 25mm increases in each concrete.

COMPRESSIVE STRENGTHS

Table 4.5: Compressive strength results

Cube type	Age (days)	Weight of cube (Kg)	Test load (KN)	Strength (N/mm2)	Average Strength (N/mm2)
100% 10mm+ 0% 25mm	7	8.7	305.28	13.50	13.85
		8.9	320.40	14.24	
		8.6	310.52	13.84	
	28	8.8	426.06	18.93	18.30
		8.9	386.00	17.16	
		8.7	424.00	18.80	
75% 10mm + 25% 25mm	7	8.2	345.41	15.35	15.50
		8.2	360.00	16.00	
		8.4	340.88	15.15	
	28	8.3	460.06	20.40	20.30
		8.5	450.00	20.00	
		8.3	440.80	19.68	
50% 10mm + 50% 25mm	7	8.7	416.25	18.50	18.99
		8.7	443.25	19.70	
		8.5	442.55	18.78	
	28	8.8	573.75	25.50	24.53
		8.7	575.00	24.80	
		8.6	524.25	23.30	
25% 10mm + 75% 25mm	7	8.2	496.74	22.00	21.80
		8.4	467.04	20.70	
		8.4	510.70	22.67	
	28	8.5	577.80	25.68	26.33
		8.5	617.63	27.45	
		8.6	582.08	25.87	
0% 10mm + 100% 25mm	7	8.6	397.43	17.66	17.60
		8.5	395.54	17.50	
		8.6	386.00	17.20	
	28	8.8	530.66	23.50	23.85
		8.7	554.48	24.64	
		8.9	526.60	23.40	
100% 20mm	7	8.3	418.67	18.60	19.86
		8.1	465.56	20.69	
		8.3	456.56	20.29	
	28	8.5	530.66	23.50	25.30
		8.3	580.56	25.80	
		8.6	598.60	26.60	

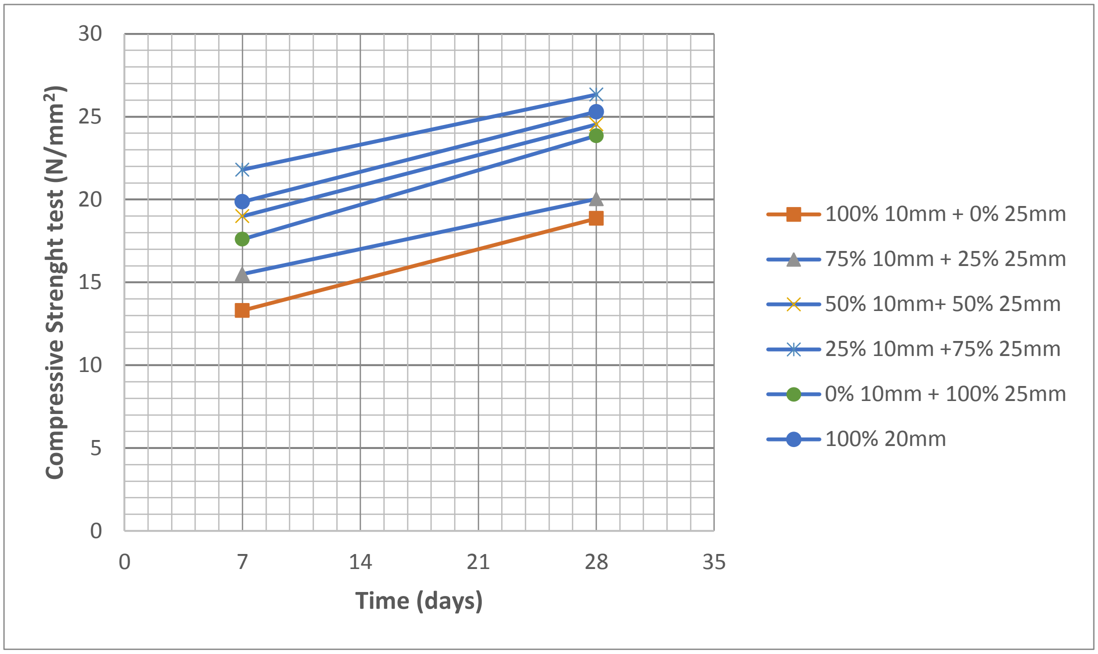

Figure 4.1: Compressive strength of the concretes at 7days and 28 days

The graph shoes that for each concrete, the compressive strength increases as the curing days increases. That is 28days curing gave more strength in each concrete than 7 days.

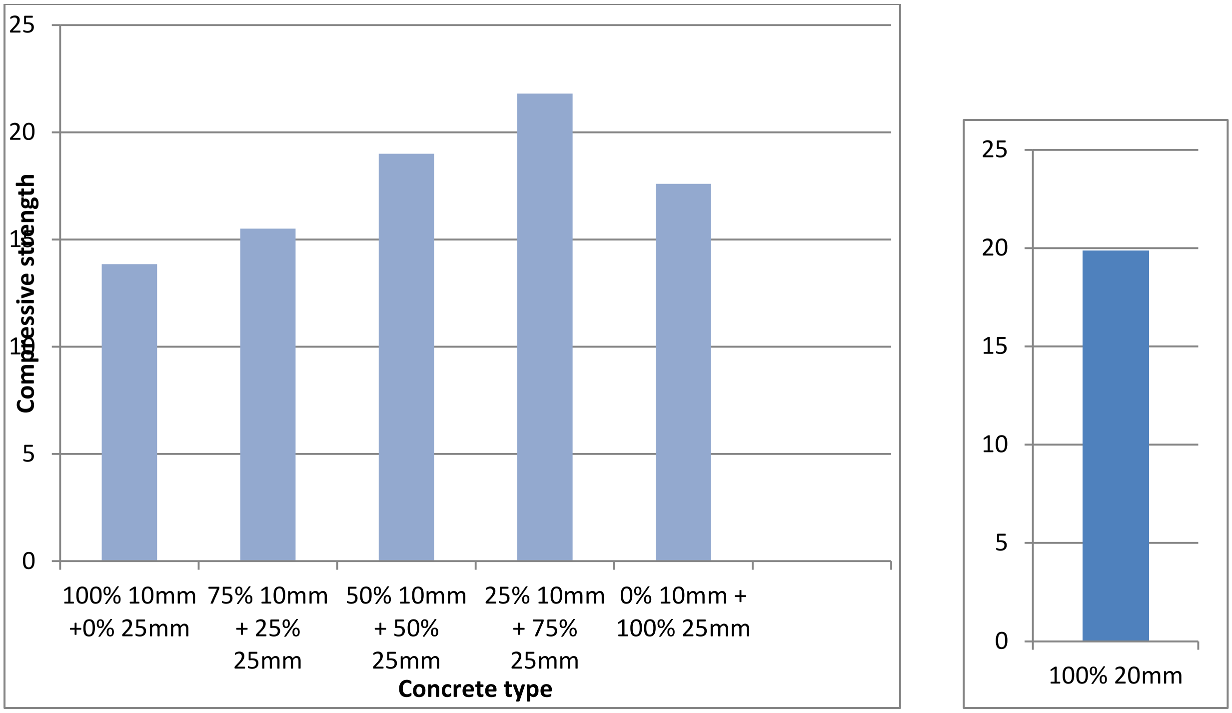

Figure 4.2: Compressive strength of the concretes at 7days

Figure 7 above shows that as the ratio of the bigger aggregate size increases (25mm), so do the compressive strength of the concrete. However the compressive strength decreased at 100% 0f 25mm.

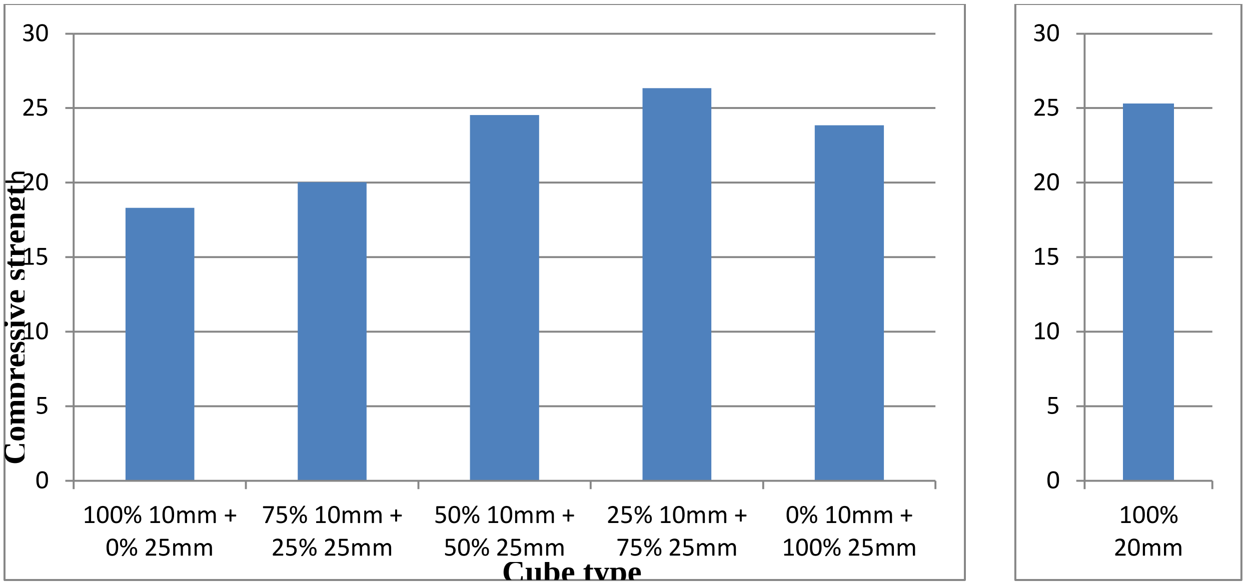

Figure 4.3: Compressive strength of the concrete at 28days

Figure 8 shows same result as figure 7.That is as the ratio of the bigger aggregate size increases (25mm), so do the compressive strength of the concrete. However the compressive strength decreased at 100% 0f 25mm. concrete made of 25%% 10mm + 75% 25mm gave more strength than concrete made with 100% 20mm.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

SUMMARY AND CONCLUSION

The study examined the influence of coarse aggregate grading on the compressive strength of concrete. Three different sized aggregates were selected and after working with them their individual concretes compressive strength were recorded. The specimens used were ordinary available chippings, sharp sand, and BUA Portland cement. The information obtained include the physical properties of the three aggregates and how they individually affect the mixed concrete, the workability of the selected aggregates determined through slump test and their compressive strength by crushing.

The study recognizes the importance of selecting a suitable sized aggregate in obtaining a concrete mix with maximum compressive strength, great durability and an increased economy. After the study, it was found that the compressive strength increases as the percentage of 25mm increases in the concretes, while it is the opposite for workability. Therefore depending on the property wanted at a time in a concrete, different percentages of 25mm and 10mm can be used. For workability 100% 10mm + 0% 25mm can be used, while 25% 10mm + 75% 25mm can be used in terms of strength. The usage of an appropriate sized aggregate will significantly reduce the lesser compressive strengths obtained when poorly sized coarse aggregates are used in concrete mix, it also increases the structure’s durability, reduces unnecessary expense encounters atimes for usage of more cement (for an increased workability through lubrication by the cement paste) and unnecessary compaction in elimination of voids when poorly graded aggregates are used. The information presented in chapter four of this study represents the observed properties of the selected aggregate as used in the concrete mix.

This concluding portion of the study is aimed at obtaining the importance of the test results obtained after working with the specimens in respect to the compressive strength of the concrete.

RECCOMMENDATIONS

Since concrete is widely used in civil Engineering practices aand since urbanization is increasingly boosted by infrastructures, it is imperative to note that a durable structure will only be achieved when a standard concrete is used. The possibility of obtaining a perfect concrete is when all its constituents are of standard and are in order, which is mostly achieved by the selected coarse aggregates. The usage of an appropriate coarse aggregate which meet up to standard in concrete mix will always enable that a strong and stable Engineering structures are constructed at an increased economy with longer durability and atimes of an outstanding aesthetic values.

The following are generally recommended by the researcher for accomplishment of the above mentioned objectives after the overall study, along with the tests and the results were conducted and obtained.

- Recognizing the uppermost importance of type and gradation of coarse aggregate in concrete mix as selecting right one will not only produce a concrete of higher compressive strength, but also enable a strong and durable concrete structure(s) to be constructed with greater economy.
- Making sure that during a concrete mix, that better constituents are selected because they will always boost the strength of the concrete.

- Depending on the particular property needed in a particular concrete when using 25mm and 10mm coarse aggregate, 100% 10mm + 0% 25mm combination should be adopted for workability, while for the best strength, 25% 10mm + 75% 25mm should be adopted.

FUTURE WORK

Future work should be done on other properties of concrete like permeability, density e.t.c, using same mix percentages of 25mm and 10mm. Other sizes can also be combined and the concrete properties checked.

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THE EFFECTS OF CURING DELAY ON THE COMPRESSIVE STRENGTH OF CONCRETE

BY

NWOJIJI OGBONNA ISWELL

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IN PARTIAL FULFILLMENT OF THEREQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG), DEGREE IN CIVIL ENGINEERING

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FACULTY OF ENGINEERING, NNAMDI AZIKIWE UNIVERSITY, AWKA

SUPERVISOR: ENGR. PROF. C.A CHIDOLUE

FEBUARY, 2022

DEDICATION

I humbly dedicate this to Almighty God who in his infinite mercy saw me through during the course of my years in the school and while undertaking my Project work and also to my God given parents, Mr. and Mrs. Nwojiji Nwonele who relentlessly supported my vision in life.

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Thank you all and may God Almighty bless you abundantly.

CERTIFICATION

This is to certisfy that this project tittled ‘The effects of curing delay on compressive strength of concrete was carried out by Nwojiji Ogbonna Iswellwith the Registration number 2016224055o of the department of Civil Engineering Nnamdi Azikiwe University, Awka. NO part of this work has been submitted to this university or any other institutionfor the award of Bachelor of Engineering (B.ENG) Degree

Nwojiji Ogbonna Iswell Date
Student

APPROVAL PAGE

I certify that this work was done by Nwojiji Ogbonna Iswell with registration number 2016224055 of the department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka, Anambra state.

______________________________	________________________
Engr. Prof.C. A. Chidolue Project Supervisor.	Date
______________________________	________________________
Engr. Dr . C.A Ezeagu. Head Of Department.	Date
______________________________	________________________
Engr.Prof.D.O.Onwuka External Supervisor	Dates

ABSTRACT

This project was carried out to determine the effects of curing delay on the compressive strength of concrete, using a 19mm granite (coarse aggregates) from Isheagu. Ebonyi state and uniformly graded sand from Omambara in Anambra state .A total of fifteen concrete cubes with mix ratio of 1:2:4 and the Cement-water ratio of 0.55 were casted and used for the experiment .Three cube were used for each set of samples, each set used for its corresponding curing delay. They are grouped as samples A1,A2,A3 for the zero delay, samples B1,B2,B3 for 7 days delay, samples C1,C2,C3 for 14 days delay, Samples D1,D2,D3 for 21 days delay and samples E1,E2,E3 for 28 days delay. All the samples were cured after their respective curing delay and the tested for its compressive strength on the 28th day.

It was discovered that their compressive strength consistently decreased with increased curing delay but the effects is highest at the early age of the concrete (i.e. between samples with zero delay and samples with 7 days delay. The final results showed that curing delay leads to a corresponding decrease in the compressive strength in concrete production

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INTRODUCTION

1.1. Background of study

Concrete is a man-made composite material composed of cement, aggregates and water in a proper proportion. Cement is a fine powdery-type substance used for construction that reacts with water, set, hardens and adheres to other materials to bind them together, (David 2018).

Aggregates are the chemically inert materials like sandstone, broken rocks, fines sand and so on, that are mixed in a fixed proportion with the binder (cement paste) to produce concrete.

The selection of the relative proportion of cement, aggregates, and water is termed mix design (PCA Manual, 2012).

Water is composed of two elements; two molecules of hydrogen and one molecule of oxygen, which are chemically combined together. A chemically active part of concrete are the cement and water (paste), these two react chemically to produce a building material known as cement mortar which binds the aggregates firmly together.

Concrete production is the process of mixing together the various ingredients such as water, aggregates and cement to produce concrete. Concrete production is time-sensitive.

Once the ingredients are mixed together, there is a limited time frame during which a concrete must be placed to form the required shape or used for the purposed and be allowed to harden (Gagg, 2014)

There is a wide varieties of equipment used to process concrete; it ranges from hand tools to heavy industrial machineries, whichever the equipment practitioners used, the objective is to produce the desired building materials. To achieve this objective, practitioner must ensure that the ingredients are properly mixed, placed, shaped and retained within the time constraints. Once the mixing is completed, the curing process begins which has to be controlled to ensure that the concrete achieves the required engineering properties.

Curing of concrete is the process of controlling the rate and extent of loss of moisture content from the concrete during cement hydration. Curing of concrete can be described more as the process of maintaining a satisfactory moisture content and a favorable temperature in concrete during the placement which follows immediately so that the hydration of cement will continue until the development of compressive strength to a sufficient degree to meet the requirements of its life service.

Curing of concrete is therefore designed primarily to keep the moisture content and temperature of the concrete, by preventing the excess loss of moisture from the concrete into the surrounding environment from the period of mixing to the period the required strength development is achieved. When to cure a concrete depends on the environmental condition in which the concrete is placed and whether it was placed in formwork, directly over ground, submerged in water and others. The best practice is to cure the concrete shortly after the chemical reaction has started, allowing the concrete to be hardened. Concrete should not be allowed to dry fast in any situation and the curing condition will likely to be maintained during the first 24 hours or at least until the final setting time of cement has past.

Neglecting of curing or delay of curing mostly at the early stage (hydration period) makes the quality of concrete to experience sorts of irreparable loss. Generally, factors like temperature, duration of curing and so on have great influence on the concrete strength development. Different curing methods are used depending on the condition of the site, size, shape and position of the concrete in question. These are as follow;

1. Water curing method.

2. Membrane method of curing.

3. by application of heat.

4. Miscellaneous method of curing.

But in this context water curing method is applied.

1.1.1 Water curing technique: This method involves flooding or total immersion of the concrete sample in water; this is the most effective curing method as the satisfactory moisture and temperature are maintained. The application of water is done to avoid drying of concrete surface, this method is mostly applicable when the concrete depth is thinner and is obtainable in some construction sites like building construction, which the curing of the slab and other members can be carried out appropriately.

Two ways of water application to the concrete are as follow.

1.1.2. By ponding the concrete: In this, a continuous wetting of the concrete surface is done without allowing the concrete to dry ,and mostly the kerbs casted around the slab helps in facilitating the curing process and its mostly applicable to dry environment.

1.1.3. By Sprinkling (Use of Sprinkler): In this case, water is sprinkled or sprayed continuously over the concrete at a constant rate and uniformly to enhance an adequate curing practice.

The moisture content and temperature of the concrete is maintained until the end of the proposed curing period which depends on the expected compressive strength.

1.1.4. Initial setting time - it is the interval between the moment water is added to the cement, to the time paste starts losing its plasticity. For ordinary Portland cement (OPC), it should not be less than 30 minutes. Experimentally we can say that initial setting time is the time elapsed between the moments when water is added to the cement to the time when the vicat plunger penetrates up to 5mm from the bottom.

1.1.5. Final setting time of cement: Final setting time of cement is regarded as the time elapsed between the moment when water is added to the cement to the time when cement lost its plasticity completely i.e. the cement get sufficient strength to resist any pressure and it shouldn't exceed 600 minutes (≤10hrs) .Experimentally we can say that the final setting time of cement is the time elapsed between the moment when water is added to the cement to the time when circular attachment fails to make any impressions (Juan, 2019).

1.2. Problem Statement.

Curing of a concrete is known as a vital process required to achieve durability and maximum strength of a concrete, but the problem comes up when there is a delay in the curing process, which results in reduction in strength development. Example are as follow:

i. Culvert built during dry season that partially absorbed water from its environment or kept dry till rainy season.

ii. Concrete material (kerbs and poles) that are not cured until rainy season, these could lead to plastic shrinkage and thermal cracks, thereby forming a weak structure within the concrete.

In this context, a proper evaluation has to be done on the area of how the delay affects the quality of concrete produced, at what rate does it affect the quality? And the level of reduction in quality of the sample in question. These are done within the series of varied periods of delay under a certain temperature limit (moderate).

1.3. Aim and Objectives.

This project is aimed at investigating the overall effect of curing delay on the compressive strength of concrete material with the objective stated below.

i. To properly cure a concrete sample for 28 days without delay in order to determine it actual compressive strength as a reference state strength.

ii. To produce and determine compressive strength of concrete samples with series of curing delay periods such as (7, 14, 21 & 28) days before they are cured for 28 days.

iii. To determine the loss in compressive strength development of the concrete due to curing delay, by comparing the compressive strength of the properly cured concrete without delay to the compressive strength of the concrete cured after series of delay.

1.4. Significance of Study.

Due to the ignorance of the some builders on the regulation of moisture content in concrete (importance of curing), there are needs to ascertain the effects of curing delay and emphasize on its negative effects on the quality of such concrete including its stability, strength, durability and properties that could be required for a structure to maintain its life service or designed purpose.

This will help the builder and engineers to have knowledge of curing delay, its negative effects and then pay more attention to the curing process while handling any construction work.

1.5. Scope of Work.

This project work is in two phases, firstly to determine the actual final compressive strength development of a properly cured concrete and secondly to get also the final compressive strength development for concrete whose curing process is delayed, using a 19mm granite from Isiagu Ebonyi state and fine sand from Omambara, Anambra state, with Bua cement and portable water obtained from water tank at concrete laboratory Nnamdi Azikiwe University, Awka.

To determine its negative effects on the concrete, different periods of curing delay (0, 7, 14, 21, & 28) days were used and then cured for 28-days after the varied delay periods. How it affects the hydration process was studied under moderate temperature and the water was constantly renewed on every seven days.

1.6. Limitations

There were several limitations on the course of this study which are:

i. Cost of materials was one of the major threats during this investigation, the cost of aggregate and cement is relatives high.

ii. Changes in temperature, as this laboratory study took long time to carryout, to maintain temperature became a problem of concern which was not 100% maintained

CHAPTER TWO

LITERATURE REVIEW

Having the aim of regulating the moisture content of the concrete to enhance proper hydration process, maximum compressive strength development, durability and other engineering properties of a concrete, scholars have done a lot of research work on it. After series of investigation carried out on concrete curing process, a general conclusion was established that curing which is designed primarily to keep concrete moisture by preventing the excess loss of moisture content from the surface of the concrete into the surrounding environment is paramount in strength development mostly at the early age of the concrete.

But the main question in this context is, what is the effect of delayed curing on concrete compressive strength. This question will be attended to afterward as it is the aim of this project work.

2.1. Concrete Material

Concrete is a construction and structural material consisting of a hard, chemically inert particulate substance, known as aggregate (usually sand and gravel), that is bonded together by cement and water (Augusryn, 2021). concrete is widely used for making architectural and engineering. Structure as foundations, bricks/blockwalls, pavements, Bridges/overpasses, Roads, runways, parking structures, Dams, pools, reservoirs, pipes, footings for gates, fences and poles and so on.

Famous concrete structures include the Burj Khalifa, Hoover Dam, the Panama Canal and the Roman Pantheon (Ejiofor, 2014). There are many formulations of concrete which provides varied properties, and concrete is the most used man-made product in the world due to its available and low cost compared to other construction materials.

Concrete constitutes of different materials such as aggregates, cement and water.

2.1.1 Properties of Cement

Cement is a fine mineral powder manufactured with very precise processes and also the main component of concrete. When mixed with water, this cement powder transforms into a paste that binds and hardens when submerged in water. Because the composition and fineness of the cement powder may vary, cement has different properties depending upon its makeup.

It is an economical and high quality construction material used in construction worldwide. Cement is made from a mixture of elements that are found in natural mineral such as limestone, clay, sand and/or shale. Cement can be classified into different types Depending on the material used and style of production, for example; Portland cement, slag cement, high-alumina cement, pozzolanic cement. But Portland cement (often referred as OPC, from ordinary Portland cement) is the most common type of cement in use in the world because it is basic ingredient of concrete, mortal, stucco and most non-specialty grout. It usually originates from limestone. It is a fine powder produced by grinding Portland cement clinker (more than 90%) with a limited amount of calcium sulfate (which controls the set time) and up to 5% minor constituent (Dunuweera, 2018).

2.1.2 Properties of Aggregate

Aggregate consists of large chunks of material in a concrete mix, generally coarse gravel or crushed rock such as limestone or granite, along with finer material such as sand. It constitutes over 80% of hardened concrete. Its properties have a Strong effect on the quality and durability of the concrete. Thus concrete is a true composite material. Redistribution of aggregate after compaction often create inhomogeneity due to the influence of vibration. This can lead to strength gradients. In addition to being decorative, exposed aggregates add robustness to a concrete drive way (Suryakanta, 2016). Aggregates used in concrete production are divided into two categories

i. Coarse aggregates: This type of aggregate consists of particles mainly retained on 5mm BS Sieve.

ii. Fine aggregates: This type includes natural sand, crushed stone sand or crushed gravel sand which consist of particle mainly passing through 5mm BS Sieve.

2.1.3 Properties of Water

BS3148 gives the requirement for the testing of water for its suitability for use in the production of concrete. If the water is good for drinking, definitely it is suitable for concrete making. Combining water with a cementitious material forms cement paste by the process of hydration.

The cement paste glues the aggregates together, fills the voids within it and makes it flow more freely. Lower water-cement ratio will yield a Stronger and more durable concrete; while higher water-cement ratio gives a free flowing concrete with a higher slump. Impure water used to make concrete causes problems when setting and can lead to premature failure of the structure.

Hydration involves many different reactions often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual particles and other components of the concrete to form a solid mass.

Reaction

Cement chemist notation: $C_3S + H \longrightarrow C\text{-}S\text{-}H + CH$

Standard notation: $Ca_3SiO_5 + H_2O \longrightarrow (CaO).(SiO_2).(H_2O)(gel) + Ca(OH)_2$

Balanced: $2Ca_3SiO_5 + 7H_2O \longrightarrow 3(CaO).2(SiO_2).4(H_2O)(gel) + 3Ca(OH)_2$

2.2 Concrete Production

Concrete production is the process of mixing together the various ingredients such as water, aggregate, and cement, to produce the building material called concrete. In concrete production, there is a limited amount of time during which the concrete may be formed into shape and place where it is to harden. Once the mix is where it should be, then curing process must be controlled to ensure the concrete attains the desired attributes.

When initially mixed, Portland cement and water rapidly form a gel of tangled chains of interlocking crystals, and components of the gel continue to react over time. Initially the gel is fluid, which improves workability and aids in placement of the material, but as the concrete sets, the chains of crystals join into a rigid structure, counteracting the fluidity of the gel and fixing the particles of aggregate in place. During curing, the cement continues to react with the residual water in a process of hydration. In properly formulated concrete, once this curing process has terminated the product has the desired physical and chemical properties.

2.3 Properties of Concrete

2.3.1 Strength: Concrete has relatively high compressive strength, but much lower tensile strength. For this reason it is usually reinforced with materials that are strong in tension (often steel). Strength of concrete can be said to be dependent on the water/cement ratio. Other factors that affect strength of concrete are.

i. Type of cement

ii. Amount and quality or brand of cement.

iii. Cleanness and grading of the aggregate.

iv. Presence or lack of admixtures

v. Handling and placement methods

vi. Temperature

vi. Mixing

vii. Curing conditions

viii. Age of concrete when in form and tested

On normal condition, the lower the water/cement ratio, the higher the strength of a concrete and its measured in pound per square inch (psi). Again, the strength of concrete depends on the characteristics of aggregate principally by affecting the water/cement ratio required for workability. Different strengths of concrete are used for different purposes. Very low-strength (2000 psi or less) concrete may be used when the concrete must be lightweight concrete is often achieved by adding air, foams, or lightweight aggregates, with the side effect that the strength is reduced. For most routine uses, 3000 psi to 4000 psi concrete is often used. 5000 psi concrete is readily commercially available as a more durable, although more expensive, opinion, 5000 psi concrete of often used for larger civil projects-strengths above 5000 psi are often used for specific building elements. For example, the lower floor columns of high-rise concrete buildings may use concrete of 12,000 psi more, to keep the size of the columns small. Bridges may use long beams of 10,000 psi concrete to lower the number of spans require. And occasionally other structural needs may require high strength concrete. If a structure must be very rigid, concrete of very high strength may be specified, even much stronger than is required to bear the service loads. Strengths as high as 19,000 have been used commercially for these reasons.

2.3.2. Workability: workability is the ability of a fresh (plastic) mix to fill the form/mold properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration) and can be modified by adding chemical admixtures, like superplasticizer with the resulting concrete having reduced quality. The use of an aggregate with an undesirable gradation can result in a very harsh mix design with a very low of water.

2.3.3 Creep: Concrete creep is defined as the deformation of structure under sustained load. Basically long term pressure or stress on concrete can make it to change shape. This deformation usually occur in the direction the force is being applied. When a stress is applied to a concrete specimen and kept constant, the specimen shows immediate strain followed by further deformation which progressing at a diminishing rate may become several times the original immediate strain. The immediate strain is often referred to as the elastic strain and the subsequent time-dependent strain is often referred to as the creep strain or simply the creep. That part of the strain which is immediately recoverable upon removal of the stress is called the elastic recovery and is less than the elastic strain. And that of the delayed recovery, the creep recovery and is much less than the creep. Some factors like aggregate, mix proportion and age of concrete affect creep (Ejiofor, 2014).

2.3.4. Durability and Permeability: This durability is the ability of concrete to withstand the environmental condition like effects of weathering to which it is exposed. Permeability is the rate or ability of water to pass through concrete. The lower the permeability, the higher the durability of a concrete.

2.3.5. Shrinkage: The volume contraction which occur as the concrete hardens and dries out is called drying shrinkage. Shrinkage is thought to be mainly due to the loss of adsorbed water in the gel. The shrinkage on first drying is partly irreversible and is called the initial drying shrinkage. If dry concrete is re-saturated with water, an expansion, sometimes referred to as the moisture movement, of about 60% of the initial drying shrinkage will occur. Shrinkage of concrete depends on the water/cement ratio and aggregate content.

2.3.6. Segregation and Bleeding: Bleeding is a form of segregation where some of the water in the concrete tends to rise to the surface of the freshly placed materials this arises due to the inability of the solid components of the concrete to hold all of the mixing water when they settle downwards. Bleeding of water continues until the cement paste has stiffened enough to end the sedimentation process.

If the bleed water is remixed during the finishing of the top surface, a week top surface will result. To avoid this, the finishing operations can be delayed until the bleed water has evaporated. Conversely, if evaporation of the surface water is faster than the rate of bleed, plastic shrinkage cracking may occur.

2.4 Testing

Tests can be made to ensure the properties of concrete correspond to specification for the application.

2.4.1 Sieve Analysis

Sieve analysis is a practice or procedure used to assess the particle size distribution of a granular material. It can also be called gradation test. The particle size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, and soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. A gradation test is performed on a sample of aggregate in a laboratory. A typical sieve analysis involves a nested column of sieves with wire mesh cloth (screen). A suitable sieve size for the aggregate should be selected and placed in order of decreasing size, from top to bottom, in a mechanical sieve shaker. A pan or bottom plate should be placed underneath the nest of sieves to collect the aggregate that passes through the smallest sieve. The entire nest is then agitated with the top cover properly tightened, and the material (particles) whose diameter is smaller than the mesh opening passes through the sieves. After the aggregate reaches the pan, the amount of material retained in each sieve is then weighed. The results of this test are provided in graphical form to identify the type of gradation of the aggregate.

The results of this test are used to describe the properties of the aggregate and to see if it is appropriate for various civil engineering purposes such as selecting the appropriate aggregate for concrete mixes and asphalt mixes as well as sizing of water production well screens. The results are presented in a graph of percent passing versus the sieve size.

→

Fig 2.1A. Mechanical sieve Mechanism.

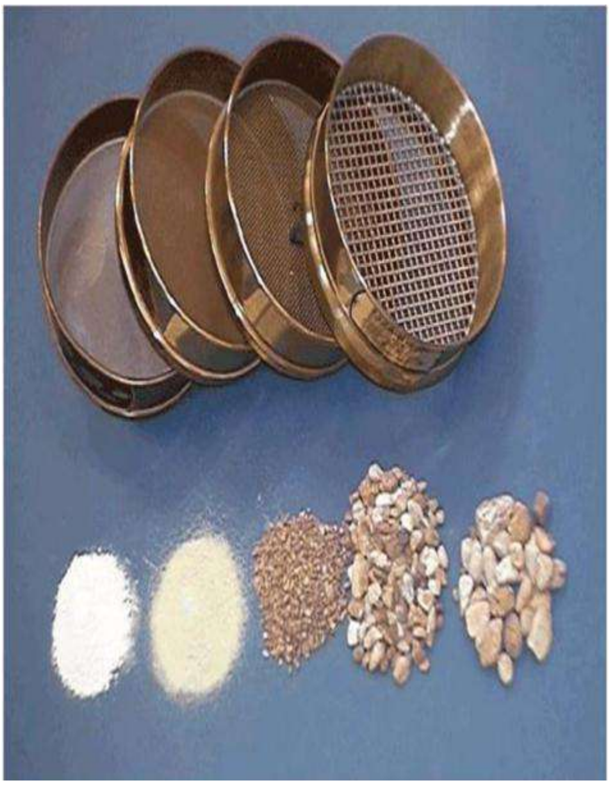

Fig 2.1B Samples & BS-Sieves

Calculation:

To find the percent of aggregate passing through each sieve, first find the percent retained in each sieve. To do so, the following equation is used,

$$\% \text{ retained} = \frac{\text{W sieve}}{\text{W total}} \times \frac{100}{1}$$

Where w_{Sieve} is the weight of aggregate retained in the sieve and W_{TOTAL} is the total weight of the aggregate. The next step is to find the cumulative percent of aggregate retained in each sieve. To do so, add up the total amount of aggregate that is retained in each sieve and the amount in the previous sieves. The cumulative percent passing of the aggregate is found by subtracting the percent retained from 100%.

Mathematically written as;

%Cumulative Passing = 100% - % Cumulative Retained

The values are then plotted on a graph with cumulative percent passing on the y-axis and logarithmic sieve size on the x-axis. The information from the graph is used for the soil classification and identification.

Table 2.1 showing of result sheet for sieve analysis

SIEVE SIZE(mm)	**MASS RETAINED (g)**	**PERCENTAGE OF MASS RETAINED (g)**	**PERCENTAGE PASSING (g)**	**COMMULATIVE % PASSING (g).**

2.4.2 Compressive Strength of Concrete Test

Out of many tests applied to the concrete this is the most important which gives an idea about all the characteristics of concrete. By this single test one judge that whether concreting has been done properly or not. For cube test two types of specimens either cubes of 15cm by 15cm by 15cm depending upon the size of aggregate used. For most of the works cubical moulds of size 15cm by 15cm by 15cm are commonly used. This concrete is poured in the mould and tamped

Properly so as not to have any voids. After 24 hours these moulds are removed and test specimen are put in water for curing. The top surface of these specimens should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen. These specimens are tested by compression testing machine after recommended days curing. Load should be applied gradually at the rate of 140kg/cm2 per minute till the specimens fails and finally write your report. Minimum of two specimens should be tested at each selected age. If strength of any specimen varies by more than 15 percent of average strength, results of such specimen should be rejected. Average of the specimens gives the crushing strength of concrete. Load at the failure divided by area of specimen will give the compressive strength of concrete. That is;

Size of the cube = 15cm by 15cm by 15cm

Area of the specimen (calculated from the mean size of the specimen) = 225cm2

Maximum load applied = ………N

The compressive strength = (load in N/Area in mm2)=………N/mm2

Fig 2.2a Compressive testing m/c

Fig 2.2b 15cm mould & Concrete cube.

Precautions:

1. The temperature of water of curing was steadily maintained.
2. The specimen was removed from water after specified curing time and wipe out excess water from the surface.
3. It was ensured that the bearing surface of the testing machine is clean
4. Any unusual feature was noted and corrected.
5. All the samples were properly labelled.

2.4.3 Slump Cone Test

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It measures factors contributing to workability. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. Workability can be measured by the concrete slump test, a simplistic measure of the plasticity of a fresh batch of concrete following the ASTMC 143 or EN 12350-2 test standards. Slump is normally measured by filling an Abrams cone with a sample from a fresh batch of concrete. The cone is placed with the wide end down onto a level, non-absorptive surface. It is then filled in three layers of equal volume, with each layer being tamped with a steel rod to consolidate the layer. when the cone is carefully lifted off, the enclosed material slumps to a certain amount due to gravity. A relatively dry sample slumps very little, having a slump value of one or two inches (25 or 50 mm) out of one foot (305 mm) a relatively wet concrete sample may slump as much as eight inches. Workability can also be measured by using the flow table test. Slump can be increased by addition of chemical admixtures such as plasticizer or superplasticizer without changing the water-cement ratio. Some other admixtures, especially air-entraining admixture, can increase the slump of Mix.(Gopal ,2015)

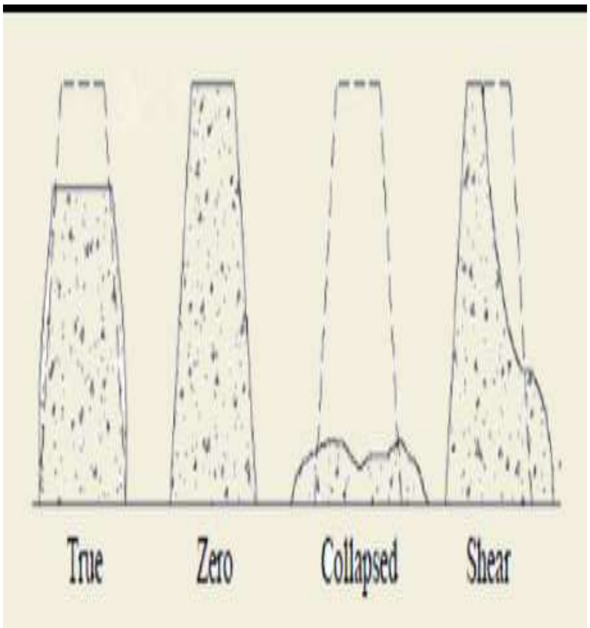

Fig 2.3a.Types of slump.

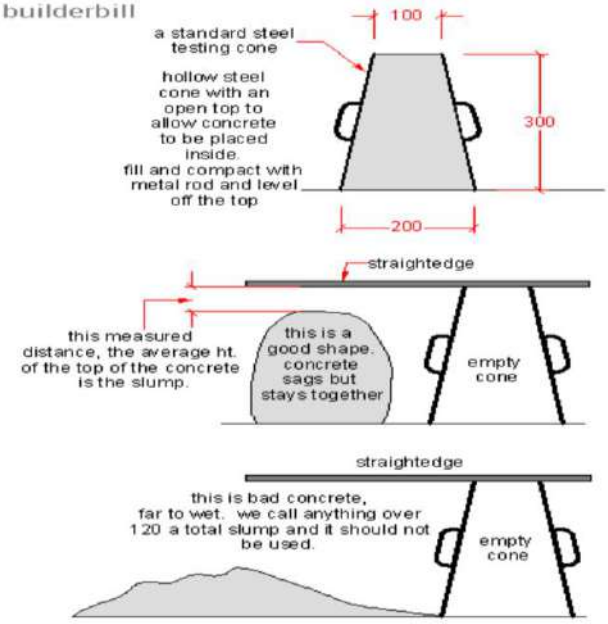

Fig 2.3b Slump Cone and slumpheight.

The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field. It is more precise and sensitive than the slump test and particularly useful for concrete mixes of very low workability as are normally used when concrete is to be compacted by vibration. Such dry concretes are insensitive to slump test.

2.5. General knowledge On Delayed curing Of Concrete.

Curing of concrete structural members is very important as it accounts for the strength, durability and performance of such concrete structures. Curing delay entails curing of concrete materials after some periods of delay which can be counted mostly in days (0,1,2,3....n) days but in this particular investigation the delay periods are taken be (0,7,14,21,28)days.

The delay of curing had a harmful effect on concrete and the first day of delay caused the largest effect. Curing after delaying increased the compressive strength of concrete, but it did not recover the reduction in strength caused by the curing delay.

There has being an investigation to know if hydration process occurs during the delay periods and the answer is Yes ,there will be hydration if curing is delayed ,the moment water is added to cement hydration starts (nothing can delay this), but the amount/degree of hydration is affected (Hussein, 2018)

Fundamentally curing minimizes the effect of external environment influencing the cement and water reaction. Internal water mixed as concrete ingredient may escape/evaporate and don't play role in cement hydration, part of cement remains un-hydrated if curing is delayed or not done.

If the curing is delayed, the extent of strength gain and impermeability achieved will depend on the environment to which the concrete was exposed during the delayed period, it may be possible that the strength achieved could be as low as, 10% or less than the strength it could have achieved in ideal curing conditions.

There can be permanent loss of strength and impermeability if curing is delayed.

Starting curing after 3-4 days would badly affect concrete quality, as with good curing 50% potential strength is achieved in these days.

The early ages curing is highly recommend (as we take care of a new born baby). As early curing of concrete begins, it will progressively gain strength and become impermeable ,thus loss of internal water required for further hydration is also reduced (progressively shielded from external environment).

A delay of 03 - 04 days will have very high negative consequences on concrete strength and impermeability, a dead concrete can't be revived.

Any hydration post 4 days delay in curing, will depend on the environment to which concrete was exposed during those period

Early age curing is highly recommended, particularly between 12 hrs. to 72 hrs. Of casting, it may be extended to as many days as feasible, for a durable concrete yield.

When concrete is not cured properly, its durability, strength and abrasive resistance are affected. Due to inadequate curing, concrete develops plastic shrinkage cracks, thermal cracks, along with a considerable loss in the strength of the surface layer.

When the surface of the concrete is not kept moist within the first 24 hours after the casting, the evaporation from the exposed horizontal surface results in plastic shrinkage cracks and a weak and dusty surface.

An excessive temperature difference between the outer and the inner layers of the concrete results in thermal cracking due to restraint to contraction of the cooling outer layers from the warmer inner concrete.

When concrete is allowed to freeze before minimum degree of hardening is achieved after casting, the concrete gets permanently damaged due to expansion of water within the concrete as it freezes. This results in irretrievable strength loss and makes concrete porous.

Fig 2.4 Thermal cracking of concrete slab

2.6 Methods of Curing Concrete.

Considerations for selecting a curing method:

a) The type of construction such as those involving large horizontal surface areas as in roads, floors, and airfields, or, those involving formed concrete in walls, columns, beams, cantilevers, and arches, etc

b) The place of construction, whether indoors and damp situations (as inside a building) or outdoor

c) The weather conditions where concrete is being laid in cold climates or in dry and hot weather.

There are several ways in which concrete materials can be cured just as were mentioned earlier.

2.6.1. Water Curing Method: The application of the water is done to avoid the drying of the concrete surface. Usually, this method applies when the concrete is thinner.

For example, in building construction, the curing of the floor slab can be done with this method (Bentz, 2006).

There are methods of applying the water on concrete.

a. Ponding the Concrete: Continuously wetting the concrete surface is done in the method without allowing the concrete surface to dry. Most of the time, a kerb cast around the slab helps to pond the relevant area.

This method is very useful in dry environments as it is not required to pour the water continuously. All the flat surfaces such as road pavements, slabs, footpaths, etc can cure with this method easily.

b. Use of Sprinklers: It is a must not allowing the concrete surface getting dry due to the evaporation. Continuous spraying the water at a constant rate and uniformly is a must to fulfill the adequate curing. Sprinklers set at adequate spacing will be used for this purpose.

As indicated in the figure below, moisture level will not reduce from the required level, and this is a very easy method as it does not require lots of involvement

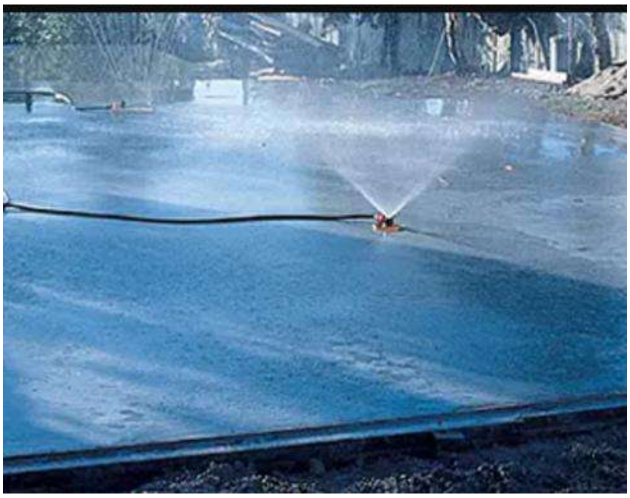

Fig 2.5a Curing by sprinkling.

Fig 2.5b Curing by ponding

c. By Immersion curing with water consists of total immersion of the hardened concrete element in a soaking tank. This method is commonly used in the laboratory for curing the concrete specimens.

d. By Wet Covering: Curing concrete with wet covering is done after the concrete has hardened sufficiently and the water covering will not damage concrete's surface. A covering is usually sand, burlap, canvas or straw, cotton mats, wet gunny bags, jute matting that is kept continuously damp during the curing process for vertical and horizontal structural members like columns (Juan Rodguez, 24 Jan 2019).

2.6.2. Membrane Curing of Concrete: In some places where there is an acute shortage of water, water curing may not be possible for reasons of economy. We know that curing of concrete is done, as water added in the concrete gets evaporated after being placed. If water curing is not possible, covering with a membrane will effectively seal off the evaporation of water from concrete. However, a small amount of water is sprayed before covering with the membrane. There are a large number of sealing compounds developed in recent years. Some of the common materials used are bituminous compounds, polyethylene or polyester film, waterproof paper, rubber compounds, etc... Initially, the bituminous compound was being used for this purpose as bituminous compound is black in color, it absorbs heat from the concrete when converted to the top surface of the concrete. This results in the increase of temperature in the body of concrete, which is undesirable. Thus are the modified materials, which are not black in color, came in use? However, bituminous compound coated with lime is being used as lime wash prevents heat absorption. To obtain the best results, a small amount of water is sprayed before covering with the membrane, normally 2 or 3 coats may be required for effective sealing of the surface to prevent the evaporation of water. The reason for large use of membrane curing is due to increase in volume of construction, shortage of water, need for conservation of water, increase in cost of labor and availability of effective curing compounds. Membrane curing is commonly preferred for curing canal lining, sloping roofs and textured surface of concrete pavements. In case of waterproofing, paper or polyethylene film are used as the membrane, sufficient care must be taken to see there is no puncture. In membrane curing, it should be checked that whether adequate lapping is given at the junction and these labs are effectively sealed (Krishna, 2010).Two common types of membrane curing are:

a. Plastic Sheeting: Curing concrete with plastic sheeting requires covering all exposed areas of the concrete as soon as possible without damaging the concrete finish. When plastic sheeting is used over flat surfaces, such as pavements or slabs, it should extend beyond the edges of the slab by a length of at least twice the thickness of the slab .these sheets can be translucent, white but not black to avoid heat absorption which can increase the temperature of the concrete.

b. Membrane-Forming Curing Compounds: Curing compounds are chemical products usually sprayed directly over the concrete surface and allowing it to dry. This is done immediately after the final finishing and should comply with ASTM C309 OR ASTM C1315. The compound forms an impermeable membrane that retards the loss of moisture from the concrete (JUAN RODRIGUEZ, 2019).

2.6.3. Application of Heat: The strength development of concrete is not the function of only the time but also the temperature. The terms heat curing, heat treatment, accelerated curing, and elevated temperature curing are often used interchangeably to mean a deliberate and defined application of some form of heat on fresh concrete with the intent of promoting rapid cement hydration. The process is a low pressure curing operation conducted in enclosed chambers, tunnels or beds where the precast elements are subjected to some form of heat exposure. Steam and radiant heat sources are often used. Steam curing refers to the application of heat by use of live steam. Radiant heat may be applied by direct electric heating elements or electric blankets, by circulating warm air around formwork, or by using pipes to circulate hot water, steam or hot oil (Cantabury, 2015).

Concrete precasting plants often need to attain relatively high concrete strengths in a matter of hours in order to meet construction time demands (ACI, 1992). The attainment of high early strength is the main engineering benefit of heat curing and is achieved by subjecting the newly cast concrete elements to elevated temperatures. Creep and shrinkage are major contributors to prestress losses in prestressed concrete. Heat curing reduces creep and shrinkage of concrete by up to 50% and 30% respectively, while prestress loss may reduce by up to 40% . The use of heat curing gives precasting technology an important edge of ensuring speedy supply of elements required for construction. Common practice is that concrete elements may be heat cured overnight and demoulded the next day, ready for use. There is also the economic benefit of quick turnaround of formwork and minimization of storage space when heat treatment is used in production. These aspects have been of key contribution to the success of concrete precasting technology.

But heat curing is riddled with obscure problems and future improvements in the precasting technology might be of critical importance. From its inception, heat curing practice has been based on the basic response of Portland cement to heat application. Since the second half of the last century, significant advances in cement chemistry and manufacture have occurred, and concrete mixtures have evolved. Undesirable durability-related problems attributed to heat curing have been exposed while high performance concretes are increasingly being used. These are some of the driving pressures for improvement of heat curing practice (Haseeb, 2017).

The exposure of concrete to higher temperature is done in the following manners:

i. Steam curing at ordinary temperature

ii. Steam curing at high temperature

iii. Curing by infrared radiation

iv. Electrical curing

2.7. Phases of Concrete Curing (According to ACI-308).

2.7.1. Initial Curing: This process is also called Bleeding of Concrete. It takes place from when water is added to the concrete to the end of final finishing.

After rising of water, evaporation takes place, and the water starts disappearing from the surface due to evaporation. Bleeding of concrete depends on many factors like thickness, length, temperature, so, to reduce the loss of water and prevent shrinkage, initial curing of concrete is required. Evaporation reducers can be used for this process.

2.7.2. Intermediate Curing of Concrete: This process is done when finishing work is finished before the final setting of cement. It is required as water plays an important role in the strength of concrete.

2.7.3. Final Concrete Curing: After the final setting of concrete, it should be cured so that one can prevent the loss of more water and increase the strength of concrete.

2.8. Factors affecting evaporation of water from surface of concrete are;

(i)Air temperature.

(ii) Fresh concrete temperature;

(iii) Relative humidity; and

(iv) Wind velocity.

The factors (i), (iii) and (iv) depend on the weather conditions and they indicate the direct environmental influences. Thus, out of four factors, only the fresh concrete temperature can be monitored or supervised by the concrete technologists.

The evaporation of the water in the first few hours can leave very low amount of water in the concrete for hydration. It leads to several shrinkage cracks. Under normal site conditions, the average loss of water varies from 2.50 to 10 N per m per hour. The major loss occurs in the top 50 mm layer and over a period of 3 hours, the loss could be about 5% of the total volume of that layer. It is also observed that there is considerable evaporation of water even before the conventional curing process has begun. The concept of early beginning of curing is therefore accepted (Article by Susmi ta B)

2.9. Effects of Improper Curing.

The frost and weathering resistances are decreased.

According to the experiment on the effects of curing periods and of delay in curing by wet Burlap method on some properties of concrete with different mix proportions (cement, water content and aggregate),the results showed that a minimum of three day(3-days) was sufficient for rich mixes, and longer period was required for learner mixes(minimum of 7-days).The delayed curing has harmful effects on the concrete and the first day of delay caused the largest affects. curing after delaying increases the compressive strength of a concrete material, but cannot recover the reduction in strength caused by curing delay (Ameer 2018).

Another experiment on the effect of delayed curing start on durability and mechanical properties of High Strength Concrete (HSC) and Normal Strength Concrete (NSC) was studied. In this study, curing start was delayed for (0, 1, 3, 7, 28) days for samples cured by immersion in water and cast with (HSC) or (NSC). Compressive strength, flexure strength, splitting tensile strength, static elastic modulus, poisson's ratio, carbonation, shrinkage, sulfate resistance and freeze-thaw resistance of concrete were measured. Scanning Electron Microscopy (SEM) as well X-Ray Diffractometer (XRD) were used to evaluate the microstructure of concrete under diverse curing circumstances. The results show that the delay in starting the curing of (HSC) and (NSC) leads to a decrease in the durability and mechanical properties of both types (especially, (HSC)) and reduces the degree of cement hydration and the amount of hydration products and increases the mean diameter of the pores. The biggest effect is delayed curing on the first day (Hussein 2018)

The strength development process which involves stiffening of the fresh concrete is termed setting. Setting and hardening of concrete indicates strength development resulting from a continuous reactions between cementitious materials and water. This setting is in two stages which are (I)Initial setting (ii) Final setting

2. 9. 1. Following are the major disadvantages of improper curing of concrete:

i. The chances of ingress of chlorides and atmospheric chemicals are very high.

ii. The compressive and flexural strengths are lowered.

iii. The cracks are formed due to plastic shrinkage, drying shrinkage and thermal effects.

iv. The durability decreases due to higher permeability.

2.10. Functions of Curing.

i. Maintaining mixing water in concrete during the early hardening process by supplying more water to the concrete.

ii. Reducing the loss of mixing water from the surface of the concrete by covering its surface.

iii. Accelerating strength gain using heat and additional moisture.

CHAPTER THREE

MATERIAL AND METHOD

This experimental program was designed and geared towards investigating the effects of curing delay on compressive strength of concrete. There are many methods of curing as were mentioned in the previous chapter but in this experiment, Water curing by immersion was used. This experiment was carried out in parts as different delay periods were involved in the process. It was done in the series of curing delay as (0, 7, 14, 21& 28) days, and were labelled in alphabetical order   with each involving 3-samples of concrete. All the samples were cured for 28-days after their various delays and the average compressive strength for each part was considered for the final results for discussion and analysis. It was done at the Civil Engineering Concrete Laboratory, Nnamdi Azikiwe University, and Awka.

3.1 Experimental Materials and Equipment.

The materials used for the execution of this research work includes; Coarse and fine aggregates, Cement and water. While the equipment or tools used are as follow: A shovel, weighing balance, hand trowel, tamping rod, Steel mould (15cm cube), Curing tank, slump cone, Oven, Bs-sieve Mechanism and crushing machine.

3.1.1 Cement: Generally, cement is of different types depending on the material used and style of production, but in this experiment Portland cement was used.

Plate 3.1. Measurement of cement

3.1.2. Aggregates: In this experiment, coarse aggregates of size 19mm (granite) from Ebony state and fine aggregates (sand) obtained in Anambra state were used for the concrete production...

Plate 3.2a. 19mm Coarse aggregates.

Plate 3.2b. Fine aggregates

3.1.3. Water: Portable water was used in this experimental work for both mixing and curing purposes.

3.2 Experimental procedure

This experiment underwent several laboratory tests such as sieve analysis (gradation test), slump test (for workability) and compressive strength test. It also involved two processes such as concrete production process and curing process.

3.2.1 Sieve analysis: The sieve analysis test (gradation test) was conducted on the aggregates.

The whole procedure of sieve analysis is to determine the particle size distribution of the fine aggregates and determine whether it is suitable to use in concrete mixing.

Procedure:

1. A prepared sample was weighed to exactly 500g.
2. Firstly, the BS- sieves were cleaned properly using a wire brush to be clear of aggregates stucked in some gaps.
3. Then the sieves were arranged onto the shaking machine (sieve mechanism) from top to bottom, by the size from biggest to the smallest (decreasing order of their size) with a plate at the bottom and the top cover well tightened.
4. The mechanical sieve shaker was set into vibration by electrical means for about 5 to 10 minutes.
5. After the sieving is done, the aggregates on each sieve were collected, weighed separately and the values recorded as the weight retained.
6. The weight retained, cumulative weight retained, Cumulative weight passing through each sieve were calculated as a percentage of the total sample weight.
7. The cumulative weight passing was plotted against sieve size to obtain the required information of the particles distributions.

Percentage weight retained=Wt retained on each sieve X100/Total Wt of sample

Percentage passing=100%-cumulative percentage retained.

3.2.2. Apparatus

i. Bs-sieve mechanism

ii. A Balance

iii. Metal plate

iv. Wire Brush

v. Metal plate

Plate 3.3 sieve Analysis test

3.3. Steps in Concrete production.

Generally same mix ratio of 1:2:4 and w/c of 0.55 were used for all the samples (cubes).

Sand and Cement were first mixed to a homogeneous state, afterwards coarse aggregate was added to it and properly mixed using shovel as it was done by hand mixing. Water as calculated was then added using measuring cylinder .The three constituents were remixed and then casted into the molds in parts as explained above under procedures.

3.3.1. Concrete Proportioning.

Mix ratio=1:2:4

W/c ratio=0.55

Vol of cube=$L^3 = 0.15^3 = 0.003375m^3$.

Density of concrete=$2400kg/m^3$.

Mass of concrete (M) =vol x d.

M=2400x0.003375=8.1kg.

Cement=1/7x8.1=1.16kg.

Sand=2/7x8.1=2.31kg.

Coarse Agg=4/7x8.1=4.629kg.

Water=1.16x0.55=0.638kg

V= (0.638/1) m^3

=0.638x1000=638ml

3.3.2. Slump Cone Test: This test was conducted to determine the degree of workability of the fresh concrete in the laboratory or at the site, which depends largely on the water-Cement ratio and other factors as

i. material properties (chemistry, fineness ,particle size distribution , moisture content and temperature of cementitious materials).

ii. Chemical admixtures dosage, type, combination.

iii. Concrete batching, mixing and transporting methods and equipment.

iv. Temperature of the concrete.

v. Time since mixing of concrete at the time of testing.

3.3.3. Procedure for Concrete Slump Cone Test:

i. The internal surface (wall) of the mould was cleaned and greased.

ii. The mould was placed on a smooth horizontal non- porous base plate.

iii. The mould was filled with a fresh concrete with the mix ratio of 1:2:4 (M15 grade) and water-Cement ratio of 0.55, in 3- approximately equal layers.

iv. Each layer was tamped with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers,it was ensured that the tamping penetrate into the underlying layer.

v. The excess concrete was removed and the surface leveled with a trowel.

vi. All the mortar or water leaked out between the mould and the base plate was cleared.

vii. The mould was lifted or raised from the concrete immediately and slowly in vertical direction.

viii. Measurement of the slump was taken as the difference between the height of the mould and that of height point of the specimen being tested, using tape and spirit level.

3.3.4. Apparatus.

i. Metal tamping rod.

ii. Slump cone.

iii. Impermeable metal base plate.

iv. A balance.

v. A metallic plate.

vi. Tape.

vii. Spirit level.

viii. Shovel.

ix. Trowel.

Plate 3.4 Slump test.

3.3.5 Compressive Strength Test: This test on concrete provides an idea about all the characteristics of concrete which determine its ability to withstand loading without cracking or deflection. Concrete compressive strength for general construction varies from 15 MPa (2200 psi) to 30 MPa (4400 psi) and higher in commercial and industrial structures.

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, and quality control during the production of concrete, etc.

American Society for Testing Materials ASTM C39/C39M specification or standard was followed.

Procedure: The production of this concrete was done using the mix ratio of 1:2:4 and water/cement ratio of 0.55.

1. The cement and fine aggregate was first mixed on a watertight none-absorbent platform with the mix ratio maintained until the mixture is thoroughly blended and is of uniform color.
2. The proportion of coarse aggregates was added and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.
3. Water was added and mix it until the concrete appears to be homogeneous and of the desired consistency.
4. The molds were Cleaned and their inner walls properly greased.
5. The molds (15cm x15cm x15cm) were filled in 3- layers approximately 5 cm thick.
6. Each layer was compacted by tamping with 25 strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet-pointed at lower end). The top surface was leveled (trim fushed with the mold's heights) and smoothen it with a trowel.
7. The samples were demolded after 24hours and water curing Commenced immediately.
8. Each cube was tested using compressive strength testing machine.

Plate 3.5 casting of concrete cubes

3.4 Steps in Curing of the Specimen.

The curing was conducted separately for each set of samples following the corresponding delay period . The total of 15 concrete cubes casted were divided into 5-sets, each set made of three samples(3 cubes) and were properly labelled alphabetically. Then each set was cured for 28- days after the delays.

3.4.1. Steps in curing for specimen A1, A2 and A3:

This was meant to have a zero delay, and it was cured for 28-days starting from the time the molds were removed. After this curing it hey were removed from the curing tank and taken to the crushing machine.

3.4.2. Steps in Curing for Specimen B1, B2, and B3.

This set of Specimens was meant to have a delay of seven days before curing commenced. So the curing of these samples started after seven days of delay and lasted for 28 days, after which they were removed from the Curing tank and taken for the next stage of the test.

3.4.3. Steps In Curing for Specimens C1, C2 and C3.

This set of specimen was meant for 14 days delay before curing commences.

The three samples were cured for twenty eight days after the 14 days delay, then they were removed from curing tank ready to be tested for its compressive strength.

3.4.4. Steps in curing Specimens D1, D2 and D3.

This set of three specimens were meant for 21-days delay, so the curing here started after twenty one days. The curing process lasted for 28 days and it was then removed and proceeded to the compressive strength testing machine.

3.4.5. Steps in Curing for Specimens E1, E2 and E3.

This last set was meant for twenty eight days delay. The curing of these samples started after the 28-days delay and was maintained for another 28 days. After the aforementioned period of curing they were removed from curing tank and taken for compressive strength testing machine.

Generally the curing water was regularly discarded and replaced with fresh water at the interval of 7-day.

3.4.6. Crushing of the specimens.

The concrete sample (cube) after curing was put in between the upper and lower crushing plate of the compressive strength testing machine in the manner that the labeled surface faced its front for easy identification and the machine was operated until the sample got fractured.

The compressive strength of the concrete in Mpa and the applied load in KN were obtained and recorded. This process was repeated for each specimen.

Plate 3.6 Crushing of concrete cubes

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULT FOR SIEVE ANALYSIS TEST

For fine aggregate

Table 4.1.Showing results for sieve analysis of fine sand

SIEVE SIZE (mm)	Weight retained (g)	% weight Retained	Cumm.Weight Retained (%)	Cumm weight passing (%)
4.75	4.63	0.926	0.926	99.070
2.00	8.82	1.764	2.690	97.31
1.80	6.13	3.226	5.916	94.084
0.85	20.30	4.060	9.976	90.024
0.60	49.74	9.948	19.924	80.076
0.45	91.81	18.362	38.286	61.74
0.30	154.01	30.802	69.088	30.912
0.15	142.84	28.568	97.656	2.344
0.075	10.30	2.060	99.716	0.284
PLATE	1.42	0.284	100.000	0.000
TOTAL	500			

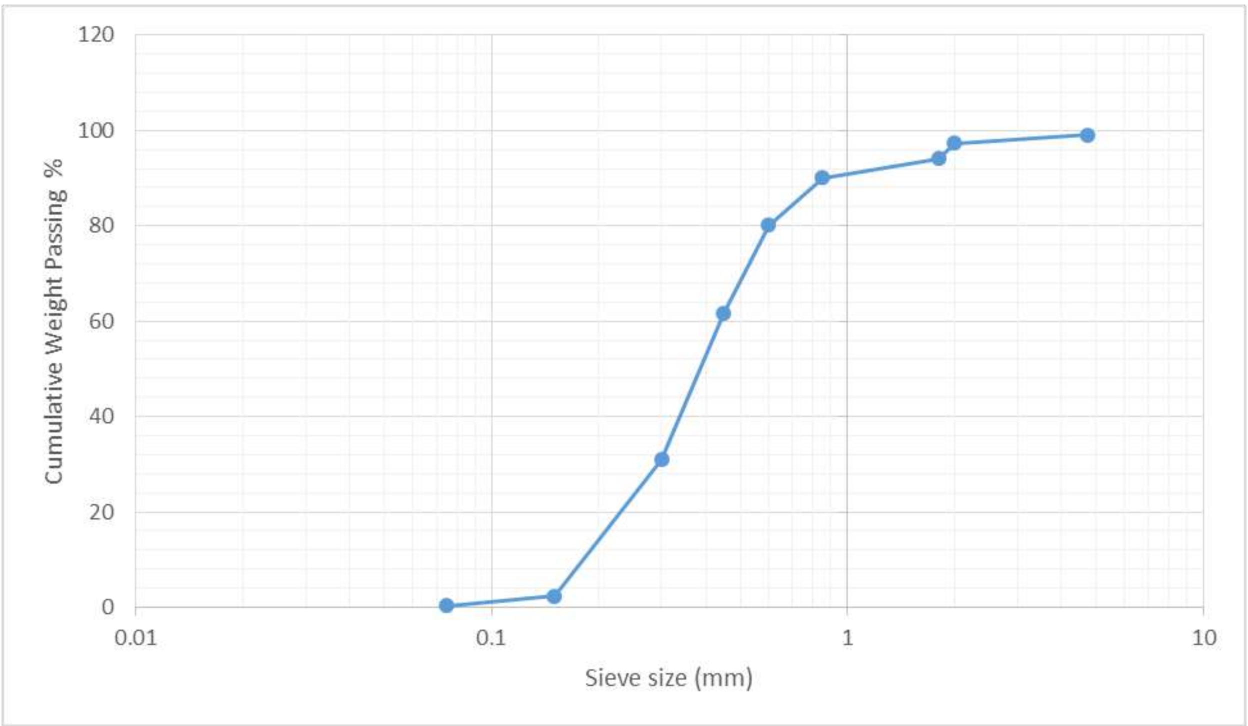

Figure 4. 1: Sieve Analysis Graph

Total mass of sample = 500g

% weight retained =$\frac{W_{SIEVE}}{W_{Total}}$ x 100

Cumm. % mass passing = 100% - % cumm. Mass retain

Plot of a % cumm. Mass passing against sieve size

Coefficient of Uniformity

CU = $\frac{D_{60}}{D_{10}} = \frac{0.45}{0.23} = 2.0$

Coefficient of curvature

Cc = $\frac{{D_{30}}^2}{D_{60}\ X\ D_{10}} = \frac{0.31^2}{0.23\ X\ 0.45} = 1.0$

Effective size = 0.23 mm

Soil classification

For well graded soil

Cu > 4 = well graded gravel

CU > 6 = well graded sand

CC = 1-3

CU < 4 = poorly graded soil

For uniformly graded soil

CU = 1 – 2 (all particles present are of the same size)

For soil with different size of particles, CU > 6

From the graph it indicates that the soil sample is uniformly graded

4.2 RESULTS FOR SLUMP TEST

Slump test conducted at concrete laboratory Nnamdi Azikiwe University, Awka

Concrete grade = M15

Mix ratio = 1:2:4

W/C = 0.55

Height of cone=300mm

Height of Slumped=203mm

Therefore;

300mm-203mm=97mm

Slump-value=97mm

Table 4.2: Showing results of slump test

Slump value	Degree of workability	Pull out Strength (N/mm^2)	Area of application
0 -5	Very low	72 - 94	In road work compacted by power operated machine (roller)
25 – 50	low	68 - 71	Light reinforce section in mass concreting or road vibrated by hand operated machine or manually compacted
50 -100	Medium	66 - 67	For heavily reinforced section or manually compacted flat slab using crushed aggregates
100 -175	high	62- 65	For section with congested reinforcement not normally suitable for vibration e.g. pilling work

The slump value obtained from the test (97mm) falls within the range 50 - 100 indicating the degree of workability as medium.

From the table above it is observed that the concrete with degree of workability (medium) is suitable for constructing structural members with heavily reinforced section which can be manually compacted such as flat slab using crush aggregate.

4.3 RESULTS FOR COMPRESSIVE STRENGTH TEST

Compressive strength $(\delta) = \frac{(Test\ load\ x\ 10^3)N}{cross\ sectionaal\ area} = \frac{P}{A}$ (N/mm^2)

Cross sectional Area of cube (A) $=150^2$

$=22500mm^2$

Table 4.3 Table showing results for curing delay and compressive strength

CUBE MARK	CURING DELAY (DAYS)	AVERAGE COMPRESSIVE STRENGTH(N/MM^2)
A	0	26.60
B	7	21.53
C	14	19.80
D	21	20.70
E	28	23.90

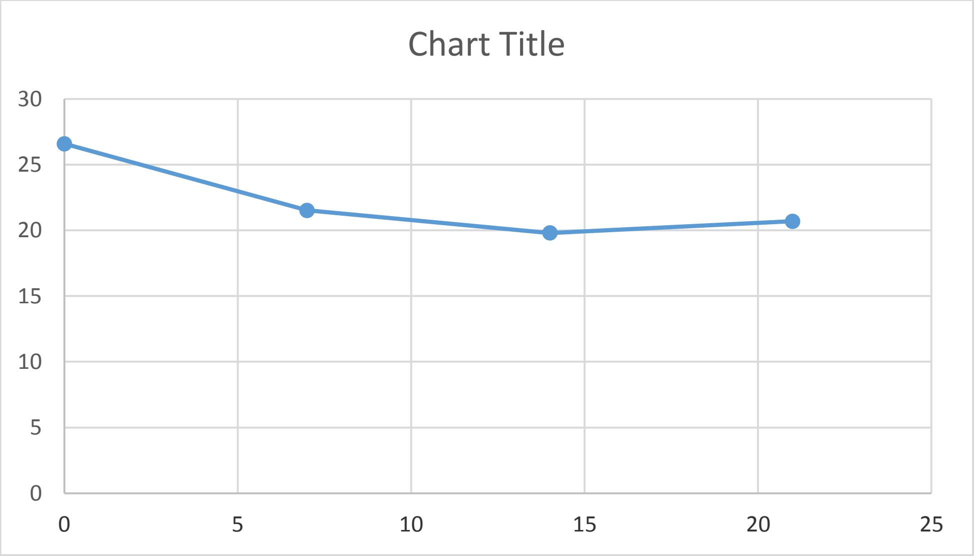

Fig. 4. 2 Showing Graph of Compressive strength against curing delay

Calculation of Compressive Strength

Compressive strength of Specimen A = 26.6Nmm^{-2}

Compressive strength of Specimen B = 21.53Nmm^{-2}

For 7 days delay (specimen B)

Percentage reduction in strength (7 days delay) = $\frac{5.07}{26.6} \times 100 = 19.06\%$

For 14 days delay (specimen C)

Compressive of specimen C= 19.80NMM^{-2}

Percentage reduction in strength (7 days delay) = $\frac{6.80}{26.6} \times 100 = 25.57\%$

Change in % strength = 25.57% - 19.06% = 7.51%

It was observed that their compressive strength consistently decreased with increased curing delay but the effect is highest at the early age of the concrete (i.e. between samples with zero delay and samples with 7 days delay). The final results showed that curing delay leads to a corresponding decrease in the compressive strength in concrete production.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This work was intentionally prepared to remain relevant in resolving complexities relating to the structural behavior and properties of concrete materials as a result of curing delay. Some conclusion made at the end of the experiment and result analyses are as follows:

From the compressive test conducted, the result analysis showed that the specimen A with zero curing delay attained the maximum compressive strength of 26.6N/MM^2.
But specimen B with 7 days curing delay experienced 19.06% reduction in compressive strength compared to the actual compressive strength of the properly cured concrete samples (specimen A).
Furthermore, specimen C with 14 days delay experienced 25.57% loss of compressive strength compared to the strength of specimen A (zero curing delay).
The above information indicates that the curing delay has a negative effect on the strength development of concrete materials.
The effect of the curing delay is mostly evident at the early age of such concrete as a construction material. There was also observation of formation of drying shrinkage due to insufficient moisture which occurred at the early age of the concrete before curing and decreased as its age advanced. The samples with delay curing experienced Loss of mass of about 0.43kg .

5.2 RECOMMENDATION

1. My recommendation is that every concrete material should be properly cured mostly at the early age.
2. In any case, an improperly cured concrete material should not be used for structures subjected to heavy loading building, Bridges etc.
3. Further research work has to be done to investigate the type of reinforcement to be used to increase the strength before using this concrete materials.

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APPENDIX

CALCULATION FOR THE QUANTITY OF CONCRETE ELEMENTS (Aggregate, cement, sand and water)

Mix ratio=1:2:4

W/c ratio=0.55

Vol of cube=L^3 =0.15^3=0.003375m^3.

Density of concrete=2400kg/m^3.

Mass of concrete (M) =vol x d.

M=2400x0.003375=8.1kg.

Cement=1/7x8.1=1.16kg.

Sand=2/7x8.1=2.31kg.

Coarse Agg=4/7x8.1=4.629kg.

Water=1.16x0.55=0.638kg

V= (0.638/1) m^3

=0.638x1000=638ml

CALCULATION FOR SLUMP TEST

Slump test conducted at concrete laboratory Nnamdi Azikiwe University, Awka

Concrete grade = M15

Mix ratio = 1:2:4

W/C = 0.55

Slump-value=97mm

CALCULATIONS ON SIEVE ANALYSIS RESULT

Total mass of sample = 500g

% weight retained =$\frac{W_{SIEVE} W_{SIEVE}}{W_{Total} \; W_{Total}}$ x 100

Cumm. % mass passing = 100% - % cumm. Mass retain

Plot of a % cumm. Mass passing against sieve size

CU = $\frac{D_{60}}{D_{10}} = \frac{0.45}{0.23} = 2.0\frac{D_{60}}{D_{10}} = \frac{0.45}{0.23} = 2.0$

CC = $\frac{{D_{30}}^2}{D_{60}\, X\, D_{10}} = \frac{0.31^2}{0.23\, X\, 0.45} = 1.0\frac{{D_{30}}^2}{D_{60}\, X\, D_{10}} = \frac{0.31^2}{0.23\, X\, 0.45} = 1.0$

Effective size = 0.23 mm

Calculation of Compressive Strength

Compressive strength of Specimen A = 26.6Nmm-2

Compressive strength of Specimen B = 21.53Nmm-2

For 7 days delay (specimen B)

Percentage reduction in strength (7 days delay) = $\frac{5.07}{26.6}$x 100 = 19.06%

For 14 days delay (specimen C)

Compressive of specimen C= 19.80NMM-2

Percentage reduction in strength (7 days delay) = $\frac{6.80}{26.6}$ x 100 = 25.57%

Change in % strength = 25.57% - 19.06% = 7.51%

APPRAISAL OF REINFORCING STEEL RODS MARKETED IN A MAJOR BUILDING MATERIALS MARKET IN ENUGU STATE

BY

OBI ODINAKACHUKWU FIDELIS

2016224025

SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING,

FACULTY OF ENGINEERING

NNAMDI AZIKIWE UNIVERSITY AWKA, ANAMBRA STATE

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN CIVIL ENGINEERING

FEBRUARY, 2022.

CERTIFICATION

I certify that this research work titled “Appraisal of Reinforcing Steel Rods Marketed in a Major Building Materials Market in Enugu State” was carried out by me, Obi Odinakachukwu Fidelis with registration number 2016224025, under the supervision of Engr. Dr. P.D Onodagu, in the department of Civil Engineering, Faculty of Engineering, Nnamdi Azikwe University, Awka.

______________________ ________________

Obi Odinakachukwu Fidelis Date

APPROVAL PAGE

This is to certify that this project titled "Appraisal of Reinforcing Steel Rods Marketed in a Major Building Materials Market in Enugu State" is presented to the department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University Awka for approval in partial fulfillment of the requirement for the degree of Bachelor of Engineering (B.Eng).

Engr. Dr. P.D Onodagu (Project supervisor)	Date
Engr. Dr. C.A. Ezeagu (Head of Department)	Date
Engr. Prof. D.O. Onwuka (External Supervisor)	Date

DEDICATION

With gratitude to the Almighty God, the giver of life, Father most merciful, I dedicate this work to my Sweet Mommy, Mrs Chidinma Cordelia Obi, whose only love meant warmth and ingenuity to me and for being my strength, courage and inspiration from the beginning, until the end of this work.

ACKNOWLEDGEMENT

In a very special way my thanks and in-depth gratitude goes immensely to the Almighty God, who bestowed me with life, wisdom and knowledge and for showering upon me His mercies, blessings, guidance, providence, protection and grace, all through my life and from the beginning until completion of my academics.

I wish to thank and appreciate my lovely supervisor, Engr. Dr. P.D. Onodagu for guiding me in this project work to ensure that this project work is a success. And also I want to appreciate the effort of the former Head of Department, Engr. Prof. C.A. Chidolue, and for the approval to use the strength of material laboratory for my test.

My sincere appreciation goes to all the lecturers of this noble department; Engr. Prof. C.M.O Nwaiwu, Engr. Prof. C.H. Aginam, Engr. Prof. Ekenta, Engr. Prof. Engr. (Mrs.) N.E Nwaiwu, Engr. Dr. C.A Ezeagu, Engr. Dr. O. Okonkwo, Engr. Dr. B. Adinna, Engr. Rev. Dr. C.M. Nwakaire, Engr. Mr. A. Nwajiaku, Engr. A. Ezewanmma, Engr. (Mrs.) Nkechi Nwokediuko and Engr. Obinna Ubani, for their moral words of advice, academic teachings, assessments, support and encouragements, which helped to mould, build and shape me into a more lettered and purposeful citizen I am today.

With much love and gratitude, I wish to use this wonderful opportunity to appreciate my Spiritual Directors; Bro Peter Ihekaibeya, Pastor Promise Anugwem and Pastor Ekene Muoneme, for their love, prayers, support, counseling, resuscitation, redemptive courage and fortitude conferred on me, especially during my bleak moments, when I thought I had lost all hope of living, and focus as a person, during my years as an undergraduate.

Loudly, with warm gratitude and unspeakable joy, I specially say a bigger thanks to my dearest sweet mother and best friend, who swore to my graduation with her pampering love, warfare prayers, support; emotionally, financially, morally, materially and everything she had. With untold gratitude, I say a warm and special thank you Mummy, for never giving up on me particularly during my days as an undergraduate.

Without mincing words, I want to express my undiluted thanks and gratitude to my lovely friends for their inspiration and insistence upon me, which kept me determined to finish this race, thank you for choosing me.

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ABSTRACT

This research entitled "Appraisal of Reinforcing Steel Bars Marketed in Major Building Materials Market in Enugu State" was undertaken to find out the characteristic properties of the reinforcing steel bars used in the Nigerian Construction Industry and marketed in Enugu State. The study investigated the yield strength, ultimate tensile strength, characteristic strength and percentage elongation of different sizes of steel bars of five different companies in relation to their level of conformity with the specified parameters in British Standard codes (BS) and Nigerian Industrial Standard (NIS) code. Thirty samples of reinforcing steel bars of 5 companies were used in the experiment. It was found that the samples tested fell short of expectations of BS4449:1997 and NIS 117:2004 while the corresponding percentage elongation was satisfactory. Only 20% and 50% of the tested bar samples met the Nigerian Industrial Standard code minimum requirements for yield strength and ultimate tensile strength respectively. That is an average of 438.30N/mm^2 yield strength and 551.50N/mm^2 ultimate tensile strength. It is therefore established that the bars have performed below expectations in ductility implying they can fail without warning and therefore the design strength employed using such reinforcement is hazardous.

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Buildings are designed to support certain loads without deforming excessively. The loads are made up principally of dead loads, imposed loads consisting of temporary, changeable or dynamic loads acting upon a structure and environmental effects such as rain and wind pressure. The process of designing a building starts with the selection of materials based on their properties and the type of stresses to be supported.

A structural component is an element that carries its self-weight and tributary load transferred from other structural members. The element to be selected must be capable to withstand the stresses generated by the design loads. The two commonly used structural materials for concrete structures are concrete (cement, aggregates and water) and steel reinforcements.

Steel is one of the prominent engineering materials in use today for construction purposes (Sambo, Ifeabunike and Onwuamaeze 2009). In construction of modern structures, such as building, bridges and dams, steel is predominantly used in reinforcing concrete. Reinforcement of concrete becomes imperative and indispensable because of the fact that steel bars embedded in the concrete resist greater percentage of the stresses in the concrete structure necessary to compensate for the fact that plain concrete is good in compression but relatively weak in tension, thereby increasing its overall strength and durability.

Steel is produced from two key components: iron ore which is one of Earth's most abundant elements and recycled steel. Its combination of strength, recyclability, availability, versatility and affordability makes steel unique. Steel is manufactured under carefully controlled conditions in specialized plants. The properties of every type of steel are determined in a laboratory and described in manufacturer's certificate. Thus, the designer only specifies the steel complying with a relevant standard, and the builder ensures that the correct steel is used appropriately.

Steel reinforcing bars available in Nigeria's Construction Industry are obtained from both internal and external sources (Shuaib-Babata and Tanimowo, 2016). The internal sources come mainly from both the indigenous major plants and the mini Mills located in different parts of the country such as Delta, Osogbo, Katsina amongst others. Imported steel bars coming into the country are mainly Russia and Ukraine (Mohammed, 2012). Others are those procured for specific uses by multinational companies for some specific projects, and are imported directly by the multinational company concerned. The importance of steel in structures cannot be neglected as the proper combination of both steel and concrete form the major components that ensures a structure is in perfect condition.

In Nigeria, reported cases of structural failure have become very frequent, especially of buildings. Several researchers have investigated into the causes of building collapse. One of the most frequently adduced causes is the non-conformance of structural properties of materials used to the actual design specifications. Ogunsemi (2002) and Ole and Abiola-Falemu (2009) show about 26% of building collapse in Nigeria occurred as a result of the use of poor standard materials. Thus there is a need to study the qualities of these materials in an attempt to curb the rate at which buildings collapse in Nigeria.

It has become a common practice to design concrete with the reinforcement steel's characteristic yield strength (Fy) of 410 N/mm^2 in place of BS8110 code specification of 460 N/mm^2. This drop in quality itself has become a reckless habit as most contractors even provide reinforcement with characteristic strength lower than 410 N/mm^2. There is a growing concern that the steel being used on sites may have been falling short of the design expectation as stipulated in the standards, because of lack of testing equipment for control and compliance purposes on sites.

Knowledge concerning the characteristics and behaviour of steel reinforcement is vital if safe, reliable and durable structures are to result. Therefore, there is a need to carry out a qualitative analysis of steel reinforcement because of the vital role it plays in engineering constructions as well as to enable all associated short-comings to be properly taken into cognizance by Nigerian Construction Industry for best structural applications within the building industry.

1.2 Problem Statement

It is suspected that one of the causes of structural failure observed in many parts of Nigeria is the use of substandard materials in structural work. The use of substandard steel bars for structural reinforcement is suspected to be the most constructive factor that may lead to structural failure.

Many reinforcing steel tests results that were conducted in reputable laboratory such as the heavy concrete laboratory of Ahmadu Bello University, Zaria failed to meet the BS4449 (1997) requirements. This might have accounted for many building collapse. Thus, quality tests on reinforcing steel in the Nigerian Construction Industry cannot be over emphasized (Mohammed, 2012).

Hence this study is aimed at investigating the compliance of the characteristic strength of the steel reinforcement bars used in Nigerian local sites to ascertain their conformity by comparing them with the British standard adopted in Nigerian structural design.

1.3 Aim and Objectives

1.3.1 Aim of the Study

The aim of this project is to evaluate the characteristic strength of reinforcing steel rods marketing in major Building Materials Markets in Nigeria.

1.3.2 Objectives of the Study

The specific objectives of this study are to:

i. Source 12mm and 16mm steel reinforcement rods from different manufacturing companies.
ii. Determine the diameter and mass of the test specimen.
iii. Determine the yield strength, ultimate tensile strength, characteristic strength and percentage elongation of the steel bars.
iv. Compare the characteristic strength of the tested steel bars with the standard code values, and make up conclusions on the level of compliance.

1.4 Significance of the Study

i. This study gives useful pointers on the ability of reinforcing steel rods to withstand tensile loads without failure.
ii. This study reveals if the Nigeria steel industries are actually in conformity with standard design specifications or not.

iii. Another importance of this study it that it revives the witfulness of all key players in the engineering family to examine the properties of building materials especially reinforcing steel in the Nigerian market beyond the index of physical properties to the measure of mechanical properties before putting them into use.

iv. This study is geared to draw the attention of the government and regulatory bodies such as NSE or COREN bodies in Nigeria to critically examine the properties of steel marketing in Nigeria and also making efficient and effective laws to properly control steel Industry in Nigeria as well as oversee imported reinforcing steel bars in order to proffer a lasting solution to the frequent building collapse cases which the country experiences.

1.5 Scope of Study

This project is narrowed down to the evaluation of characteristic strength of 12mm and 16mm reinforcing steel bars marketing in Building Materials Market (New Kenyatta), Enugu, Nigeria.

CHAPTER TWO

LITERATURE REVIEW

2.1 About Reinforcing Steel Bars

Steel is an alloy of iron and carbon containing less than 2% carbon and 1% manganese and small amounts of silicon, phosphorus, sulphur and oxygen. Steel is the world's most important engineering and construction material (Worldsteel.org).

Reinforcing steel bar (rebar for short) is a steel bar or mesh of steel wires used as a tension device in reinforced concrete and reinforced masonry structures to strengthen and aid the concrete under tension. Concrete is strong under compression, but has weak tensile strength (Wikipedia.com).

Reinforced concrete refers to concrete in which steel is embedded in such a manner that the two materials act together in resisting forces. The reinforcing steel—rods, bars, or meshes—absorbs the tensile, shear, and sometimes the compressive stresses in a concrete structure (Adam, 2020).

Plain concrete does not easily withstand tensile and shear stress caused by wind, earthquakes, vibrations, and other forces and is therefore unsuitable in most structural applications. In reinforced concrete, the tensile strength of steel and the compressive strength of concrete work together to allow the member to sustain these stresses over considerable spans. Steel and concrete have similar coefficients of thermal expansion, so a concrete structural member reinforced with steel will experience minimal differential stress as the temperature changes.

The most common type of reinforcing steel (as distinct from pre-stressing steel) is in the form of bars/wires. They are classified according to strength grades (mild steel, or medium-tensile or high-tensile), methods of production (hot-rolled or cold-reduced or cold-worked), surface characteristics (plain or deformed), and weldability (Advisory note, 1991).

Rebar's surface is often "deformed" with ribs, lugs or indentations to promote a better bond with the concrete and reduce the risk of slippage.

2.1.1 Brief History of Rebars

Reinforcing bars in masonry construction have been used since at least the 15th century (2,500 meters of rebar was used in the Château de Vincennes). However, it was not until the mid-19th century that rebar displayed its greatest strengths with the embedding of steel bars into concrete, thus producing modern reinforced concrete. Several people in Europe and North America developed reinforced concrete in the 1850s. These include Joseph-Louis Lambot of France, who built reinforced concrete boats in Paris (1854) and Thaddeus Hyatt of the United States, who produced and tested reinforced concrete beams. Joseph Monier of France is one of the most notable figures for the invention and popularization of reinforced concrete (Wikipedia.com).

Requirements for deformations on steel bar reinforcement were not standardized in U.S. construction until about 1950. Modern requirements for deformations were established in "Tentative Specifications for the Deformations of Deformed Steel Bars for Concrete Reinforcement", ASTM A305-47T. Subsequently, changes were made that increased rib height and reduced rib spacing for certain bar sizes, and the qualification of “tentative” was removed when the updated standard ASTM A305-49 was issued in 1949. The requirements for deformations found in current specifications for steel bar reinforcing, such as ASTM A615 and ASTM A706, among others, are the same as those specified in ASTM A305-49 (Wikipedia.com).

2.1.2 Requirements for Reinforcing Steel

The UK Certification Authority for Reinforcing Steels (UK CARES Part 1) has prescribed that satisfactory reinforcing steel must be able to:

i. bend into shape with precision to fit complicated structures.

ii. possess a minimum strength to discharge its load bearing function.

iii. possess ductility to satisfy formability requirements to be bent into the designed shape and also sufficient ductility to provide progressive failure under certain conditions.

iv. possess good weldability in part, for site fabrications and in part to minimize damage.

v. possess good fatigue properties for many structures of particular design.

vi. possess good bond properties.

The authority (UK CARES Part 1) went further to highlight some conflicts that often arise such as between strength and ductility or between strength and weldability which must be sorted through metallurgical controls during manufacturing processes (Mohammed, 2012).

2.1.3 Use in Concrete and Masonry

Most steel reinforcement is divided into primary and secondary reinforcement, but there are other minor uses (Muboshgu, 2019).

i. Primary reinforcement refers to the steel which is employed to guarantee the resistance needed by the structure as a whole to support the design loads.

ii. Secondary reinforcement, also known as distribution or thermal reinforcement is employed for durability and aesthetic reasons, by providing enough localized resistance to limit cracking and resist stresses caused by effects such as temperature changes and shrinkage.

iii. Rebar is also employed to confer resistance to concentrated loads by providing enough localized resistance and stiffness for a load to spread through a wider area.

iv. Rebar may also be used to hold other steel bars in the correct position to accommodate their loads.

2.2 Steel Industry in Nigeria

Iron and steel industry in Nigeria developed as a public funded integral industry. Between 1979 and 1983, Nigeria government jump started iron and steel production with emphasis on the importance of iron and steel in developing and driving local production of goods. A strong iron and steel industry was also projected to reduce demand of foreign currency used towards the importation of steel products (Ade-Ajayi, Adegbite and Iyanda, 2019).

2.2.1 Brief History of Steel Production in Nigeria

The Iron and steel industry in Nigeria was first conceptualized in 1958 when the idea was mooted by Nigeria's national development planners. At this period widespread consultations took place both within and outside the country with western experts as to the viability and economic advantages of large-scale steel production. The general opinion however, was that Nigeria was not yet ready for a project as demanding and sensitive as a steel plant. The primary reason canvassed was the high cost of the technological and associated infrastructural development necessary for a full-scale steel industry in Nigeria.

In addition, it was thought that the country would be unable to provide the required manpower and skills necessary to put a steel plant into successful and continuous operation. Igwe (1983) was to note that between 1961 and 1965, the first republic government of Nigeria was to receive several suggestions from foreign companies on why steel production in Nigeria was not feasible ranging from purported lack of domestic market to overriding diplomatic interests and international politics. This pessimism notwithstanding, proposals were received from various organizations and countries between 1961 and 1966. The proposals ranged from those of small plants of the order of 100,000 tons per annum to medium capacity plants up to 300,000 tons per annum (Agbu, 1992).

According to the National Council on Science and Technology (NCST), the initial attempt was to build rolling mills and to establish the market potential for the steel products, before the efforts became directed towards the establishment of an integrated iron and steel plant (Ogban-Iyam, 1981). Some of the companies that submitted proposals included the consortium of Westinghouse and Koppers in 1961, Demag, Ferrostal - Wellman, Mckee and David Ashmore all in 1963. While Westinghouse and Koppers proposed the use of Strategic Udy process (Direct reduction process using coal/lignite and electricity and Basic Oxygen Converter) for a plant of 143,000 tonne per annum capacity to produce merchant bars, squares or round bars and sheets; Mckee proposed the use of the blast furnace and basic oxygen furnace for a 300,000 tonne capacity plant to produce rounds and squares, wire rod, hoop, small rails, sheets, tin plate and pig iron (Agbu, 1992).

However, it was from 1967 that significant progress was made towards the establishment of an iron and steel plant in Nigeria following the involvement of the then Soviet Union. In 1967, a team of Soviet experts arrived in Nigeria to conduct a feasibility study on the establishment of an iron and steel plant, as a follow-up on a technical/economic agreement between the governments of Nigeria and the Soviet Union (Ogban-Iyam, 1981).

In their report, the use of the blast furnace process was recommended for the proposed steel plant. The report also observed that the then known iron deposits in the country were of poor quality and suggested further geological surveys to see if better ores could be found. Therefore, in 1968, the Soviet geological experts after a general geological investigation of Nigeria reported that there were high prospects for finding rich iron ore and coal deposits in the country. Consequently, Nigeria signed a contract in 1970 with Technoexport of the then Union of Soviet Socialist Republics (USSR) under which they agreed to provide specialists and equipment to carry out further geological surveys in order to determine the quantity of the deposits of iron ore and coal resources that could be used in the proposed iron and steel industry (Chukwumerije, 1982).

In brief, the main achievement of the survey that followed was the discovery of Itakpe ore deposits in the then Kwara state, but now located in Kogi state; and the establishment of the Nigerian Steel Development Authority (NSDA) and the first furnace steel plant at Ajaokuta in the middle part of the country. It is on record that there were eleven possible locations for this project, later whittled down to three, namely, Warri, Onitsha and Ajaokuta (Ogbu and Tisdel, 1995). Ajaokuta, a virgin land was subsequently chosen with the implication that all or most basic infrastructure had to be built from the scratch. This contributed immensely to the overall cost of setting up this plant and the eventual cost escalation it experienced.

Steel making infrastructure reached an advanced stage in 1982 with the commissioning of Aladja Steel complex (Agbu, 2007).

2.2.2 Some Steel Producing Industries in Nigeria and Their Location

Table 2.1 Names and Locations of Some Steel Companies in Nigeria

S/N	Name of Firm	Location
1	Sunflag Steel Company Ltd	Ikeja
2	Nigeria Yong Xing Steel Company Ltd	Benin
3	Monarch Steel Mill	Ikorodu
4	Phoenix Steel Company	Ikorodu
5	Universal Steel Company	Ikeja
6	Niger Steel Company	Enugu
7	Ajaokuta Steel Company Ltd	Ajaokuta
8	Land Craft Industries Ltd.	Ikorodu
9	Inner Galaxy Steel Company Ltd	Umuahala
10	KAM Steel Integrated Company Ltd	Sagamu
11	Union Steel Company	Ilorin
12	Continental Iron and Steel Company	Ikeja
13	Federal Steel Industry	Otta
14	Metcombe Steel Company	Owerri
15	Lion Steel Group	Abuja
16	Top Steel Nigeria	Ikorodu
17	Nigerian Spanish Company	Kano
18	Allied Steel Company	Onitsha
19	Generated Steel Mill	Asaba

2.3 Mechanical Properties of Reinforcing Bars

In classifying structural steels, mechanical properties are fundamental factors (AZO Mining, 2018). Hence, it is highly important to investigate the minimum standards for the mechanical properties in order to determine the steels' performance characteristics.

Steel has a number of properties, including: hardness, toughness, tensile strength, yield strength, elongation, fatigue strength, corrosion, plasticity, malleability and creep.

Tensile properties are composed of the reaction of the materials to resist when forces are applied in tension. Determining the tensile properties is crucial because it provides information about the modulus of elasticity, elastic limit, elongation, proportional limit, reduction in area, tensile strength, yield point, yield strength, and other tensile properties. The tensile properties of reinforcing steel bar is related to the ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength of reinforcing steel bar, yield stress (YS) and percentage elongation (%). These tensile properties are determined through tensile test (Mohammed, 2012).

Sharp (1966) in his studies of the properties of steel concluded that "by nature of the raw materials and method of manufacture, all steel products contain varying amounts of alloying minerals such as sulphur, manganese, phosphorus and traces of other elements, if other elements are added to the steel, such as chromium, cobalt, or nickel, the steel becomes an alloy steel". Steels are described as mild, medium- or high-carbon steels depending on the percentage of carbon they contain, although this is never greater than about 1.5%. Kareem (2009), in his related studies, corroborated the earlier statement by confirming that the classification of steel into various grades is done based on the percentage composition of carbon which usually ranges from 0.05% to 0.15 %.

The percentages of carbon and other elements such as manganese, molybdenum, vanadium, silicon, chromium, nitrogen and sulphur in steel have a direct effect on its strength and deformation characteristics (John, 1993, Amstead, 1987, Colin, 1987, and Kareem, 2002). This implies that the chemical composition of steel is a determinant of its classification, strength and deformation characteristics such as yield and tensile strengths, elongation and bendability which are important to engineers in the design of safe, functional and economical structure. They further asserted that steel grades with a high level of dissolved gases, particularly oxygen and nitrogen, if not controlled by addition of small elements with a particular affinity for them to float out in the liquid steel at high temperature, can behave in a brittle manner. Manganese, chromium, molybdenum, nickel and copper also affect the strength to a lesser extent than carbon, although their sole effect is on the microstructure of the steel. Charles and Mark (2002) also stated that varying the amount of alloying elements and the form of their presence in the steel (solute elements, precipitated phase) controls properties such as the hardness, ductility, and tensile strength of the resulting steel. Steel with increased carbon content can be made harder and stronger than iron, but such steel is also less ductile than iron.

Kareem (2009) referred to previous literatures by Skinner and Rogers (1979), Walker (1986) and Gilchrist (1989) relating to the oxidation of carbon in steel and its relationship with hardness as highlighted by John (1983), Amstead (1987) and Colin (1987). They investigated the tensile and chemical composition of some selected locally produced reinforcement bars and compared the results with global standards. It was concluded that the physical properties of the selected bars are in good agreement with what is obtainable in both local and international standards except in the case of the chemical analysis results where it was discovered that the percentage carbon content in steel is relatively low as compared to similar local product.

An analysis undertaken by Sanmbo, David, Adeosun, and Olatunde (2009) revealed that the problem of low strength characteristics prevalent in hot rolled steel bars entails two factors, namely: metallurgical and process dysfunction. They further enumerated impact strength, modulus of elasticity, percentage elongation, ultimate tensile and yield strengths as the most important mechanical characteristics of steel.

2.4 Advantages and Disadvantages of Steel Reinforcement Bars

Steel reinforcement is a reinforcing choice compared to other reinforcing materials due to its unique advantages. They are:

i. Compatibility with Concrete: The fresh concrete is placed on the formwork mold already prepared with reinforcement. The steel reinforcement won’t float in concrete during the concrete placing procedure. Hence, steel reinforcement does not demand special tying up with formworks.

ii. Robustness of Steel Reinforcement: The steel reinforcement bars are robust in nature that they have the ability to withstand the severity, the wear and tear during the construction activities.

iii. Bent Property of Steel Reinforcement: Steel reinforcement can be bent to the required shape size and specification although the steel bars once manufactured to standard size. Hence fabricated steel bars are delivered easily at the site.

iv. Recycling Property: After steel reinforced left over the service life of a structure is recycled again and used for new construction.

v. Easily Available: It is easily available at any reason region. Every region of a country will have a steel supplier or manufacturer. Hence steel reinforcement is easily available.

vi. Elastic: Steel reinforcement has high solidarity to weight proportion which implies it has high quality per unit mass. So no matter how huge the general structure is, the steel areas will be small and lightweight, unlike other building structure materials.

The main disadvantages of steel reinforcement bars are mentioned below:

i. Reactive Nature of Steel Reinforcement: In concrete structures where the cover is small and subjected to external moisture and salt action, the reinforcement undergoes reaction and starts to corrode. These can lessen the strength of concrete and finally to failure.

ii. At higher temperatures, the steel reinforcement may liquefy. This is the motivation behind why the steel support is tied up and not welded.

iii. Expensive: The cost of steel reinforcement in high. This will increase the cost of construction.

2.5 Steelmaking

Steelmaking is the process of producing steel from iron ore and/or scrap. In steelmaking, impurities such as nitrogen, silicon, phosphorus, sulfur and excess carbon (the most important impurity) are removed from the sourced iron, and alloying elements such as manganese, nickel, chromium, carbon and vanadium are added to produce different grades of steel. Limiting dissolved gases such as nitrogen and oxygen and entrained impurities (termed "inclusions") in the steel is also important to ensure the quality of the products cast from the liquid steel (wikipedia.com).

Generally, there are three core stages in the production of steel when utilizing iron respective of the production method employed. These are iron making, steelmaking and rolling.

The process for production of steels has significant effect on the properties of the steel produced. As stated in various codes, the percentage by weight of elemental composition of reinforcement steel constituents varies with the production process, and the composition of these steel constituents determines the mechanical properties of steels (Mohammed, 2012).

The most widely used steel production processes (Mohammed, 2012) are:

a. The Blast Furnace Method

b. The Direct Reduction Method

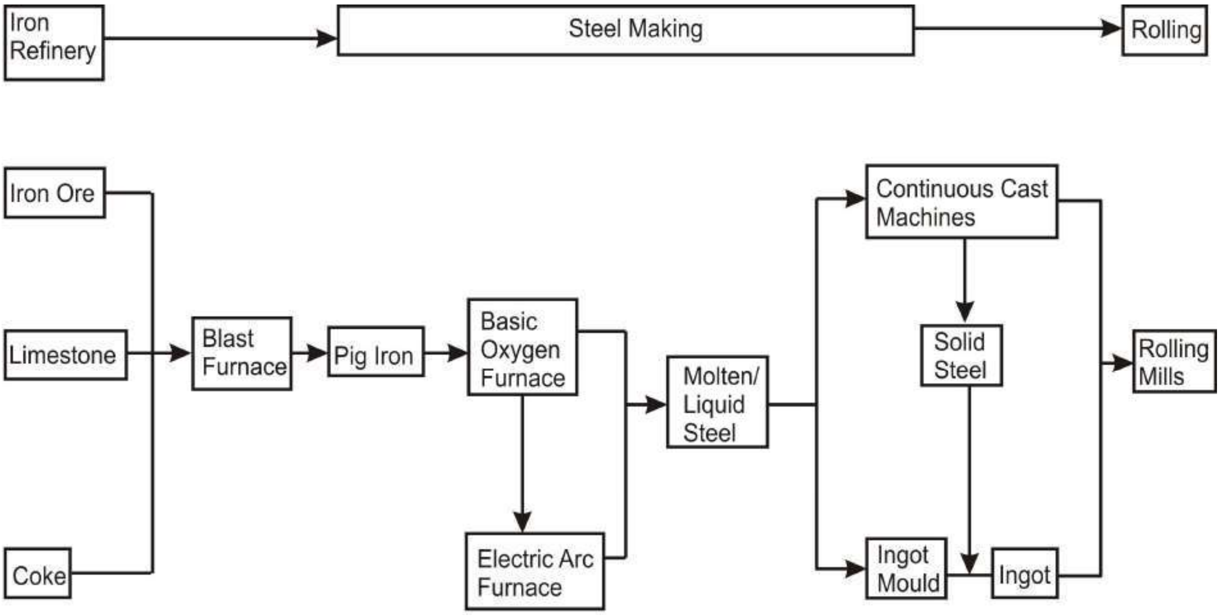
c. The Mini Mill

d. The COREX.

2.5.1 The Blast Furnace Method

The blast furnace is the first step in producing steel from iron oxides. Blast furnaces produce pig iron from iron ore by the reducing action of carbon (supplied as coke) at a high temperature in the presence of a fluxing agent such as limestone (Chelsey, 2021).

This requires a high level of capital investment, and is therefore only used by large steel producing works, typically with an output of several million tons of steel per annum. An example of this technology is the Ajaokuta Steel Rolling Company (Umeojiaku, 2021).

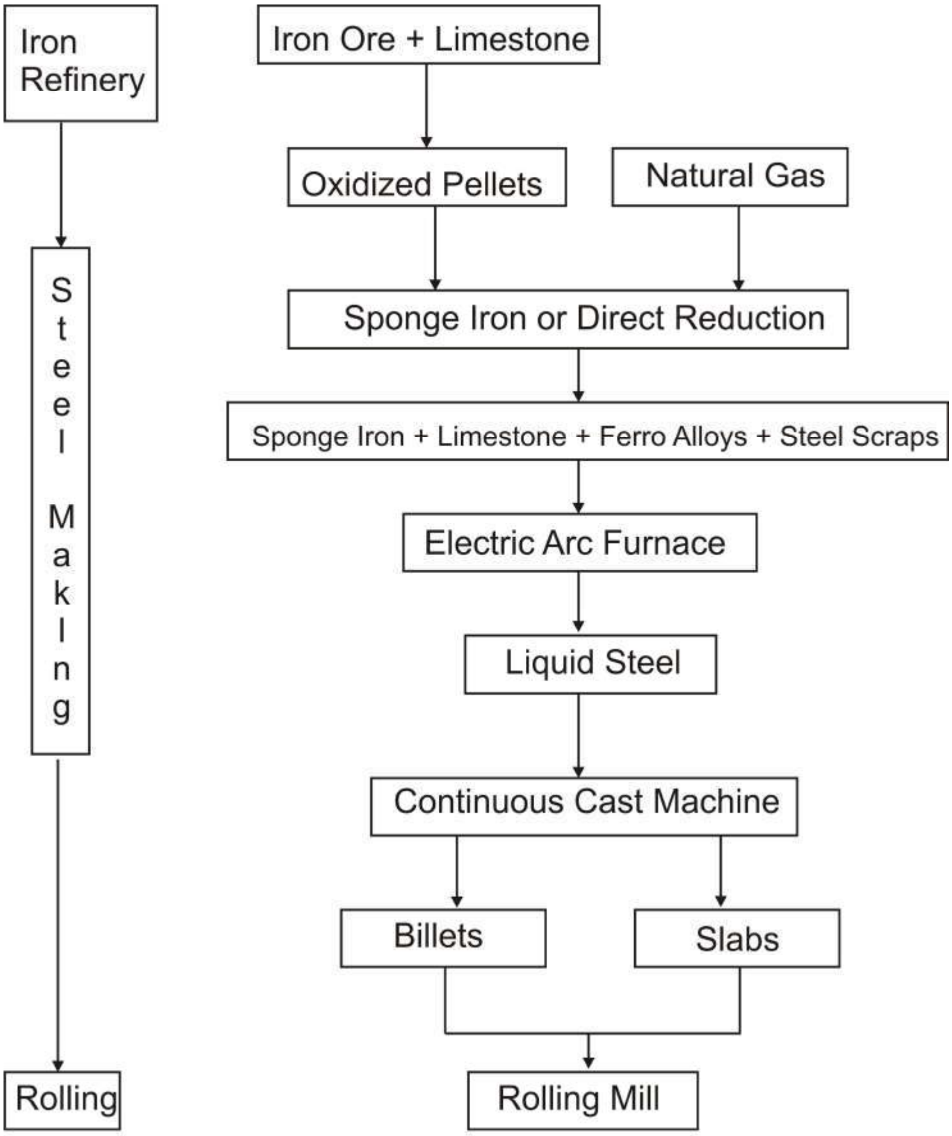


Source: Omoweh, 2005

Figure 2.1: Flow Chart of Steel Making by Blast Furnace Method.

2.5.2 The Direct Reduction Method

The Direct Reduction involves the combination of the iron ore with limestone to form the oxygen pellets which mixes with the natural gas which acts as a reducing agent to form the sponge iron otherwise called direct reduced iron. At this stage, steel scraps are added to the sponge iron along with all alloying minerals and calcium carbonate. These are passed through the Electric arc furnace which produces the liquid steel. At this stage, the liquid steel passes through a continuous cast machine to form the billets (rounds) and slabs (flats) Scrap metal is charged into the furnace which are finally rolled. An example of this technology is The Delta Steel Company. Figure 2.3 gives the illustration of the production process in the direct reduction method line as given by Omoweh (2005).

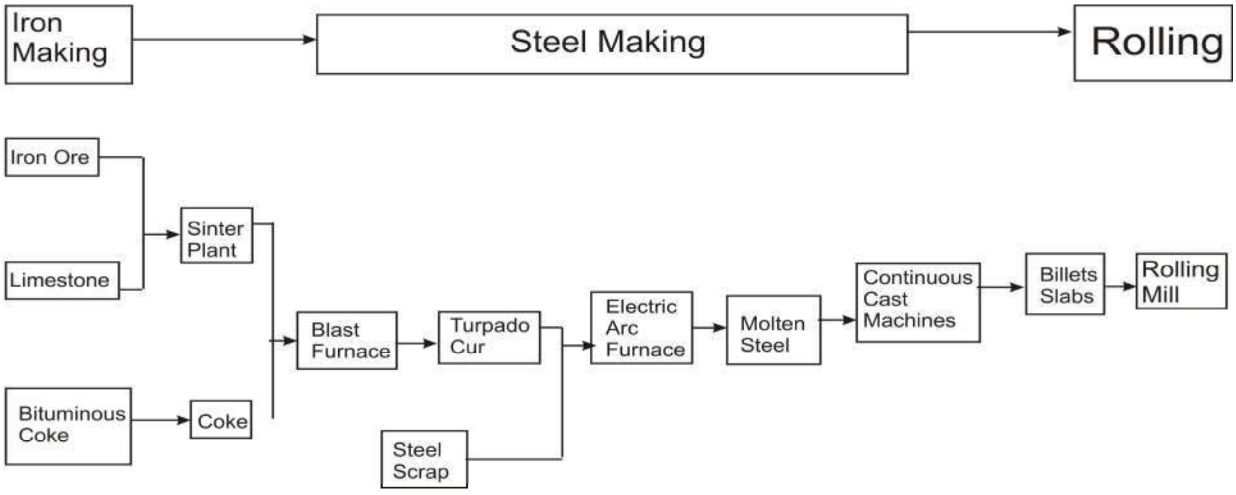


Source: Omoweh, 2005

Figure 2.2: Production Chart of Steel Making by Direct Reduction Process.

2.5.3 The Mini Mills

Mini steel mills normally use the electric arc furnace (EAF) to produce steel from returned steel, scrap, and direct reduced iron. EAF is a batch process with a cycle time of about two to three hours. Since the process uses scrap metal instead of molten iron, coke making or iron making operations are eliminated. It can also be seen in the Nigerian Spanish company in Kano.



Source: Omoweh, 2005

Figure 2.3: Production Chart of Steel Making based on The Mini Mill Process.

2.5.4 The COREX

COREX is a smelting-reduction process developed by Siemens VAI, for cost-efficient and environmentally friendly production of hot metal from iron ore and low grade coal. COREX process may be beneficial in saving energy and investment costs, while reducing environmental pollution. As at today worldwide, only one operating COREX plant exists (Shumacher and Sathaye, 1998).

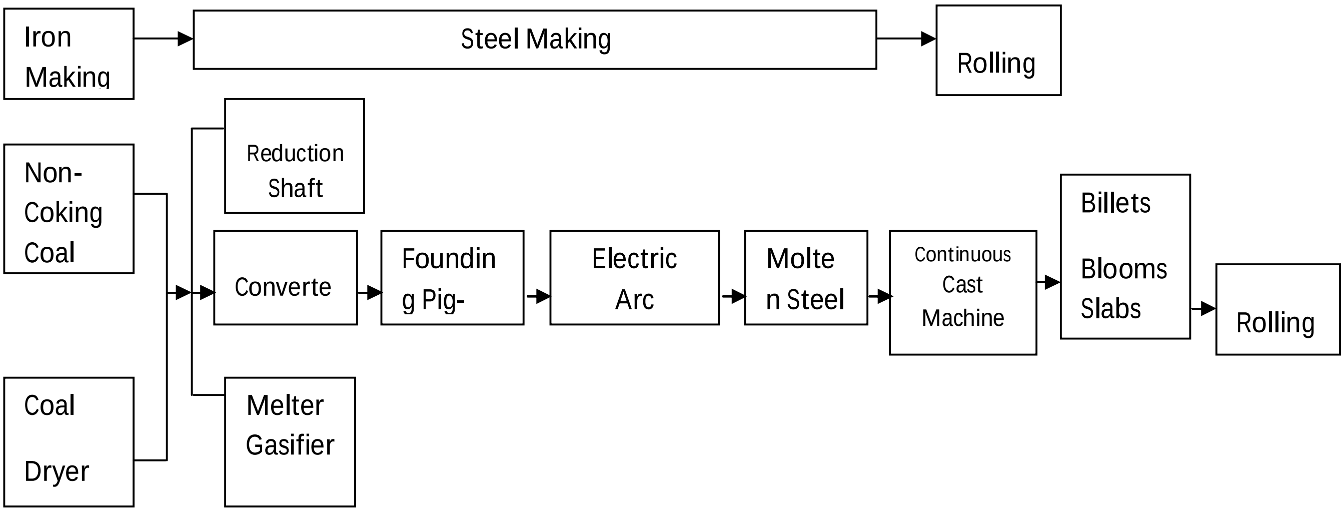


Figure 2.4: Flow Chart of Steel Making COREX

2.6 Standard Codes Used in Different Countries and Their Provisions for the Characteristic Properties of Steel

Table 2.2 Standard Codes Requirements for Characteristic Properties on Rebars

Country	**Standard Codes**	**Symbol of Grade**	**Yield strength MPA (min)**	**Tensile strength MPA (min)**	**Elongation (min)%**
United Kingdom	BS4449:1997	460A 460B	460 460	600 600	12 14
	BS4449:2005 A2:2009 (Table 10)	B500A B500B B500C	485 485 485	650 650 650	12 12 12
USA	ASTM A706/A706M-14	G-60 G-80	415 550	550 690	14 12
	ASTM A615/A615M-14	G-60 G-75 G-80	415 520 550	620 690 725	9 12 7
Japan	JIS G3112-2010 (Table 3)	SD345 SD390 SD490	345 390 490	490 560 620	18 16 12
Europe	EN10025-2	S450	440	550	12
	EN10025-3	S420 S460	420 460	520 540	14 14
India	IS:1786 (2008)	Fe 415 Fe 415D	415 415	485 500	14 18
	IS:1786/85	Fe 500 Fe 500D	500 500	540 565	12 16
Nigeria	NIS 117(2004)	G 420	420	500	12
	NST65-Mn (1994)	G 420	420	600	14

2.6 DEFINITION OF TERMS

The following definitions apply (Umeojiaku, 2021).

i. Bar: A steel product of plain round or deformed profile, produced by hot rolling.
ii. Deformed bar: Bar or with surface characteristics designed to increase its bond with concrete, the degree of deformation being as defined in the relevant standards.
iii. Yield Strength: The yield strength is of a material (steel bar) is the stress a material can withstand without permanent deformation. It can also be defined as the stress which will cause a permanent deformation of 0.2% of the original dimension.
iv. Gauge length (L): The length of the parallel portion of the test piece on which elongation is measured at any moment during the test.
v. Original gauge length (L_o): The length between gauge length marks on the piece measured at room temperature before the testing.
vi. Final gauge length after fracture (L_u): The length between gauge length marks on the test piece measured after rupture, at room temperature. The two piece having been carefully fitted back together so that their axes lie in a straight line.
vii. Parallel length (L_e): Length of the parallel reduced section of the test piece.
viii. Elongation: Increase in the original gauge length at any moment during the test.
ix. Percentage Elongation (%): Elongation expressed as percentage of the original gauge length.
x. Percentage Elongation after fracture: A permanent elongation of the gauge length after fracture, (L_u- L_o), expressed as percentage of the original gauge length.
xi. Yield point: The yield point is specified in MPa or N/mm^2. It designates the stress up to which no permanent plastic deformation occurs in a material under tensile loading.

xii. Ultimate Tensile Strength: This is the maximum stress that a material can withstand while being stretched or pulled before breaking. It is specified in MPa or N/mm^2.

xiii. Characteristic Strength of Steel: The term characteristic strength means that value below which not more than 5% of the test results are expected to fall as per IS 456:2000, the characteristic strength of steel is equal to the minimum yield stress or 0.2 percent proof stress.

xiv. Stress-strain curves: The two chief numerical characteristics which determine the character of reinforcement are its yield point (generally identical in tension and in compression) and its modulus of elasticity E. The latter is practically the same for all reinforcing steels and is taken as E=200 kN/mm^2. In addition, however, the shape of the stress-strain curve of tensile test of steel, and particularly of its initial portion, has significant influence on the performance of reinforced- concrete members. Low-carbon steels, typified by the 250 MPa steel tensile test stress-strain curve, which show an elastic portion followed by a "yield plateau," i.e. by a horizontal portion of the curve where strain continues to increase at constant stress. For such steels the yield point is that stress at which the yield plateau establishes itself. With further strains the stress begins to increase again, though at a slower rate, a process which is known as strain- hardening. The curve flattens out when the tensile strength is reached; it then turns down until fracture occurs.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Sample Collection

Thirty samples of reinforcing steel bars of five different companies were obtained from the major Building Materials Market at New Kenyatta, Enugu state, Nigeria. The samples collected from the market are as shown in Table 3.1 below.

Table 3.1 Steel Reinforcing Bar Samples Collected

S/N	Company	Diameter Collected (mm)
01	Inner Galaxy Steel Company Ltd	12, 16
02	Monarch Steel Mill	12, 16
03	Nigeria Yong Xing Steel Company Ltd	12, 16
04	Yongxing Steel Company	12, 16
05	Premium Steel and Mines Ltd	12, 16

3.2 Apparatus Used

The following apparatus were used during the process of collecting the samples.

i. Steel Measuring tape
ii. White marker
iii. Hack saw.

3.3 The Procedure for Sample Collection

i. The rod from which the test piece was to be cut was inserted and clamped in a vice.

ii. Using a steel measuring tape, the required test piece length of 30cm was measured from one end and marked with a white marker.

iii. The measured length was then cut-off using a hacksaw. The cut was made on the 30cm mark on the steel bar sample.

3.4 Test Sample Identification

3.4.1 Apparatus Used

i. Masking tape

ii. Marker

The five companies from which samples were collected from have been labelled in an alphabetical order such as A, B, C, D and E for identification purposes. The order of identification does not mean A is better than B, as the designations are only for identification purposes.

Figure 3.1: 12mm Rebar samples grouped based on the company

Figure 3.2: 16mm Rebar samples grouped based on the company

3.5 Tensile Testing Procedures

3.5.1 Scope and Location of Test

Scope

The procedures undertaken during the course of this project work was in accordance with the method for tensile testing of Reinforcing steel bars specified in BS4449:1997.

Location of Test

The test was conducted at the Nnamdi Azikiwe University Strength of Material Laboratory Awka and Abia State Ministry of Works Material Testing Laboratory.

3.5.2 Sample Type and Geometry

3.5.2.1 Shape and Dimensions

All samples have circular (round) cross-sections and are 30cm long.

3.5.2.2 Test Sample Type

The samples are ribbed surfaced and un-machined: neither the cross-section nor shape of the sample was altered.

3.5.3 Determination of the Diameter of the Sample

3.5.3.1 Equipment Used

Digital Vernier Calliper

3.5.3.2 Procedure

i. The samples were cleaned with a dry cloth to keep the surface clean and grease free.
ii. Before taking every reading, the calliper was closed to ensure 0.000 reading. If not so, the zero button was pressed so that it did read 0.000.
iii. The sample to be measured was held in a vertical position and the jaws of the calliper were slid open.

iv. The sample was placed in between the jaws and the internal jaw was pushed to grip the test piece perpendicularly along the central region of the longitudinal axis (parallel length).
v. Then the measurement was read from the display.
vi. The procedure was repeated for three cross sections and the average of the results was recorded.

Figure 3.3: Determination of diameter of sample

3.5.4 Determination of the Mass of the Sample

3.5.4.1 Apparatus Used

Weighing balance of 0.01g sensitivity.

3.5.4.2 Procedure

i. The windows and electric fans were closed/turned off to avoid error in the reading of the weighing balance.
ii. The sample to be measured was then placed on the weighing balance and the result was recorded.

3.5.5 Determination of the Effective Cross-Sectional Area of the Sample

3.5.5.1 Apparatus Used

i. Measuring tape
ii. Weighing balance of 0.01g sensitivity.

3.5.5.2 Procedure

i. The length of the sample as well as the mass was determined.
ii. The effective cross sectional area was determined using the relationship as provided by BS4449 (1997):

$$A_{eff} = \frac{M}{0.00785L}$$

where

A_{eff} is the effective cross sectional area of the bar (mm^2);

M is the mass of the bar (kg);

L is the length of the bar (m)

3.5.6 Determination of the Gauge Length

3.5.6.1 Procedure

From the result of the diameter of the steel bars obtained, the individual cross sectional area of the samples were calculated using the formula;

$$A = \frac{\pi d^2}{4}$$

where

d is the circular bar diameter (mm)

From the relationship between the original gauge length L_o and the original cross-sectional area A, the original gauge length was calculated as follows;

$$L_o = K\sqrt{A}$$

where

L_o is the original gauge length

K is the coefficient of proportionality

A is the cross-sectional area

The internationally adopted value for K is 5.65, hence,

$$L_o = 5.65\sqrt{A}$$

3.5.7 Marking of the Original Gauge Length on the Sample

3.5.7.1 Apparatus Used

i. Marking tool (scriber)
ii. Meter rule
iii. Measuring tape

3.5.7.2 Procedures

i. The length of the sample was measured using the measuring tape and the centre of the longitudinal axis for each sample was determined by dividing the length by two.
ii. The centre of each sample was marked with a thin line stroke for the sake of accuracy using a marker.
iii. The value of the predetermined gauge length for each sample was divided by two and one half of the gauge length was measured and marked to the right from the centre and the other half, measured and marked to the left from the centre using the meter rule and the scriber on the samples.
iv. Each end of the original gauge length L_o, was marked by means of fine scribed lines.

3.5.8 Strength Test Process

3.5.8.1 Equipment Used

The Universal Testing Machine (UTM): A Universal Testing Machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the mechanical properties (tension, compression etc.) of a given test specimen by exerting tensile, compressive or transverse stresses. The machine has been named so because of the wide range of tests it can perform over different kind of materials. Different tests like peel test, flexural test, tension test, bend test, friction test, spring test etc. can be performed with the help of UTM (Wikipedia.com).

Components of a Universal Testing Machine

A Universal Testing Machine consists of two main parts:

1. Loading unit
2. Control unit

The arrangement of the test specimen and the exertion of the load are held in the loading unit. The variation in the application of load and the corresponding test result are obtained from the control unit.

1. Loading Unit

The loading unit of a UTM consists of the following components:

i. Load Frame
ii. Upper crosshead and Lower crosshead
iii. Elongation Scale

i. Load Frame

The load frame of a universal testing machine consists of a table where the specimen is placed for the compression test, upper crosshead, and lower crosshead.

ii. Upper Crosshead and Lower Crosshead

The upper crosshead is used to clamp one end of the test specimen. The lower crosshead in the load frame is the movable crosshead whose screws can be loosened for height adjustment and tightened. Both the crossheads have a tapered slot at the centre. This slot has a pair of racked jaws that is intended to grip and hold the tensile test specimen.

iii. Elongation Scale

The relative movement of the lower and upper table is measured by an elongation scale which is provided along with the loading unit.

2. Control Unit

The main components of the control unit in a universal testing machine are:

- i. Hydraulic Power Unit
- ii. Load Measuring Unit
- iii. Control Devices

i. Hydraulic Power Unit

This unit consists of an oil pump that provides non-pulsating oil flow into the main cylinder of the load unit. This flow helps in the smooth application of load on the specimen. The oil pump in a hydraulic power unit is run by an electric motor and sump.

ii. Load Measuring Unit

This unit has a pendulum dynamometer unit that has a small cylinder with a piston which moves with the non-pulsating oil flow. The range of load application can be adjusted by means of a knob in the load measuring unit (0-100 kN; 0-250 kN; 0-500 kN and 0-1000 kN). The accuracy of measuring unit controls the overall accuracy of the machine.

iii. Control Devices

The control devices can be electric or hydraulic. Electric control devices make use of switches to move the crossheads and switch on/off the unit. A hydraulic control device consists of two valves, Right Control Valve and Left Control Valve or Release Valve. A right control valve is used to apply load on the specimen. The left control valve is used to release the load application.

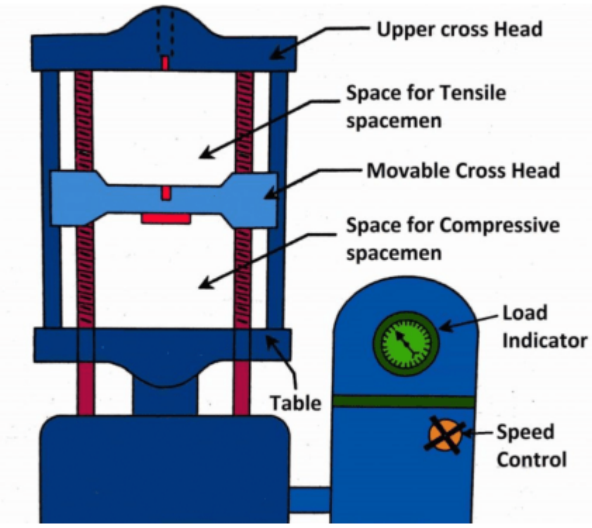


Figure 3.4: Components of a UTM

3.5.8.2 Sample Testing Using UTM

1. Placing and Gripping the Sample on the Machine

Procedures:

i. The testing machine was switched to tensile testing mode by pressing the electric control button which moved the movable cross head upwards, closer to the upper cross head.

ii. Racked jaws were inserted to the cross heads. The type of racked jaw inserted depends on the bar size intended to be tested.

iii. The sample with marked gauge length was held in an upright position and inserted into the gripping jaws by operating the upper cross head handle and lower cross head handle simultaneously.

iv. The upper part as well as the lower part of the sample was adjusted properly to fit into the central axis of the gripping jaws and the region where the gauge length was marked was positioned in the space between the jaws at equal distances from the jaws. Every endeavour was made to ensure that samples were held in such a way that the forces is applied as axially as possible, in order to minimize bending.

v. After the specimen had been properly placed, the jaws were then locked.

2. Load Application

Procedure:

i. The data for the sample to be tested were input in the load measuring unit. The data includes; the sample diameter and the geometry.

ii. The load application sequence was activated and the right control valve was turned slowly to get the desired loading rate of 3mm/s.

iii. The axial force applied to the sample stretches it until it fractures.

iv. After the fracture the loading sequence was turned off and the results of the test displayed on the digital screen were recorded.

The results of the test displayed on the digital screen include;

i. The lower yield load in kN

ii. The upper yield load in kN

iii. The maximum load in kN

iv. The final gauge length in mm

v. The upper yield strength in MPa

vi. The lower yield strength in MPa

vii. The ultimate strength in MPa and

viii. The area of the steel bar in mm^2.

However the values for the final gauge length were calculated manually since the bar areas differ.

Figure 3.5: Placing and gripping the Sample on the machine

Figure 3.6: Fractured test sample in the UTM

3.5.9 Manual Determination of Yield Strength and Ultimate Tensile Strength

The upper yield strength corresponds to the load that is required to initiate yielding. The lower yield strength corresponds to the minimum load that is required to maintain yield. Normally the lower yield point is used to determine the yield strength of reinforcing steel bars during testing because the upper yield is momentary and unstable in nature.

The yield and tensile strengths of the tested samples can be determined manually as follows;

$$R_{el} = \frac{F_{el}}{A}$$

where

R_{el} is the lower yield strength (N/mm^2);

F_{el} is the load of lower yield (N);

A is the original cross-sectional area before testing (mm^2).

$$R_m = \frac{F_{max}}{A}$$

where

R_m is the ultimate tensile strength (N/mm^2);

F_{max} is the maximum load before fracture (N);

A is the original cross-section area before testing (mm^2).

The lower yield stress is used to compute the characteristic strength of the steel.

3.5.10 Determination of the Percentage Elongation after Fracture

3.5.10.1 Apparatus Used

i. Meter rule

3.5.10.2 Procedure

i. The broken samples were placed on a flat surface.
ii. The broken samples were carefully fitted back together so that their axes lie in a straight line with the side where the initial gauge length was marked facing upward.
iii. Using a meter rule, the final gauge length which is the distance between the two marked points is measured and recorded.
iv. Special precautions were taken to ensure proper contact between the broken parts of the sample when measuring the final gauge length.
v. The percentage elongation was then calculated from the equation below.

$$E\ (\%) = \frac{L_f - L_o}{L_o} \times 100$$

where

E is the percentage elongation;

L_o is the original gauge length;

L_f is the final gauge length after fracture.

Figure 3.7: Fractured 16mm test samples

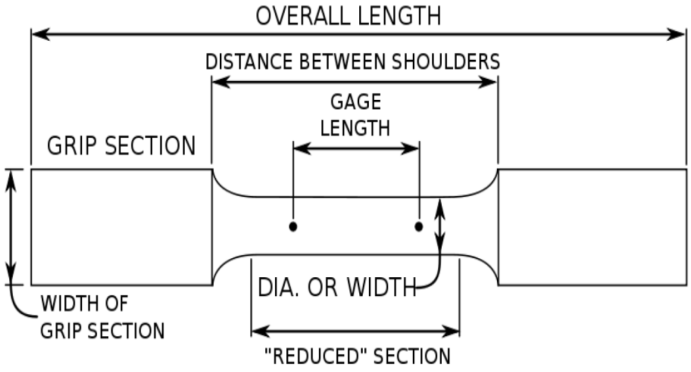


Figure 3.8: Sample layout with property labelling

3.5.11 Determination of the Characteristic Strength of Steel Bars

The characteristic strength of steel bars can be calculated using the equation shown below.

$f_c = f_m – 1.64\ ð.$

where

f_c is the characteristic strength;

f_m is the mean yield strength;

ð is the standard deviation.

3.5.11.1 Procedure for Calculating Standard Deviation

To calculate the standard deviation of the yield strength for a particular company bar size:

i. The mean (the average of the yield strengths for that company bar for a particular size) was determined.

ii. Then the mean yield strength was subtracted from each bar yield strength and the result squared.

iii. Then those squared differences were summed and divided by the number of samples (N) minus one.

iv. And lastly the square root of the value from step three is calculated, which is thus the standard deviation.

CHAPTER FOUR

RESULT AND ANALYSIS

4.1 General Introduction

A summary of observed results from the experiment in chapter three are provided in this chapter for analysis and discussion.

4.2 Diameters, Masses and Cross-Sectional Areas

The average measured diameter, mass, cross-sectional area and effective cross-sectional area of the tested samples are shown in Table 4.1.

Table 4.1 Diameters, Masses and Cross Sectional Areas Test Results for the Five Companies

S/N	Company	Bar Identification Mark	Average Measured Diameter (mm)	Measured Cross-Sectional Area (mm^2)	Mass (kg)	Effective Cross-Sectional Area (mm^2)
01	A	A_{12} -1	10.80	91.62	0.1892	80.34
02		A_{12}-2	10.80	91.62	0.1889	80.21
03		A_{12}-3	10.96	94.36	0.1969	83.61
04		A_{16} -1	13.60	145.29	0.2691	114.27
05		A_{16}-2	13.60	145.29	0.2688	114.14
06		A_{16}-3	13.65	146.36	0.2740	116.34
07	B	B_{12}-1	10.96	94.36	0.2062	87.56
08		B_{12}-2	10.98	94.70	0.2067	87.77
09		B_{12}-3	10.75	90.77	0.2057	87.34
10		B_{16} -1	14.33	161.30	0.3280	139.28
11		B_{16}-2	14.58	166.98	0.3521	149.51
12		B_{16}-3	14.47	164.47	0.3391	143.99

13	C	C_{12}-1	10.76	90.94	0.2291	97.28
14		C_{12}-2	11.03	95.56	0.2272	96.48
15		C_{12}-3	10.98	94.70	0.2282	96.90
16		C_{16}-1	15.27	183.16	0.4966	210.87
17		C_{16}-2	15.51	188.96	0.5089	216.09
18		C_{16}-3	14.86	173.45	0.4804	203.99
19	D	D_{12}-1	10.76	90.94	0.2268	96.31
20		D_{12}-2	10.95	94.18	0.2277	96.69
21		D_{12}-3	11.02	95.39	0.2281	96.86
22		D_{16}-1	15.04	177.68	0.3390	143.95
23		D_{16}-2	15.23	182.20	0.3635	154.35
24		D_{16}-3	15.16	180.53	0.3492	148.28
25	E	E_{12}-1	10.20	81.72	0.1949	82.76
26		E_{12}-2	10.96	94.36	0.1966	83.48
27		E_{12}-3	9.86	76.37	0.1967	83.52
28		E_{16}-1	14.40	162.88	0.3260	138.43
29		E_{16}-2	14.60	167.44	0.3304	140.30
30		E_{16}-3	14.60	167.44	0.3298	140.04

4.3 Measured and Market Diameter Differences for the Five Companies

Table 4.2 presents the differences between the companies' specified diameters and the physically measured diameters for the five different companies.

Table 4.2 Measured and Market Diameter Differences for the Five Companies

S/N	Company	Bar Identification Mark	Average Market Assumed Diameter (mm)	Average Measured Diameter (mm^2)	Difference (mm)	Remarks
01	A	A_{12}-1	12	10.80	1.20	Not Satisfactory
02		A_{12}-2	12	10.80	1.20	Not Satisfactory
03		A_{12}-3	12	10.96	1.04	Not Satisfactory
04		A_{16}-1	16	13.60	2.40	Not Satisfactory
05		A_{16}-2	16	13.60	2.40	Not Satisfactory
06		A_{16}-3	16	13.65	2.35	Not Satisfactory
07	B	B_{12}-1	12	10.96	1.04	Not Satisfactory
08		B_{12}-2	12	10.98	1.02	Not Satisfactory
09		B_{12}-3	12	10.75	1.25	Not Satisfactory
10		B_{16}-1	16	14.33	1.67	Not Satisfactory
11		B_{16}-2	16	14.58	1.42	Not Satisfactory
12		B_{16}-3	16	14.47	1.53	Not Satisfactory
13	C	C_{12}-1	12	10.76	1.24	Not Satisfactory
14		C_{12}-2	12	11.03	0.97	Not Satisfactory
15		C_{12}-3	12	10.98	1.02	Not Satisfactory
16		C_{16}-1	16	15.27	0.73	Not Satisfactory
17		C_{16}-2	16	15.51	0.49	Not Satisfactory
18		C_{16}-3	16	14.86	1.14	Not Satisfactory

19	D	D_{12}-1	12	10.76	1.24	Not Satisfactory
20		D_{12}-2	12	10.95	1.05	Not Satisfactory
21		D_{12}-3	12	11.02	0.98	Not Satisfactory
22		D_{16}-1	16	15.04	0.96	Not Satisfactory
23		D_{16}-2	16	15.23	0.77	Not Satisfactory
24		D_{16}-3	16	15.16	0.84	Not Satisfactory
25	E	E_{12}-1	12	10.20	1.80	Not Satisfactory
26		E_{12}-2	12	10.96	1.04	Not Satisfactory
27		E_{12}-3	12	9.86	2.14	Not Satisfactory
28		E_{16}-1	16	14.40	1.60	Not Satisfactory
29		E_{16}-2	16	14.60	1.40	Not Satisfactory
30		E_{16}-3	16	14.60	1.40	Not Satisfactory

From Table 4.2, it was observed that the assumed market diameters for all the reinforcing steel bars are greater than the physically measured diameters for all the bars considered. A very large discrepancy was also observed on 16mm reinforcing steel bars of company **A** which is designated and sold in the market as 16mm bar as against their measured diameters of 13.60mm and 13.65mm. Hence, they are not satisfactory for practical purposes.

4.4 Effective Cross Sectional Areas and Tolerances

In line with BS4449(1997) requirements which specify ± 6.0% for 8mm and 10mm bars and ±4.5% for 12mm bars and above, it can be seen from Table 4.3 that the tolerance for most of the reinforcing bars irrespective of origin fall out of range. Twenty-three bars are out of range, while only seven bars fall within the acceptable range.

Table 4.3: Differences in Measured and Effective Cross Sectional Areas of the Bars

S/N	Company	Bar Identification Mark	Measured Cross-Sectional Area (mm^2)	Effective Cross-Sectional Area (mm^2)	Tolerance (%)	BS 4449/ 1997 Tolerance (%)	Remarks
01	A	A_{12}-1	91.62	80.34	+12.31	±4.5	Out of Range
02		A_{12}-2	91.62	80.21	+12.45	±4.5	Out of Range
03		A_{12}-3	94.36	83.61	+11.39	±4.5	Out of Range
04		A_{16}-1	145.29	114.27	+21.35	±4.5	Out of Range
05		A_{16}-2	145.29	114.14	+21.40	±4.5	Out of Range
06		A_{16}-3	146.36	116.34	+20.51	±4.5	Out of Range
07	B	B_{12}-1	94.36	87.56	+7.21	±4.5	Out of Range
08		B_{12}-2	94.70	87.77	+7.32	±4.5	Out of Range
09		B_{12}-3	90.77	87.34	+3.78	±4.5	Within Range
10		B_{16}-1	161.30	139.28	+13.65	±4.5	Out of Range
11		B_{16}-2	166.98	149.51	+10.46	±4.5	Out of Range
12		B_{16}-3	164.47	143.99	+12.45	±4.5	Out of Range
13	C	C_{12}-1	90.94	97.28	-6.97	±4.5	Out of Range
14		C_{12}-2	95.56	96.48	-0.96	±4.5	Within Range
15		C_{12}-3	94.70	96.90	-2.32	±4.5	Within Range

16		C_{16}-1	183.16	210.87	-15.13	±4.5	Out of Range
17		C_{16}-2	188.96	216.09	-14.36	±4.5	Out of Range
18		C_{16}-3	173.45	203.99	-17.61	±4.5	Out of Range
19	D	D_{12}-1	90.94	96.31	-0.06	±4.5	Within Range
20		D_{12}-2	94.18	96.69	-2.67	±4.5	Within Range
21		D_{12}-3	95.39	96.86	-1.54	±4.5	Within Range
22		D_{16}-1	177.68	143.95	+18.98	±4.5	Out of Range
23		D_{16}-2	182.20	154.35	+15.29	±4.5	Out of Range
24		D_{16}-3	180.53	148.28	+17.86	±4.5	Out of Range
25	E	E_{12}-1	81.72	82.76	-1.27	±4.5	Within Range
26		E_{12}-2	94.36	83.48	+11.53	±4.5	Out of Range
27		E_{12}-3	76.37	83.52	-9.36	±4.5	Out of Range
28		E_{16}-1	162.88	138.43	+15.01	±4.5	Out of Range
29		E_{16}-2	167.44	140.30	+16.21	±4.5	Out of Range
30		E_{16}-3	167.44	140.04	+16.36	±4.5	Out of Range

Out of Range => Not Satisfactory; Within Range => Satisfactory

This indicates that the reinforcing steel bars that are out of range have varying diameters along the length which is not the best for reinforcing bars. This should be clearly checked to ensure an average close diameter throughout the length.

4.5 Yield Strength and Ultimate Strength

The yield strength and ultimate tensile strength results gotten from the test as shown in Table 4.4 and Table 4.5 respectively are compared with the Nigerian Industrial Standard code requirements.

Table 4.4: Yield Strength Test Results for the Five Companies and Comparison with the Nigerian Industrial Standard Code Provisions

Company	Bar Identification Mark	Load at Yield Point (KN)	Yield Stress (N/mm^2)	Average Yield Stress (N/mm^2)	Min. Yield Strength based on NIS 117 (2004) Provisions	Remark
A	A_{12}-1	30.91	337.37	339.39	420	Below Code
	A_{12}-2	30.75	335.63			
	A_{12}-3	32.57	345.17			
	A_{16}-1	63.04	433.89	431.76	420	Above Code
	A_{16}-2	62.72	431.69			
	A_{16}-3	62.89	429.69			
B	B_{12}-1	32.98	349.51	348.64	420	Below Code
	B_{12}-2	30.74	324.60			
	B_{12}-3	33.75	371.82			
	B_{16}-1	57.81	358.40	390.84	420	Below Code
	B_{16}-2	67.38	403.52			
	B_{16}-3	67.53	410.59			
C	C_{12}-1	38.23	420.39	418.30	420	Below Code
	C_{12}-2	40.37	422.46			
	C_{12}-3	39.02	412.04			
	C_{16}-1	82.30	448.26	444.83	420	Above Code
	C_{16}-2	82.40	436.07			
	C_{16}-3	78.08	450.16			

D	D_{12}-1	36.72	403.78	403.79	420	Below Code
	D_{12}-2	37.79	401.25			
	D_{12}-3	38.76	406.33			
	D_{16}-1	65.61	369.26	365.96	420	Below Code
	D_{16}-2	65.72	360.70			
	D_{16}-3	66.42	367.92			
E	E_{12}-1	29.26	358.05	347.52	420	Below Code
	E_{12}-2	31.41	332.87			
	E_{12}-3	26.97	351.63			
	E_{16}-1	58.59	359.71	361.28	420	Below Code
	E_{16}-2	60.25	359.88			
	E_{16}-3	60.99	364.25			

Above Code => Satisfactory Below Code => Not Satisfactory

From Table 4.4, it was observed that only two sets out of the ten sets of samples (Company A 16mm bar and Company C 16mm bar) met the code minimum requirement for minimum yield strength.

Table 4.5: Ultimate Tensile Strength Test Result for the Five Companies and Comparison with the Nigerian Industrial Standard Code Provisions

Company	Bar Identification Mark	Maximum Load Before Fracture (KN)	Ultimate Tensile Strength (N/mm^2)	Average Ultimate Tensile Strength (N/mm^2)	Min. Ultimate Tensile Strength based on NIS 117 (2004) Provisions	Remark
A	A_{12}-1	42.64	465.40	472.79	500	Below Code
	A_{12}-2	41.92	457.54			
	A_{12}-3	46.75	495.44			
	A_{16}-1	82.77	569.69	568.42	500	Above Code
	A_{16}-2	82.06	564.80			
	A_{16}-3	83.54	570.78			

B	B_{12}-1	45.34	480.50	470.50	500	Below Code
	B_{12}-2	41.98	443.29			
	B_{12}-3	44.27	487.72			
	B_{16}-1	82.84	513.58	507.25	500	Above Code
	B_{16}-2	84.20	504.25			
	B_{16}-3	82.88	503.92			
C	C_{12}-1	52.27	574.77	566.40	500	Above Code
	C_{12}-2	53.95	564.57			
	C_{12}-3	53.02	559.87			
	C_{16}-1	109.52	597.95	599.99	500	Above Code
	C_{16}-2	110.04	582.35			
	C_{16}-3	107.48	619.66			
D	D_{12}-1	42.17	463.71	481.15	500	Below Code
	D_{12}-2	46.59	494.69			
	D_{12}-3	46.27	485.06			
	D_{16}-1	93.83	528.08	521.43	500	Above Code
	D_{16}-2	94.22	517.12			
	D_{16}-3	93.71	519.08			
E	E_{12}-1	40.39	494.25	495.38	500	Below Code
	E_{12}-2	44.36	470.11			
	E_{12}-3	40.02	521.77			
	E_{16}-1	80.75	495.76	489.19	500	Below Code
	E_{16}-2	81.65	487.64			
	E_{16}-3	81.07	484.17			

Above Code => Satisfactory   Below Code => Not Satisfactory

From Table 4.5, it was observed that 50% of samples passed the minimum ultimate tensile strength requirement of the NIS code whereas the remaining 50% did not meet up to the code requirement.

4.6 Characteristic Strengths

The characteristic strengths computed from the yield strengths are shown in Table 4.6 and are compared with the code requirements as shown in Table 4.7.

Table 4.6: Characteristic Strength Values

Company	Bar Identification Mark	Yield Strength (N/mm^2)	Average Yield Strength (N/mm^2)	Standard Deviation	Characteristic Strength (N/mm^2)
A	A_{12}-1	337.37	339.39	8.33	331
	A_{12}-2	335.63			
	A_{12}-3	345.17			
	A_{16}-1	433.89	431.76	3.45	428
	A_{16}-2	431.69			
	A_{16}-3	429.69			
B	B_{12}-1	349.51	348.64	38.74	310
	B_{12}-2	324.60			
	B_{12}-3	371.82			
	B_{16}-1	358.40	390.84	46.43	344
	B_{16}-2	403.52			
	B_{16}-3	410.59			
C	C_{12}-1	420.39	418.30	9.05	409
	C_{12}-2	422.46			
	C_{12}-3	412.04			
	C_{16}-1	448.26	444.83	12.54	432
	C_{16}-2	436.07			
	C_{16}-3	450.16			
D	D_{12}-1	403.78	403.79	4.17	400
	D_{12}-2	401.25			
	D_{12}-3	406.33			

	D_{16}-1	369.26	365.96	7.55	358
	D_{16}-2	360.70			
	D_{16}-3	367.92			
E	E_{12}-1	358.05	347.52	21.46	326
	E_{12}-2	332.87			
	E_{12}-3	351.63			
	E_{16}-1	359.71	361.28	4.22	357
	E_{16}-2	359.88			
	E_{16}-3	364.25			

Table 4.7: Comparison of the Tested Sample Characteristic Strength Values with BS4449/1997 Provisions

Company	**Bar Size (mm)**	**Characteristic Strength (N/mm^2)**	**Min. Characteristic Strength based on BS4449/1997 Provisions (N/mm^2)**	**Remarks**
A	12	331	460	Below Code Unsatisfactory
	16	428	460	Below Code Unsatisfactory
B	12	310	460	Below Code Unsatisfactory
	16	344	460	Below Code Unsatisfactory
C	12	409	460	Below Code Unsatisfactory
	16	432	460	Below Code Unsatisfactory

D	12	400	460	Below Code Unsatisfactory
	16	358	460	Below Code Unsatisfactory
E	12	326	460	Below Code Unsatisfactory
	16	357	460	Below Code Unsatisfactory

From Table 4.7, it was observed that none of the tested bar samples was able to meet the minimum code provisions for characteristic strength.

4.7 Ultimate to Yield Strength Ratio

Table 4.8 shows the ratio of the ultimate to yield strength.

Table 4.8: Ultimate to Yield Strength Ratio Value for the Tested Samples

Company	Bar Identification Mark	Yield Stress (N/mm^2)	Ultimate Tensile Stress (N/mm^2)	Ultimate to Yield Ratio	Min. Characteristic Strength based on BS4449/1997 Provisions	Remarks
A	A_{12}-1	337.37	465.40	1.38	>1.15	Above Code Satisfactory
	A_{12}-2	335.63	457.54	1.36	>1.15	Above Code Satisfactory
	A_{12}-3	345.17	495.44	1.44	>1.15	Above Code Satisfactory
	A_{16}-1	433.89	569.69	1.31	>1.15	Above Code Satisfactory
	A_{16}-2	431.69	564.80	1.31	>1.15	Above Code Satisfactory

	A_{16}-3	429.69	570.78	1.33	>1.15	Above Code Satisfactory
B	B_{12}-1	349.51	480.50	1.37	>1.15	Above Code Satisfactory
	B_{12}-2	324.60	443.29	1.37	>1.15	Above Code Satisfactory
	B_{12}-3	371.82	487.72	1.31	>1.15	Above Code Satisfactory
	B_{16}-1	358.40	513.58	1.43	>1.15	Above Code Satisfactory
	B_{16}-2	403.52	504.25	1.25	>1.15	Above Code Satisfactory
	B_{16}-3	410.59	503.92	1.23	>1.15	Above Code Satisfactory
C	C_{12}-1	420.39	574.77	1.37	>1.15	Above Code Satisfactory
	C_{12}-2	422.46	564.57	1.34	>1.15	Above Code Satisfactory
	C_{12}-3	412.04	559.87	1.36	>1.15	Above Code Satisfactory
	C_{16}-1	448.26	597.95	1.33	>1.15	Above Code Satisfactory
	C_{16}-2	436.07	582.35	1.34	>1.15	Above Code Satisfactory
	C_{16}-3	450.16	619.66	1.38	>1.15	Above Code Satisfactory
D	D_{12}-1	403.78	463.71	1.16	>1.15	Above Code Satisfactory

	D_{12}-2	401.25	494.69	1.23	>1.15	Above Code Satisfactory
	D_{12}-3	406.33	485.06	1.19	>1.15	Above Code Satisfactory
	D_{16}-1	369.26	528.08	1.43	>1.15	Above Code Satisfactory
	D_{16}-2	360.70	517.12	1.43	>1.15	Above Code Satisfactory
	D_{16}-3	367.92	519.08	1.41	>1.15	Above Code Satisfactory
E	E_{12}-1	358.05	494.25	1.38	>1.15	Above Code Satisfactory
	E_{12}-2	332.87	470.11	1.41	>1.15	Above Code Satisfactory
	E_{12}-3	351.63	521.77	1.48	>1.15	Above Code Satisfactory
	E_{16}-1	359.71	495.76	1.38	>1.15	Above Code Satisfactory
	E_{16}-2	359.88	487.64	1.36	>1.15	Above Code Satisfactory
	E_{16}-3	364.25	484.17	1.33	>1.15	Above Code Satisfactory

It was observed that the ultimate to yield strength ratio values in respect of all the thirty samples are above the minimum code provisions. The ratios from Table 4.8 are in a reasonable range and are satisfactory. However, when the ratio is too high (>2.00), it is not good either. It implies high carbon content which may lack of ductility.

4.8 Percentage Elongation

In accordance with BS4449:1997 the minimum percentage elongation specified is 12% for grade 460A and 14% for grade 460B. Hence the comparison would be made for a minimum percentage elongation of 12%.

Table 4.9: Percentage Elongation Test Results

S/N	Company	Bar Identification Mark	Initial Gauge Length (mm)	Final Gauge Length (mm)	Elongation (%)	Average Elongation (%)
01	A	A_{12}-1	54.00	61.50	13.89	13.80
02		A_{12}-2	54.00	61.00	12.96	
03		A_{12}-3	55.0	63.00	14.55	
04		A_{16}-1	68.00	76.00	11.76	13.53
05		A_{16}-2	68.00	78.00	14.71	
06		A_{16}-3	68.00	77.60	14.12	
07	B	B_{12}-1	55.00	61.20	11.27	11.10
08		B_{12}-2	55.00	61.00	10.91	
09		B_{12}-3	54.00	60.00	11.11	
10		B_{16}-1	72.00	81.00	12.50	13.22
11		B_{16}-2	73.00	83.00	13.70	
12		B_{16}-3	72.00	81.70	13.47	
13	C	C_{12}-1	54.00	61.50	13.89	13.12
14		C_{12}-2	55.00	62.00	12.73	
15		C_{12}-3	55.00	62.00	12.73	
16		C_{16}-1	76.00	87.20	14.74	14.14
17		C_{16}-2	78.00	88.00	12.82	
18		C_{16}-3	74.00	85.00	14.86	

19	D	D_{12}-1	54.00	60.50	12.04	12.32
20		D_{12}-2	55.00	61.70	12.18	
21		D_{12}-3	55.00	62.00	12.73	
22		D_{16}-1	75.00	84.60	12.00	13.78
23		D_{16}-2	76.00	87.00	14.47	
24		D_{16}-3	76.00	87.30	14.87	
25	E	E_{12}-1	51.00	57.20	12.16	11.73
26		E_{12}-2	55.00	61.50	11.82	
27		E_{12}-3	49.00	54.50	11.22	
28		E_{16}-1	72.00	81.50	13.19	12.75
29		E_{16}-2	73.00	82.00	12.33	
30		E_{16}-3	73.00	82.30	12.74	

Table 4.10: Comparison of the Tested Samples Percentage Elongation with Standard Code Minimum Specified Value

S/N	Company	Bar Size (mm)	Average Elongation (%)	Min. BS 4449/1997 provision	Remarks
01	A	12	13.80	12.00	Above Code, Satisfactory
		16	13.53	12.00	Above Code, Satisfactory
02	B	12	11.10	12.00	Below Code, Unsatisfactory
		16	13.22	12.00	Above Code, Satisfactory
03	C	12	13.12	12.00	Above Code, Satisfactory
		16	14.14	12.00	Above Code, Satisfactory

04	D	12	12.32	12.00	Above Code, Satisfactory
		16	13.78	12.00	Above Code, Satisfactory
05	E	12	11.73	12.00	Below Code, Unsatisfactory
		16	12.75	12.00	Above Code, Satisfactory

From Table 4.10, it was observed that all the 16mm bars of the five companies met the minimum code requirements on elongation. Also three out of the five companies have their 12mm bars above the minimum code requirement on elongation. Hence 80% of the companies samples tested passed the elongation test. The samples that failed in elongation should not be used in reinforcement as they will not give warning prior to failure due to low ductility.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the results of the characteristic strength test conducted and the observations and the analyses carried out, the following conclusions were made.

1. The cause of the inadequacy in the mechanical properties of the steels may be attributed to the inconsistencies in the value of the cross-sectional areas of the steels as discovered in this study as it was observed that all the reinforcing steel bars of the five companies do not have their diameters measured up to the nominal diameter as provided by the code (BS 4449:1997).
2. For the reinforcing steel bars of the companies studied, their characteristic strength values when compared to BS 4449:1997 standards are low for high tensile steel which is 460N/mm^2 minimum value. Only about nineteen percent of the samples were above code specification.
3. The characteristic strength values of the samples for the companies studied are similar or resemble that of mild steel. This is not out of place to say that the products are actually mild steel but presented as high yield steel and openly sold in the market as high tensile steel after rethreading.
4. All the reinforcement bar samples complied with the minimum ultimate to yield strength ratio as specified by BS 4449: 1969 and 1997 code provisions.
5. The percentage elongation values for 80% of the locally produced bar samples are within acceptable code limits which denotes that the majority of them have good ductility.

5.2 Recommendations

On the basis of the findings of this study, the following recommendations are hereby made.

1. There should be technical information on all steel reinforcement sold in the open markets so as to guide the designers on their strength and deformation characteristics.
2. Steel bars produced in Nigeria should not be used for the reinforcement of structural concrete without first subjecting them appropriately to tensile test so as to ascertain whether the mechanical properties are up to that required to carry out the construction work.
3. Regulatory authorities such as the Standards Organization of Nigeria, Council for the Regulation of Engineering in Nigeria and tertiary institutions should strengthen their collaborations on ensuring quality standards through materials testing.
4. Steel rolling mills in the country should be compelled to carry along or make their quality testing facilities available to regulatory and other quality enforcement agencies for periodic inspection and compliance.
5. All imported reinforcing steel must be checked for quality compliance prior to accepting such consignment into the country and such must be accompanied with an accredited certification.

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APPENDIX A

A.1 Calculations on Cross Sectional Area of the Bar Samples

Cross sectional area of the steel, A= $\frac{\pi D^2}{4}$

Where

D is the circular bar diameter (mm)

For:

A_{12} – 1, D =10.80mm; A = $\frac{\pi\times 10.80^2}{4}$ = $\underline{91.62\text{mm}^2}$

A_{12} – 2, D =10.80mm; A = $\frac{\pi\times 10.80^2}{4}$ = $\underline{91.62\text{mm}^2}$

A_{12} – 3, D =10.96mm; A = $\frac{\pi\times 10.96^2}{4}$ = $\underline{94.36\text{mm}^2}$

A_{16} – 1, D =13.60mm; A = $\frac{\pi\times 13.60^2}{4}$ = $\underline{145.29\text{mm}^2}$

A_{16} – 2, D =13.60mm; A = $\frac{\pi\times 13.60^2}{4}$ = $\underline{145.29\text{mm}^2}$

A_{16} – 3, D =13.65mm; A = $\frac{\pi\times 13.65^2}{4}$ = $\underline{146.36\text{mm}^2}$

B_{12} – 1, D =10.96mm; A = $\frac{\pi\times 10.96^2}{4}$ = $\underline{94.36\text{mm}^2}$

B_{12} – 2, D =10.98mm; A = $\frac{\pi\times 10.98^2}{4}$ = $\underline{91.70\text{mm}^2}$

B_{12} – 3, D =10.75mm; A = $\frac{\pi\times 10.75^2}{4}$ = $\underline{90.77\text{mm}^2}$

B_{16} – 1, D =14.33mm; A = $\frac{\pi\times 14.33^2}{4}$ = $\underline{161.30\text{mm}^2}$

B_{16} – 2, D =14.58mm; A = $\frac{\pi\times 14.58^2}{4}$ = $\underline{166.98\text{mm}^2}$

B_{16} – 3, D =14.47mm; A = $\frac{\pi\times 14.47^2}{4}$ = $\underline{164.47\text{mm}^2}$

C_{12} – 1, D =10.76mm; A = $\frac{\pi\times 10.76^2}{4}$ = $\underline{90.94\text{mm}^2}$

C_{12} – 2, D =11.03mm; $A = \frac{\pi \times 11.03^2}{4} = \underline{95.56\text{mm}^2}$

C_{12} – 3, D =10.98mm; $A = \frac{\pi \times 10.98^2}{4} = \underline{94.70\text{mm}^2}$

C_{16} – 1, D =15.27mm; $A = \frac{\pi \times 15.27^2}{4} = \underline{183.16\text{mm}^2}$

C_{16} – 2, D =15.51mm; $A = \frac{\pi \times 15.51^2}{4} = \underline{188.96\text{mm}^2}$

C_{16} – 3, D =14.86mm; $A = \frac{\pi \times 14.86^2}{4} = \underline{173.45\text{mm}^2}$

D_{12} – 1, D =10.76mm; $A = \frac{\pi \times 10.76^2}{4} = \underline{90.94\text{mm}^2}$

D_{12} – 2, D =10.95mm; $A = \frac{\pi \times 10.95^2}{4} = \underline{94.18\text{mm}^2}$

D_{12} – 3, D =11.02mm; $A = \frac{\pi \times 11.02^2}{4} = \underline{95.39\text{mm}^2}$

D_{16} – 1, D =15.04mm; $A = \frac{\pi \times 15.04^2}{4} = \underline{177.68\text{mm}^2}$

D_{16} – 2, D =15.23mm; $A = \frac{\pi \times 15.23^2}{4} = \underline{182.20\text{mm}^2}$

D_{16} – 3, D =15.16mm; $A = \frac{\pi \times 15.16^2}{4} = \underline{180.53\text{mm}^2}$

E_{12} – 1, D =10.20mm; $A = \frac{\pi \times 10.20^2}{4} = \underline{81.72\text{mm}^2}$

E_{12} – 2, D =10.96mm; $A = \frac{\pi \times 10.96^2}{4} = \underline{94.36\text{mm}^2}$

E_{12} – 3, D =9.86mm; $A = \frac{\pi \times 9.86^2}{4} = \underline{76.37\text{mm}^2}$

E_{16} – 1, D =14.40mm; $A = \frac{\pi \times 14.40^2}{4} = \underline{162.88\text{mm}^2}$

E_{16} – 2, D =14.60mm; $A = \frac{\pi \times 14.60^2}{4} = \underline{167.44\text{mm}^2}$

E_{16} – 3, D =14.60mm; $A = \frac{\pi \times 14.60^2}{4} = \underline{167.44\text{mm}^2}$

A.2 Calculations on Effective Cross-Sectional Area

Effective area, $A_{eff} = \frac{M}{0.00785L}$

where

L is the length of the bar, equal to 0.30m

M is the mass of the bar (kg)

For:

A_{12} –1, M = 0.1892; $A_{eff} = \frac{0.1892}{0.00785\times0.30}$ = 80.34mm^2

A_{12} –2, M = 0.1889; $A_{eff} = \frac{0.1889}{0.00785\times0.30}$ = 80.21mm^2

A_{12} –3, M = 0.1969; $A_{eff} = \frac{0.1969}{0.00785\times0.30}$ = 83.61mm^2

A_{16} –1, M = 0.2691; $A_{eff} = \frac{0.2691}{0.00785\times0.32}$ = 114.27mm^2

A_{16} –2, M = 0.2688; $A_{eff} = \frac{0.2688}{0.00785\times0.30}$ = 114.14mm^2

A_{16} –3, M = 0.2740; $A_{eff} = \frac{0.2740}{0.00785\times0.30}$ = 116.34mm^2

B_{12} –1, M = 0.2062; $A_{eff} = \frac{0.2062}{0.00785\times0.30}$ = 87.56mm^2

B_{12} –2, M = 0.2067; $A_{eff} = \frac{0.2067}{0.00785\times0.30}$ = 87.77mm^2

B_{12} –3, M = 0.2057; $A_{eff} = \frac{0.2057}{0.00785\times0.30}$ = 87.34mm^2

B_{16} –1, M = 0.3280; $A_{eff} = \frac{0.3280}{0.00785\times0.30}$ = 139.38mm^2

B_{16} –2, M = 0.3521; $A_{eff} = \frac{0.3521}{0.00785\times0.30}$ = 149.51mm^2

B_{16} –3, M = 0.3391; $A_{eff} = \frac{0.3391}{0.00785\times0.30}$ = 143.99mm^2

C_{12} –1, M = 0.2291; $A_{eff} = \frac{0.2291}{0.00785\times0.30}$ = 97.28mm^2

C_{12} –2, M = 0.2272; $A_{eff} = \frac{0.2272}{0.00785\times0.30}$ = 96.48mm^2

C_{12} –3, M = 0.2282; $A_{eff} = \frac{0.2282}{0.00785\times0.30}$ = 96.90mm^2

C_{16} –1, M = 0.4966; $A_{eff} = \frac{0.4966}{0.00785 \times 0.30}$ = 210.87mm^2

C_{16} –2, M = 0.5089; $A_{eff} = \frac{0.5089}{0.00785 \times 0.30}$ = 216.09mm^2

C_{16} –3, M = 0.4804; $A_{eff} = \frac{0.4804}{0.00785 \times 0.30}$ = 203.99mm^2

D_{12} –1, M = 0.2268; $A_{eff} = \frac{0.2268}{0.00785 \times 0.30}$ = 96.31mm^2

D_{12} –2, M = 0.2277; $A_{eff} = \frac{0.2277}{0.00785 \times 0.30}$ = 96.69mm^2

D_{12} –3, M = 0.2281; $A_{eff} = \frac{0.2281}{0.00785 \times 0.30}$ = 96.86mm^2

D_{16} –1, M = 0.3390; $A_{eff} = \frac{0.3390}{0.00785 \times 0.30}$ = 143.95mm^2

D_{16} –2, M = 0.3635; $A_{eff} = \frac{0.3635}{0.00785 \times 0.30}$ = 154.35mm^2

D_{16} –3, M = 0.3492; $A_{eff} = \frac{0.3492}{0.00785 \times 0.30}$ = 148.28mm^2

E_{12} –1, M = 0.1949; $A_{eff} = \frac{0.1949}{0.00785 \times 0.30}$ = 82.76mm^2

E_{12} –2, M = 0.1966; $A_{eff} = \frac{0.1966}{0.00785 \times 0.30}$ = 83.48mm^2

E_{12} –3, M = 0.1967; $A_{eff} = \frac{0.1967}{0.00785 \times 0.30}$ = 83.52mm^2

E_{16} –1, M = 0.3260; $A_{eff} = \frac{0.3260}{0.00785 \times 0.30}$ = 138.43mm^2

E_{16} –2, M = 0.3304; $A_{eff} = \frac{0.3304}{0.00785 \times 0.30}$ = 140.30mm^2

E_{16} –3, M = 0.3298; $A_{eff} = \frac{0.3298}{0.00785 \times 0.30}$ = 140.04mm^2

A.3 Calculations on Tolerance

Tolerance (%) = $\frac{\text{Measured cross sectional area(mm}^2\text{)} - \text{Effective cross sectiional area(mm}^2\text{)}}{\text{Measured cross seectional area (mm}^2\text{)}}\times$ 100%

For:

A_{12} -1, A =91.62mm^2 and A_{eff} =80.34mm^2; T (%) = $\frac{91.62-80.34}{91.62}\times$ 100% = +12.31 %

A_{12} -2, A =91.62mm^2 and A_{eff} =80.21mm^2; T (%) = $\frac{91.62-80.21}{91.62}\times$ 100% = +12.45 %

A_{12} -3, A =94.36mm^2 and A_{eff} =83.61mm^2; T (%) = $\frac{94.36-83.61}{94.36}\times$ 100% = +11.39 %

A_{16} -1, A =145.29mm^2 and A_{eff} =114.27mm^2; T (%) = $\frac{145.29-114.27}{145.29}\times$ 100% = +21.35 %

A_{16} -2, A =145.29mm^2 and A_{eff} =114.14mm^2; T (%) = $\frac{145.29-114.14}{145.29}\times$ 100% = +21.40 %

A_{16} -3, A =146.36mm^2 and A_{eff} =116.34mm^2; T (%) = $\frac{145.36-116.34}{145.36}\times$ 100% = +20.51 %

B_{12} -1, A =94.36mm^2 and A_{eff} =87.56mm^2; T (%) = $\frac{94.36-87.56}{94.36}\times$ 100% = +7.21 %

B_{12} -2, A =94.70mm^2 and A_{eff} =87.77mm^2; T (%) = $\frac{94.70-87.77}{94.70}\times$ 100% = +7.32 %

B_{12} -3, A =90.77mm^2 and A_{eff} =87.34mm^2; T (%) = $\frac{90.77-87.34}{90.77}\times$ 100% = +3.78 %

B_{16} -1, A =161.30mm^2 and A_{eff} =139.28mm^2; T (%) = $\frac{161.30-139.28}{161.30}\times$ 100% = +13.65 %

B_{16} -2, A =166.98mm^2 and A_{eff} =149.51mm^2; T (%) = $\frac{166.98-149.51}{166.98}\times$ 100% = +10.46 %

B_{16} -3, A =164.47mm^2 and A_{eff} =143.99mm^2; T (%) = $\frac{164.47-143.99}{164.47}\times$ 100% = +12.45 %

C$_{12}$ -1, A =90.94mm^2 and A$_{eff}$ =97.28mm^2; T (%) = $\frac{90.47-97.28}{90.47}\times$ 100% = -6.97 %

C$_{12}$ -2, A =95.56mm^2 and A$_{eff}$ =96.48mm^2; T (%) = $\frac{95.56-96.48}{95.56}\times$ 100% = -0.96 %

C$_{12}$ -3, A =94.70mm^2 and A$_{eff}$ =96.90mm^2; T (%) = $\frac{94.70-96.90}{94.70}\times$ 100% = -2.32 %

C$_{16}$ -1, A =183.16mm^2 and A$_{eff}$ =210.87mm^2; T (%) = $\frac{183.16-210.87}{183.16}\times$ 100% = -15.13 %

C$_{16}$ -2, A =188.96mm^2 and A$_{eff}$ =216.09mm^2; T (%) = $\frac{188.96-216.09}{188.96}\times$ 100% = -14.36 %

C$_{16}$ -3, A =173.45mm^2 and A$_{eff}$ =203.99mm^2; T (%) = $\frac{173.45-203.99}{173.45}\times$ 100% = -17.61 %

D$_{12}$ -1, A =90.94mm^2 and A$_{eff}$ =96.31mm^2; T (%) = $\frac{90.94-96.31}{90.94}\times$ 100% = -0.06 %

D$_{12}$ -2, A =94.18mm^2 and A$_{eff}$ =96.69mm^2; T (%) = $\frac{94.18-96.69}{94.18}\times$ 100% = -2.67 %

D$_{12}$ -3, A =95.39mm^2 and A$_{eff}$ =96.86mm^2; T (%) = $\frac{95.39-96.86}{95.39}\times$ 100% = -1.54 %

D$_{16}$ -1, A =177.68mm^2 and A$_{eff}$ =143.95mm^2; T (%) = $\frac{177.68-143.95}{177.68}\times$ 100% = +18.98 %

D$_{16}$ -2, A =182.20mm^2 and A$_{eff}$ =154.35mm^2; T (%) = $\frac{182.20-154.35}{182.20}\times$ 100% = +15.29 %

D$_{16}$ -3, A =180.53mm^2 and A$_{eff}$ =148.28mm^2; T (%) = $\frac{180.53-148.28}{180.53}\times$ 100% = +17.86 %

E$_{12}$ -1, A =81.72mm^2 and A$_{eff}$ =82.76mm^2; T (%) = $\frac{81.72-82.76}{81.72}\times$ 100% = -1.27 %

E$_{12}$ -2, A =94.36mm^2 and A$_{eff}$ =83.48mm^2; T (%) = $\frac{94.36-83.48}{94.36}\times$ 100% = +11.53 %

E$_{12}$ -3, A =76.37mm^2 and A$_{eff}$ =83.52mm^2; T (%) = $\frac{76.37-83.53}{76.37}\times$ 100% = -9.36 %

E_{16} -1, A =162.88mm^2 and A_{eff} =138.43mm^2; T (%) = $\frac{162.88-138.43}{162.88}\times$ 100% = +15.01 %

E_{16} -2, A =167.44mm^2 and A_{eff} =140.30mm^2; T (%) = $\frac{167.44-140.30}{167.44}\times$ 100% = +16.21 %

E_{16} -3, A =198.08mm^2 and A_{eff} =140.04mm^2; T (%) = $\frac{198.08-140.04}{198.08}\times$ 100% = +16.36 %

A.4 Calculations on Yield Strength

Yield strength (R_{el}) = $\frac{F_{el}}{A}$ (N/mm^2)

F_{el} is the load of lower yield (N),

A is the original cross-sectional area (mm^2).

For 12mm bars

A_{12} –1, F_{el} = 30910N, A = 91.62mm^2; R_{el} = $\frac{30910}{91.62}$ = 337.37 N/mm^2

A_{12} –2, F_{el} = 30750N, A = 91.62mm^2; R_{el} = $\frac{30750}{91.62}$ = 335.63 N/mm^2

A_{12} –3, F_{el} = 32570N, A = 94.36mm^2; R_{el} = $\frac{32570}{94.36}$ = 345.17 N/mm^2

Average Yield strength = $\frac{337.37+335.63+345.17}{3}$ = 339.39 N/mm^2

For 16mm bars

A_{16} –1, F_{el} = 63040N, A = 145.29mm^2; R_{el} = $\frac{63040}{145.29}$ = 433.89 N/mm^2

A_{16} –2, F_{el} = 62720N, A = 145.29mm^2; R_{el} = $\frac{62720}{145.29}$ = 431.69 N/mm^2

A_{16} –3, F_{el} = 62890N, A = 146.36mm^2; R_{el} = $\frac{62890}{146.36}$ = 429.69 N/mm^2

Average Yield strength = $\frac{433.89+431.69+429.69}{3}$ = 431.76 N/mm^2

A.5 Calculations on Ultimate Tensile Strength

The Ultimate Tensile Strength (R_m) = $\frac{F_{max}}{A}$ (N/mm^2)

F_{max} is the maximum load before fracture (N)

A is the original cross-sectional area (mm^2).

For 12mm bar;

B_{12} –1, F_{max} = 45340N, A =94.36mm^2; R_m = $\frac{45340}{94.36}$ = 480.50mm^2

B_{12} –2, F_{max} = 41980N, A =94.70mm^2; R_m = $\frac{41980}{94.70}$ = 443.29mm^2

B_{12} –3, F_{max} = 44270N, A =90.77mm^2; R_m = $\frac{44270}{90.77}$ = 487.72mm^2

Average ultimate strength = $\frac{480.50+443.29+487.72}{3}$ = 470.50mm^2

For 16mm bar;

B_{16} –1, F_{max} = 82840N, A =161.30mm^2; R_m = $\frac{82840}{161.30}$ = 513.58mm^2

B_{16} –2, F_{max} = 84200N, A =166.98mm^2; R_m = $\frac{84200}{166.98}$ = 504.25mm^2

B_{16} –3, F_{max} = 82880N, A =164.47mm^2; R_m = $\frac{82880}{164.47}$ = 503.92mm^2

Average ultimate strength = $\frac{513.58+504.58+503.92}{3}$ = 507.25mm^2

A.6 Calculation of Standard Deviation of Bar Samples

The values for the yield strengths for company A-12mm bars are

A_{12}-1 = 337.37, A_{12}-2= 335.63 and A_{12}-3= 345.17

The average would be = 339.39 that is; $\frac{337.37+335.63+345.17}{3}$

Subtracting the average from the yield strength values and squaring the results we have;

A_{12}-1, 337.37 – 339.39 = -2.02 → -2.02^2 = 4.0804

A_{12}-2, 335.63 – 339.39 = -3.76 → -3.76^2 = 14.1376

A_{12}-3, 345.17 – 339.39 = 5.78 → 5.78^2 = 33.4084

Then the sum of the squared differences divided by (N-1) is $\frac{4.0804+14.1376+33.4084}{3-1}$ = 25.8132

Lastly, the standard deviation which is the square root of the above mean is calculated as

$\sqrt{25.8132}$ = $\underline{\underline{5.08}}$

This procedure is repeated for other bar samples.

A.7 Characteristic Strength Calculations

For company A, 12mm bar diameter, the characteristic strength of the steel is calculated as follows; $f_c = f_m – 1.64$ ð

Where

f_c = characteristic strength,

f_m = mean/average yield strength and

ð = standard deviation.

f_m=339.39 N/mm^2

ð = 5.08

f_c = 339.39 – 1.64(5.08) = 331.06 N/mm^2 ≈ 331.00 N/mm^2.

Thus for company A 12mm bar the characteristic strength is 331 N/mm^2

Also,

For Set A_{16}, f_m=431.76 N/mm^2, ð = 2.10; f_c = 431.76 – 1.64(2.10) = 428 N/mm^2

For Set B_{12}, f_m= 348.64 N/mm^2, ð = 23.62; f_c = 348.64 – 1.64(23.62) = 310 N/mm^2

For Set B_{16}, f_m=390.84 N/mm^2, ð = 28.31; f_c = 390.84 – 1.64(28.84) = 344 N/mm^2

For Set C_{12}, f_m= 418.30 N/mm^2, ð = 5.52; f_c = 418.30 – 1.64(5.52) = 409 N/mm^2

For Set C_{16}, f_m= 444.83 N/mm^2, ð = 7.65; f_c = 444.83 – 1.64(7.65) = 432 N/mm^2

For Set D_{12}, f_m= 403.79 N/mm^2, ð = 2.54; f_c = 403.79 – 1.64(2.54) = 400 N/mm^2

For Set D_{16}, f_m= 365.96 N/mm^2, ð = 4.60; f_c = 365.96 – 1.64(4.60) = 358 N/mm^2

For Set E_{12}, f_m= 347.52 N/mm^2, ð = 13.08; f_c = 347.52 – 1.64(13.08) = 327 N/mm^2

For Set E_{16}, f_m= 361.28 N/mm^2, ð = 2.57; f_c = 361.28 – 1.64(2.57) = 356 N/mm^2

A.8 Calculation on Ultimate Strength to Yield Strength Ratio

Ultimate to yield ratio = $\frac{\text{Ultimate Strength}}{\text{Yield Strength}}$

For

A_{12} -1, Ultimate to yield ratio = $\frac{445.53}{311.87}$ = 1.43

A_{12} -2, Ultimate to yield ratio = $\frac{445.53}{311.87}$ = 1.43

A_{12} -3, Ultimate to yield ratio = $\frac{445.53}{311.87}$ = 1.43

A_{16} -1, Ultimate to yield ratio = $\frac{489.93}{340.23}$ = 1.44

A_{16} -2, Ultimate to yield ratio = $\frac{489.93}{340.23}$ = 1.44

A_{16} -3, Ultimate to yield ratio = $\frac{489.93}{340.23}$ = 1.44

B_{12} -1, Ultimate to yield ratio = $\frac{418.57}{293.00}$ = 1.43

B_{12} -2, Ultimate to yield ratio = $\frac{418.57}{293.00}$ = 1.43

B_{12} -3, Ultimate to yield ratio = $\frac{418.57}{293.00}$ = 1.43

B_{16} -1, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

B_{16} -2, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

B_{16} -3, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

C_{12} -1, Ultimate to yield ratio = $\frac{364.28}{254.99}$ = 1.42

C_{12} -2, Ultimate to yield ratio = $\frac{364.28}{254.99}$ = 1.42

C_{12} -3, Ultimate to yield ratio = $\frac{364.28}{254.99}$ = 1.42

C_{16} -1, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

C_{16} -2, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

C_{16} -3, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

D_{12} -1, Ultimate to yield ratio = $\frac{567.72}{397.16}$ = 1.43

D_{12} -2, Ultimate to yield ratio = $\frac{567.72}{397.16}$ = 1.43

D_{12} -3, Ultimate to yield ratio = $\frac{567.72}{397.16}$ = 1.43

D_{16} -1, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

D_{16} -2, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

D_{16} -3, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

E_{12} -1, Ultimate to yield ratio = $\frac{401.12}{280.78}$ = 1.42

E_{12} -2, Ultimate to yield ratio = $\frac{401.12}{280.78}$ = 1.42

E_{12} -3, Ultimate to yield ratio = $\frac{401.12}{280.78}$ = 1.42

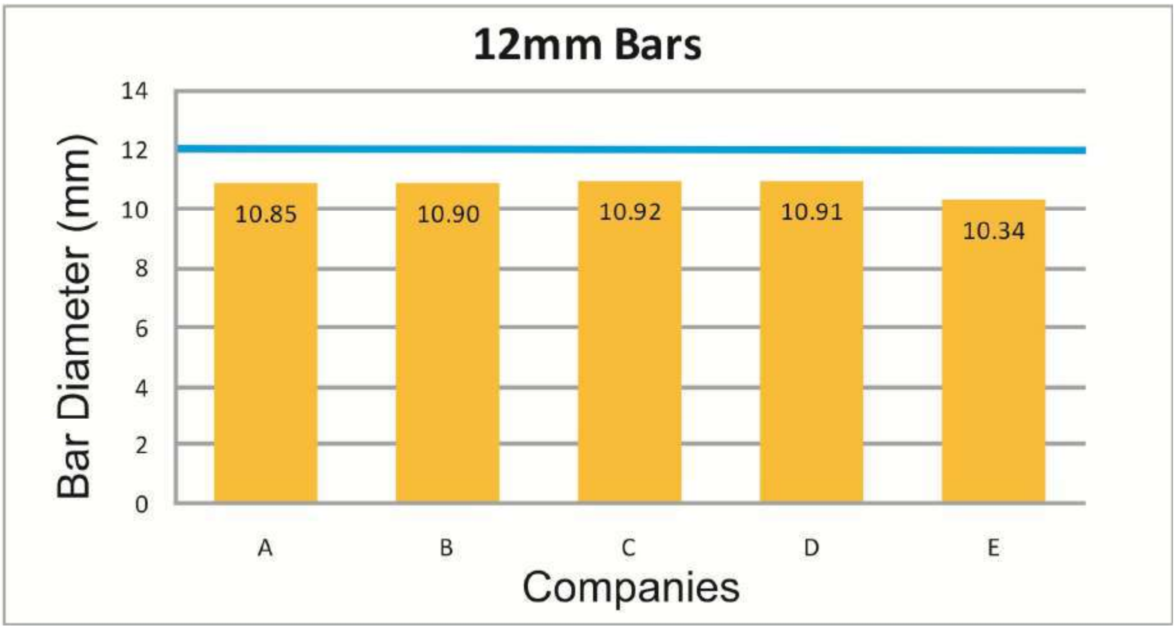
E_{16} -1, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

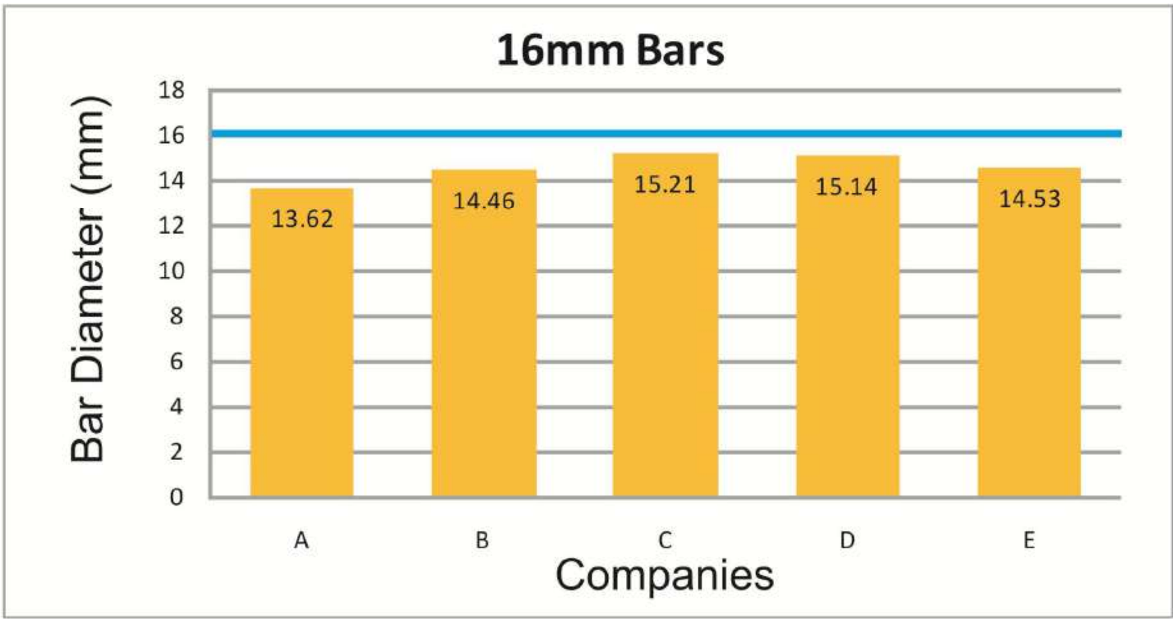
E_{16} -2, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

E_{16} -3, Ultimate to yield ratio = $\frac{376.58}{282.90}$ = 1.64

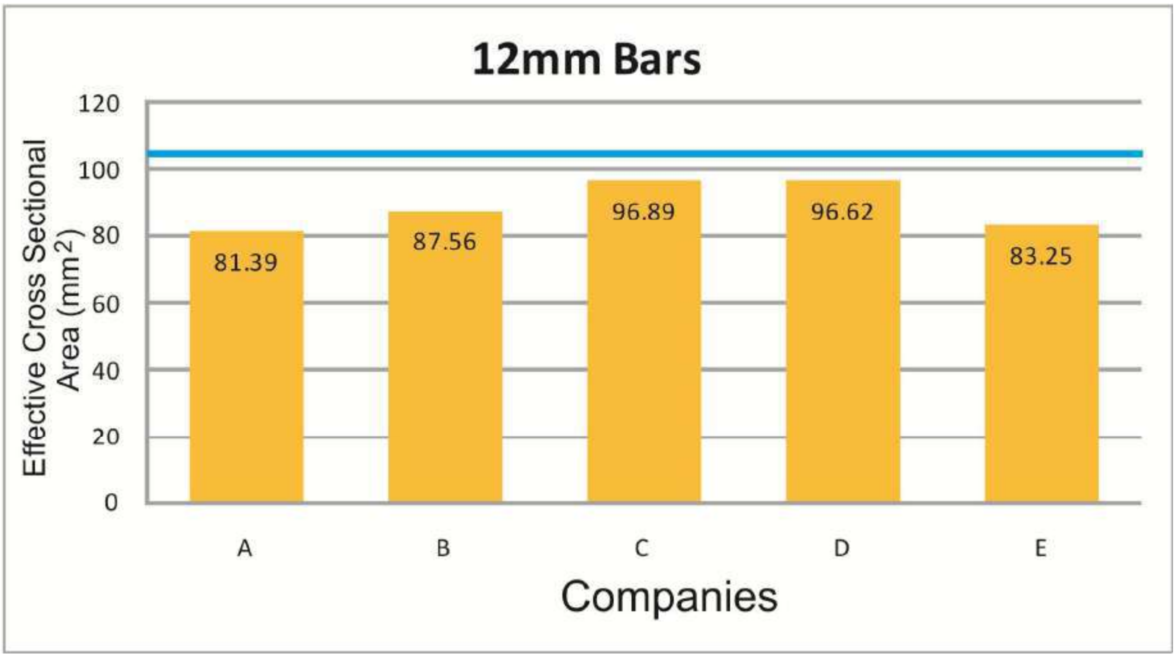
APPENDIX B

B.1 Results of the 12mm and 16mm Test Sample Average Diameters with Comparison.

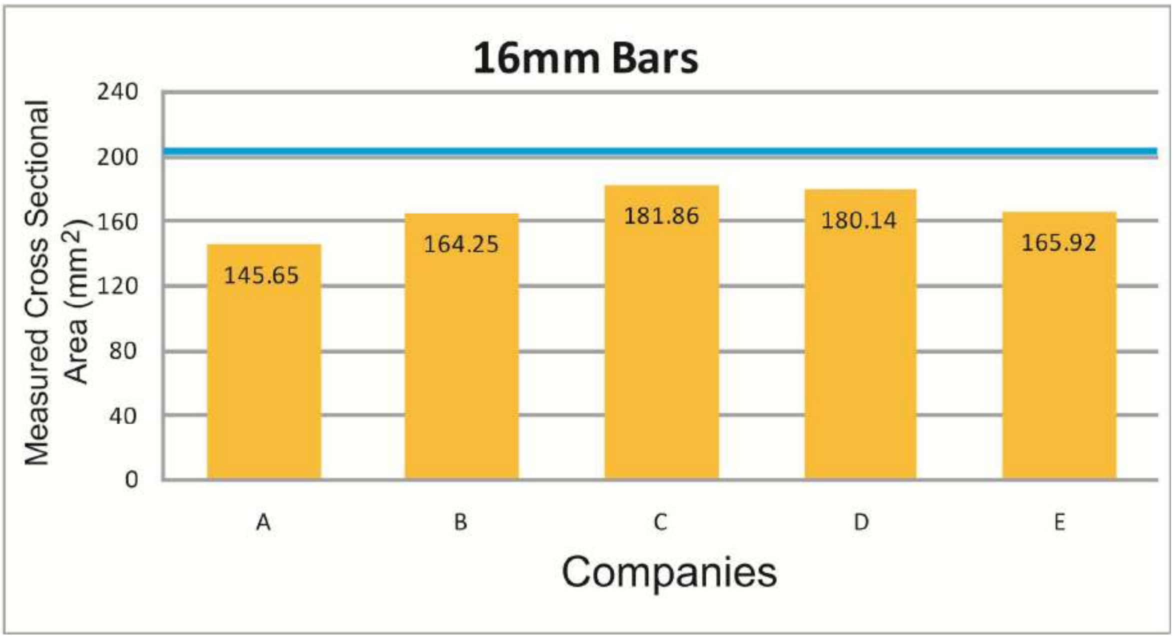




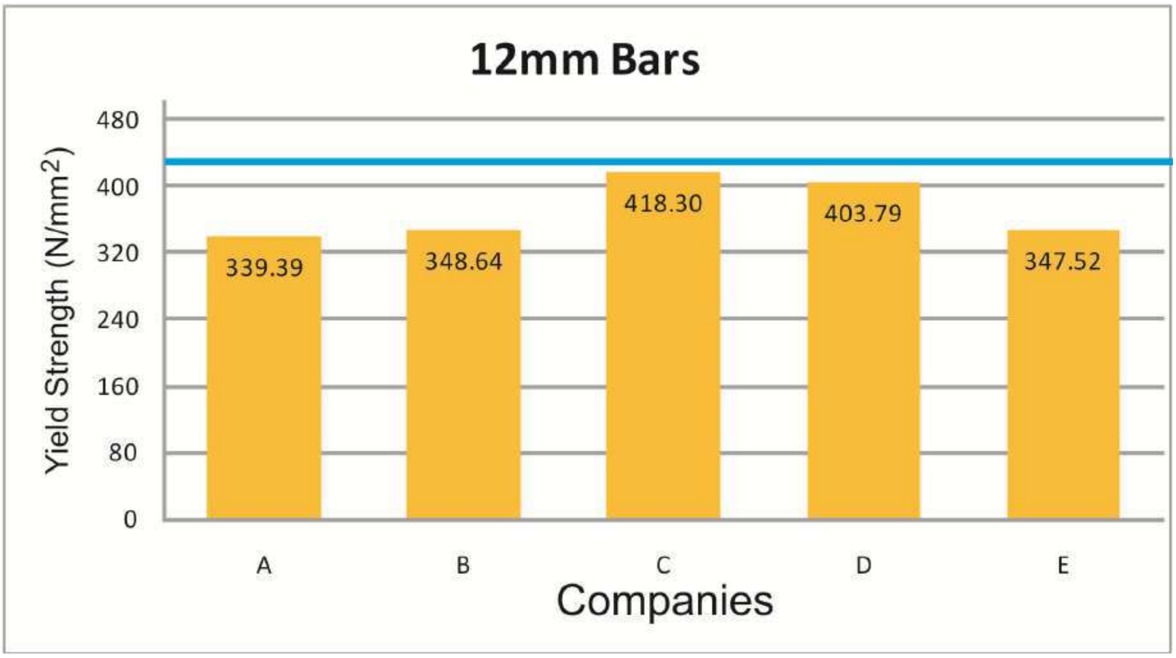
B.2 Results of the 12mm and 16mm Test Sample Average Effective Cross-Sectional Areas with Comparison.

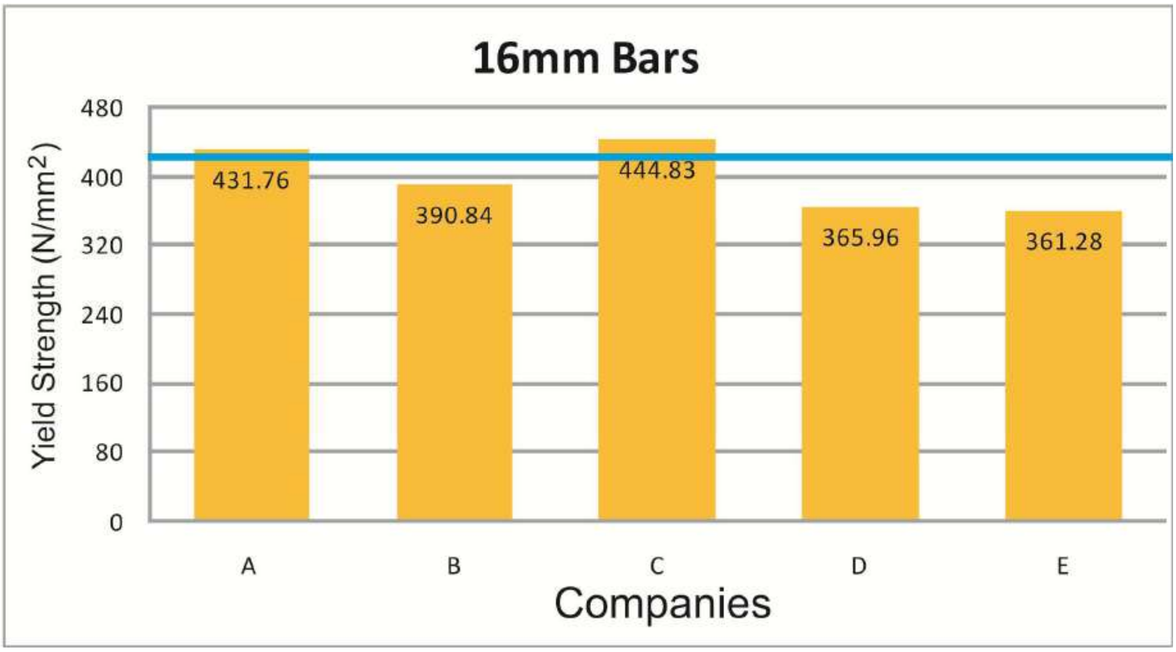


B.3 Results of the 12mm and 16mm Test Samples Average Measured Cross-Sectional Areas with Comparison.

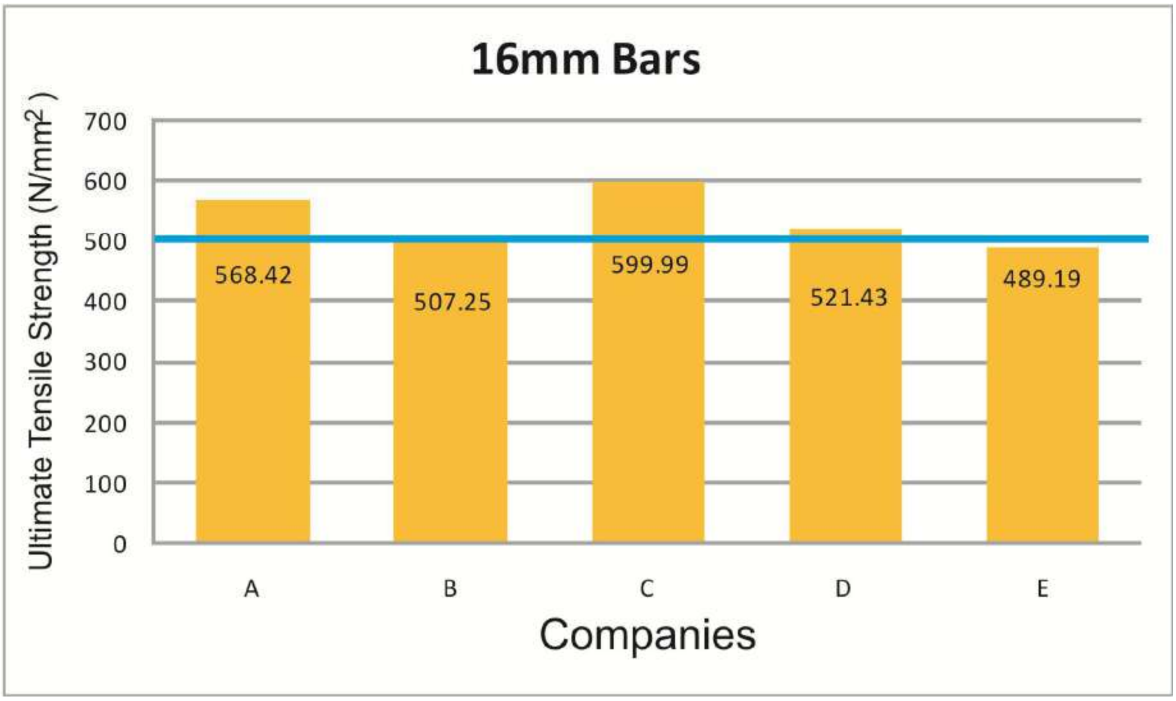


B.4 Results of the 12mm and 16mm Test Samples Yield Strengths with Comparison.

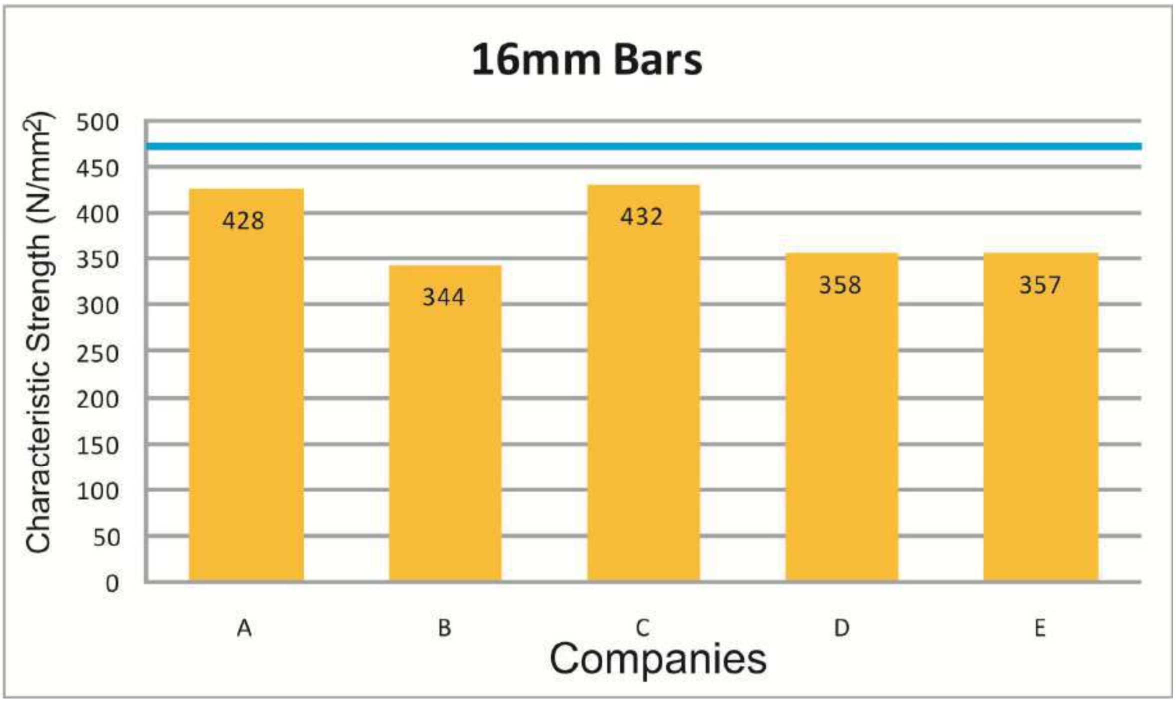




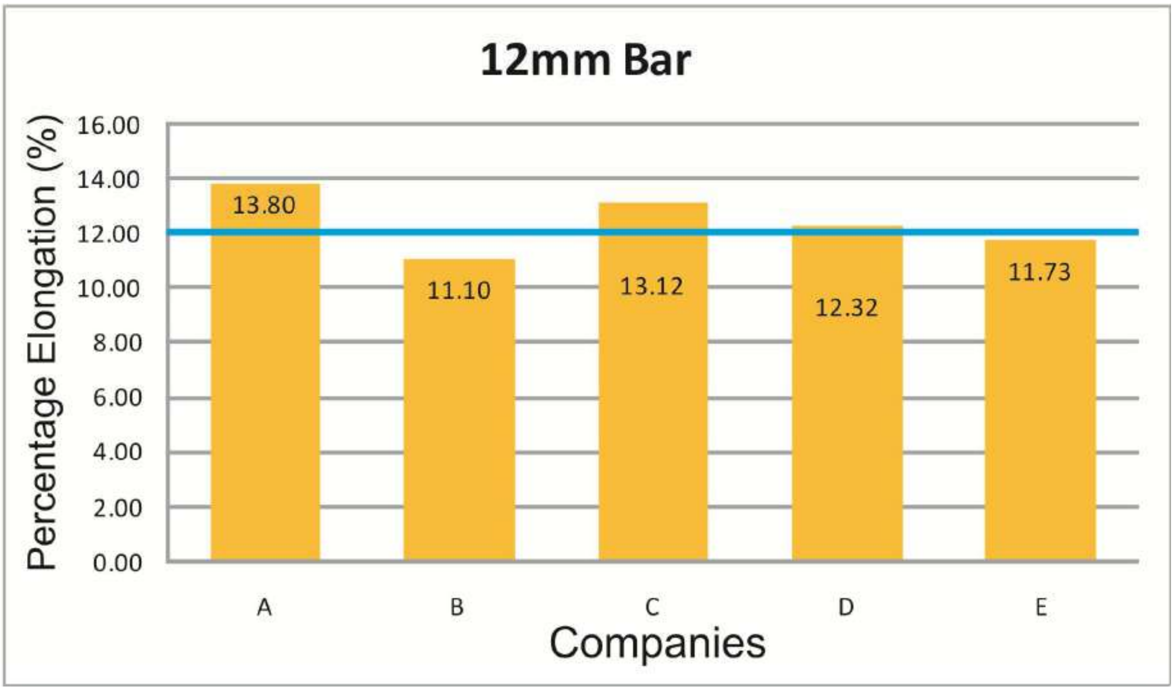
B.5 Results of the 12mm and 16mm Test Samples Ultimate Tensile Strengths with Comparison.

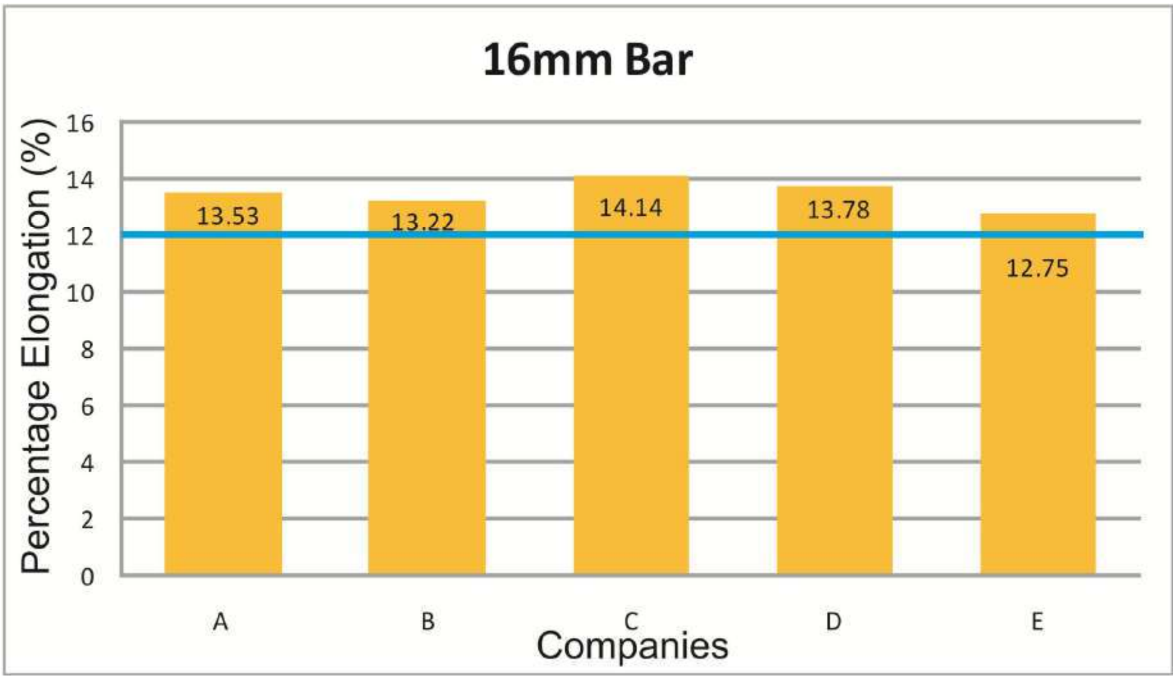


B.6 Results of the 12mm and 16mm Test Samples Characteristic Strengths with Comparison.



B.7 Results of the 12mm and 16mm Test Samples Percentage Elongation with comparison.





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THE EFFECTS OF PARTIAL REPLACEMENT OF FINE AGGREGATE WITH QUARRY DUST ON CONCRETE PROPERTIES

BY

OBIELOSI DOMINIC CHUKWUEMELIE

2016224017

SUBMITTED TO

THE DEPARTMENT OF CIVIL ENGINEERING,

FACULTY OF ENGINEERING

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING DEGREE (B.ENG) IN CIVIL ENGINEERING

NNAMDI AZIKIWE UNIVERSITY, AWKA.

February, 2022.

`

CERTIFICATION PAGE

This is to certify that this project titled “The effects of partial replacement of fine aggregate with quarry dust in concrete properties” was carried out by Obielosi Dominic Chukwuemelie with registration number; 2016224017 in the department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka.

______________________ ______________________

Obielosi Dominic Chukwuemelie Date

`

APPROVAL PAGE

This is to certify that this project topic titled “The effects of partial replacement of fine aggregate with quarry dust in concrete properties” is an authentic academic work undertaken by Obielosi Dominic Chukwuemelie, with registration number; 2016224017 in the department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka.

________________________ ________________________

Engr. I. K. Omaliko Date

(Project supervisor)

________________________ ________________________

Engr. Dr. C. A. Ezeagu Date

(Head of Department)

________________________ ________________________

Engr. Prof. D. O. Onwuka Date

(External Examiner)

`

DEDICATION

To my loving sister, Late Miss. Obielosi Marycynthia Chioma.

ACKNOWLEDGEMENT

I thank the almighty God who has sustained me till this very day, the Architect and Designer of my life.

My sincere gratitude goes to my parents Mr. & Mrs. Bethrand Obielosi, who God has used as an instrument to bless my life, their prayers and financial supports has kept me going and also to my understanding siblings may God bless and reward you abundantly.

My profound gratitude goes to my project supervisor Engr. Kenneth Omaliko who is really a mentor; he motivated and guided me throughout this project work. And to the head of department Dr. C.A. Ezeagu, past Head of Department Engr. Prof. C.A. Chidolue, Engr. Prof. (Mrs), N.E. Nwaiwu, Engr. Prof. C.M.O. Nwaiwu, Engr. Prof. C.A. Aginam, Engr. Dr. O. Odinaka, Engr. Chukwunonso, Engr. Samson and Engr. John for their invaluable tutorship and professional guidance. To all the lecturers in the department of civil engineering who i was not able to mention their names may God bless and reward you all abundantly.

Special thanks go to the Department of Quality Control, IDC Construction, especially to the Head of the Unit in the person of Engr. Emeka, for the warm reception that he accorded to me during my stay in the company.

Finally, I thank all my course mates and friends who contributed in one way or the other towards the success of this work. You are all wonderful. May God bless you all.

`

ABSTRACT

Natural river sand is one of the important constituent materials in concrete production, while quarry dust is a material obtained from crusher plants. However, due to natural river sand scarcity and environmental degradation caused by excessive mining, there is a need to investigate an alternative material of the same quality that can replace river sand in concrete production. In the present study, experiments were carried out to study the gradation of aggregates, workability, and compressive strength of concrete made using quarry dust as a replacement for fine aggregate at 0, 25, 50, 75, and 100%. A nominal mix ratio of 1:2:4 and a water-cement ratio of 0.55 were adopted for this work, and mix compositions were calculated by the absolute volume method.

Workability and compressive strength were determined at different replacement levels of fine aggregate, and the optimum replacement level was determined based on compressive strength. Results showed that replacing 50% of fine aggregate with quarry dust gave a concrete with a maximum compressive strength of 25.10 N/mm^2 on the 28th day of curing, when compared with all other replacement levels, including the control. Also, there was a significant decrease in workability as the percentage of quarry dust increased. From the overall result obtained, it was observed that the compressive strength of concrete is directly proportional to the cuing ages of the concrete specimens.

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CHAPTER ONE

INTRODUCTION

The world around us is rapidly evolving and so is the world infrastructure. The infrastructure industry has witnessed a rapid and enormous growth in last decade. This decade has proven to be a golden era for the infrastructure industry & the construction community. But with this rapid growth, the resources were also rapidly utilized. Consequentially today, the infrastructure industry is facing a serious problem of shortage of construction materials due to the rapid depletion of the resources.

Thus as civil engineers it is our role towards the industry to contribute in the eco-friendly and green construction and development. Our main focus as engineers should be towards maintaining the balance between construction and sustainable environment. One of the way to achieve that can be using of alternative material and material sources.

Limestone and granite are two types of aggregates commonly used in construction industry. In Nigeria, mostly crushed granite rocks are used as coarse aggregates in concrete production because of good physical properties, hard, tough, high compressive strength and durability of granite against chemical attack (Anaezeofor, 2016). The consumption of sand as fine aggregate in concrete production is very high. Several developing countries including Nigeria have encountered some strain in the supply of natural sand in order to meet the increasing needs of infrastructural development in recent years (Raman*et al.*, 2007).

Extensive use of sand in construction industry in Nigeria for fine aggregates in concrete will lead more dredging of rivers and for sand which pollute the environment. River sand is expensive due to excessive cost of transportation from natural sources and its availability. Also large-scale depletion of these sources creates environmental problems. As environmental transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete Industry needs to be found. In such a situation the quarry dust can be an economic alternative to the river sand.

Some aggregate producers use the term quarry dust when referring to quarry fines, or may only mean material produced in excess of market demand when referring to quarry fines or dusts (WRAP, 2006). The use of these quarry dust as a partial or full replacement in concrete production will be studied in this work.

1.1 BACKGROUND OF STUDY

Concrete is the most widely used composite material today. The constituents of concrete are coarse aggregate, fine aggregate, binding material (Cement) and water(Agrawal et al., 2017). The importance of fine aggregate (Natural river sand) in concrete production cannot be over emphasized. As a result of its relative importance in concrete production, the demand for it is very high among the construction industry. Also, Nigeria as one of the developing nations is seriously experiencing excessive excavation and mining of natural river sand which has negative environmental consequences. Among these are erosion and failure of river banks, lowering of river beds and damage of structures situated closer to the rivers, saline water intrusion into the land and coastal erosion are the major adverse effects due to intensive river sand mining.

Stone dust is considered a waste material obtained from crusher plants and has potential to be used as partial replacement of natural river sand in concrete(Amit *et al.*, 2015). Owing to these, there is need to investigate the use of quarry dust as alternative material which can totally or partially replace natural river sand in concrete production. Quarry dust as a residue obtained from quarrying of rocks has gained the trust of many contractors in the construction industry as an alternate material for fine aggregate in concrete. The advantages of utilizing residue or aggregates obtained as waste materials are pronounced in the aspects of reduction

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in environmental degradation and waste management cost, reduction of production cost as well as augmenting the quality of concrete(Sandeep *et al*., 2014). Since concrete is the most important part in structural contraction, the aggregate content should be in a form of good strength and clean for structural purposes. Naturally aggregate have a pronounced influence on the properties of fresh concretes well as hardened concrete (Shetty,2005).

Quarry dust, a by-product from the crushing process during quarrying activities is one of those materials that have recently gained attention to be used as concrete aggregates, especially as fine aggregates. Quarry dust have been used for different activities in the construction industry, such as road construction, and manufacture of building materials, such a lightweight aggregates, bricks, tiles and autoclave blocks(Sivakumar and Prakash 2011).

1.2 AIMS AND OBJECTIVES

The aim of this project is to determine the effects of partial replacement of fine aggregate with quarry dust on the compressive strength of concrete.

The objectives of this research are as follows:

1 To gather an abundance of pertinent information through an in-depth review of previous studies and pinpoint the areas that need to be addressed.

2 To carry out a sieve analysis of the quarry dust, fine and coarse aggregate

3 To design the mix proportions and determining the workability of the fresh concrete.

4 To determine the specific gravity and water absorption of aggregates.

5 Curing of all the concrete specimens for 7, 14, 21 and 28 (days) and determining the compressive strength of the hardened concrete.

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1.3 SCOPE OF STUDY

This study is concerned with the effect of quarry dust on the compressive strength of concrete and also the variations in the workability of the various percentages of quarry dust replacement this will done with the use of slump test. Also a sieve analysis, Specific gravity and Water absorption tests were carried out on the aggregates to be used with the quarry dust.

Effects on other properties of the concrete such as creep, shrinkage, durability, etc.were not considered in this study. The size of mould used is 150cm x 150cm x 150cm.The Fine aggregate will be replaced with quarry dust at percentages of 0%, 25%, 50%, 75%, and 100 %.The mix ratio of 1:2:4 and a water to cement ratio of 0.55 were adopted for this research. The hardened concrete was crushed after 7, 14, 21 and 28 days curing to determine the compressive strength of concrete at each curing date.

1.4 SIGNIFICANCE OF STUDY

The Importance of conducting this study is to check if quarry dust will be a good replacement of river sand as fine aggregate in concrete production and to check of what percentage of replacement gives the best compressive strength and best workability. Also, quarry dust as a replacement of river sand as fine aggregate will reduce the waste incurred in the quarries and will aid of conserve the depletion of sand as a natural resources.

CHAPTER TWO

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LITERATURE REVIEW

2.1 INTRODUCTION

Concrete, in construction, structural material consisting of a hard, chemically inert particulate substance, known as aggregate (usually sand and gravel), that is bonded together by cement and water (Britannica, 2021).

Among the ancient Assyrians and Babylonians, the bonding substance most often used was clay. The Egyptians developed a substance more closely resembling modern concrete by using lime and gypsum as binders. Lime (calcium oxide), derived from limestone, chalk, or (where available) oyster shells, continued to be the primary pozzolanic, or cement-forming, agent until the early 1800s. In 1824 an English inventor, Joseph Aspdin, burned and ground together a mixture of limestone and clay. This mixture, called Portland cement, has remained the dominant cementing agent used in concrete production.

Concrete is a crucially important construction material, vital to every economy in the world. Much of the economic development of the last fifteen years or so has been underpinned by increases in the use of concrete, particularly in Nigeria. The truth is that sustainability doesn't get much tougher than in concrete - in terms of emissions of greenhouse gases from cement works and other key parts of the industry, as well as local air pollution, waste, and health and safety issues (Porritt, 2009).

Concrete is a mixture of binding material (like cement, lime, polymer), water, aggregates (fine and coarse aggregates), and in some cases, admixtures. The cement and water form a paste that hardens and bonds the aggregates together. It is often looked upon as "man-made rock" and is a versatile construction material, adaptable to a wide variety of infrastructural and residential uses. Concrete has strength, durability, versatility, and economy. It can be placed or moulded into virtually any shape and reproduce any surface texture. In the United

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States almost twice as much concrete is used as all other construction materials combined (Shelton and Harper, 2007). Demand for concrete with higher strength and better quality, coupled with larger and faster mixer trucks, led to the emergence of the ready-mix concrete industry in the post-World War II period.

The ready-mix concrete producer has made concrete an appropriate construction material for many infrastructural applications with proper materials and techniques, concrete can withstand many acids, silage, milk, manure, fertilizers, water, fire, and abrasion. Concrete can be finished to produce surfaces ranging from glass-smooth to coarsely textured, and it can be coloured with pigments or painted. Concrete has substantial strength in compression, but is weak in tension. Most structural uses such as beams, slabs, and columns involve reinforced concrete, which depends on concrete's strength in compression and steel's strength in tension. “Since concrete is a structural material, strength is a desirable property"(Shelton and Harper 2007).

2.2 LIMITATIONS OF CONCRETE

1. Concrete is relatively of low tensile strength compared to other building material.
2. It is of low ductability.
3. It has low strength to weight ratio.
4. It is susceptible to cracking.

2.3 CLASSIFICATION OF CONCRETE

2.3.1 Based On Unit Weight

a. Ultra-light concrete: $< 1,200$ kg/m^3

b. Lightweight concrete: 1200- 1,800 kg/m^3

c. Normal-weight concrete: 2,400 kg/m^3

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d. Heavyweight concrete: > 3,200 kg/m^3

a. Ultra-light concrete

Ultra-light Weight Concrete is created with the addition of either polystyrene beads (non-structural) or a lightweight aggregate (structural) to the formula. Although both formulations are lightweight products, they have several important differences that make each one suitable to specific projects. Ultra-light weight concrete has a density less than 1,200kg/m^3.The present study presents a methodology to design ultra-lightweight concrete that could be potentially applied in monolithic concrete structures, performing as both load bearing element and thermal insulator.

b. Light weight concrete

Lightweight concrete is a mixture made with lightweight coarse aggregates such as shale, clay, or slate, which give it its characteristic low density. Structural lightweight concrete has an in-place density of 90 to 115 lb/ft^3, whereas the density of regular weight concrete ranges from 140 to 150 lb/ft^3. This makes lightweight concrete ideal for building modern structures that require minimal cross sections in the foundation. It is being increasingly used to build sleek foundations, and has emerged as a viable alternative to regular concrete.

The lightweight is due to the cellular or high internal porous microstructure, which gives this type of aggregate a low bulk specific gravity. The most important aspect of lightweight aggregate is the porosity. They have high absorption values, which requires a modified approach to concrete proportioning. For instance, slump loss in lightweight concrete due to absorption can be an acute problem, which can be alleviated by prewetting (but not saturating) the aggregate before batching.

Lightweight concrete is a cost effective alternative to normal concrete, especially since it does not compromise on the structure's strength. The higher porosity of LWC also influences

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its thermal conductivity, making it suitable for projects that require insulation from heat damage.

c. **Normal weight concrete**

The nominal weight of normal concrete is 144 lb / ft^3 for non-air-entrained concrete, but is less the air-entrained concrete. The weight of concrete plus steel reinforcement is often assumed as 150lb/ft^3.Strength for normal-weight concrete ranges from 2000 to 20,000 psi. It may be used for concrete paving mixes. It can be produced with many variable characteristics including strength, fluidity, color and weight.

d. **Heavy weight concrete**

Concretes made with heavyweight aggregates are used for shielding and structural purposes in construction of nuclear reactors and other structures exposed to high intensity radiation. Heavyweight aggregates are used where heavyweight is needed, such as ship's ballast and encasement of underwater pipes, and for making shielding concretes because absorption of such radiation is proportional to density, and consequently, these aggregates have greater capacity for absorption than those ordinarily used for normal concrete. With such aggregates, concrete weighing up to about 385lb/ft^3 can be produced. Concrete made with limonite or magnetite can develop densities of 210 to 224 lb/ft^3 and compressive strengths of 3200 to 5700 psi. With barite, concrete may weigh 230 lb/ft^3 and have a strength of 6000 psi.

With steel punching and sheared bars as coarse aggregate and steel shot as fine aggregate, densities of 250 to 288 lb/ft^3 and strengths of about 5600 psi can be attained. Generally, grading of aggregates and mix proportions are similar to those used for normal concrete. The properties of heavyweight concrete are similar to those of normal-weight concrete. Mixing and placing operations, however, are more difficult than those for normal-weight concrete, because of segregation. Good grading, high cement content, low W/C, and air

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entrainment should be employed to preventsegregation. Sometimes, heavyweight aggregates are grouted in place to avoid segregation. Heavyweight concretes usually do not have good resistance to weathering or abrasion.

2.3.2 BasedOn Strength

a. Low-strength concrete: < 20 MPa compressive strength
b. Moderate-strength concrete: 20 -50 MPa compressive strength
c. High-strength concrete: 50 - 200 MPa compressive strength
d. Ultra high-strength concrete:> 200 MPa compressive strength

a. Low strength concrete

A weak concrete is considered generally anything with a characteristic compressive strength of below 20 MPa.

b. Moderate strength concrete

A moderate strength concrete is defined as concrete with compressive a strength between 20 MPa.

c. High strength concrete

A moderate strength concrete is defined as concrete with a compressive strength between 50 to 200 MPa.

d. Ultra high strength concrete

Ultra high strength concrete is defined as concrete with a compressive strength above 220MPa.

2.4 PROPERTIES OF CONCRETE

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To obtain a good quality concrete, its properties in both fresh and hardened states play important rules.

2.4.1 Properties of Fresh Concrete

a. Segregation
b. Bleeding
c. Harshness
d. Workability

a. Bleeding

Bleeding can be referred to as water gain. It is a particular form of segregation in which some of the water from concrete comes out to the surface of the concrete, being of the lowest specific gravity among all the ingredients of concrete. This also refers to the appearance of water along with cement particles on the surface of freshly laid concrete on compaction and finishing. Bleeding is predominantly observed in a highly wet mix, badly proportioned and insufficiently mixed concrete.

Due to bleeding, water comes and accumulates at the surface. Sometimes, along with this water, certain quantity of cement also comes to the surface. Bleeding causes the formation of pores in the concrete making it porous and weak. The surface layer (consisting of water and some cement particles) dries and cracks making the concrete surface weak. This bleeding can be controlled by controlling the quantity of water, providing finer grading of fine aggregates, using finely ground cement and performing suitable optimum compaction.

b. **Harshness**

This is the resistance offered by concrete to its surface finishing, that is, the concrete which cannot be easily finished with a smooth surface. This happens as a result of the presence of lesser fine aggregates, lesser cement mortar and the use of poorly graded crushed or angular

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aggregates and insufficient water content required for workability. The surface of harsh concrete remains rough and porous.

c. **Segregation**

This is the separation of the coarse particles from the mix which results in non-homogeneity of the concrete mix. To keep the concrete mass cohesive, sufficient fine aggregates must be present in the concrete mass. Apart from suitable grading and enough proportion of lines, the concrete should not be thrown from a height to avoid segregation. Segregation results in honeycomb decrease in the density and ultimate loss of strength of hardened concrete.

d. **Workability**

This can be defined as the ease with which concrete can be compacted hundred percent having regards to mode of compaction and place of deposition. It can also be defined as the property of concrete which determines the amount of useful internal work necessary to produce full compaction. The workability of concrete depends on the quantity of water, grading of aggregates, and the percentage of fine materials in the mix. It is measured in terms of slump test, compacting factor and Vee-Bee degrees. In the test, four results can be expected; zero slump, true slump, shear slump and collapse slump. The desired one is the true slump. Workability is being characterized by consistency, mobility and compatibility. Workability is the ease with which freshly mixed concrete can be placed, compacted and finished without segregation. It is the amount of useful internal work necessary to produce fully compacted concrete.

Ilangovana et al., (2010) in their investigation on the strength comparison of concrete made with quarry dust and conventional natural sand examined their workability measured in terms of slump values, V-B time and compacting factor. The test results yielded slump values of 90mm, 60mm and 40mm for grade 20, 30 and 40 concrete respectively with natural sand as fine aggregate. The correspondent values for concrete with quarry dust as fine aggregate were

80mm, 70mm and 30mm for the same concrete grades respectively. The overall workability value of quarry dust concrete is less compared to conventional concrete for a given water/cement ratio. The above findings were confirmed by other researchers.

According to Aginam et al.2016, concrete consistency with quarry dust as coarse aggregates, the result of the workability tests carried out with 0.65 w/c ratio for the two brands of Portland cement used, Dangote and Ibeto. It was observed that in both cases, the workability of the concrete decreased as the percentage of quarry dust increased. In each of the cases, a true slump was achieved which consistently got lesser as the quantity of the quarry dust increased, strongly suggesting that the quarry dust is more water absorbing than gravel.

2.5 Test to determine workability of concrete

There are majorly four tests widely used for measuring the workability of concrete, there include; Compaction factor test, Vebe test, Flow test and Slump test.

2.5.1 Slump test

This test is carried out to determine the workability of concrete. It requires a slump cone for the test. The slump cone is a container having the shape of a frustum of a cone with diameter at bottom 200mm and 50mm at the top and 300mm high. The cone is placed over an impervious platform and is filled with concrete in four layers. Each layer is being tamped with a 16mm pointed rod for 25 times. After filling completely the cone is gently removed. The reduction in the height of the concrete is called slump. The higher the slump, the more workable is the concrete. The three types of slump usually observed are; true slump, shear slump and collapse slump. Below shows the slump cone used to conduct slump test.

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2.6 Factors affecting on workability of cement concrete

Workable concrete is the one which exhibits very little internal friction between particle and particle or which overcomes the frictional resistance offered by the formwork surface or reinforcement contained in the concrete with just the amount of compacting efforts forthcoming .the factor helping concrete to have more lubricating effect to reduce internal friction for helping easy compaction are given below.

a. Water content
b. Shape of aggregate
c. Size of aggregate
d. Grading of aggregate
e. Surface texture
f. Porosity and absorption of aggregate
g. Air entraining agents
h. Temperature

2.7 Properties of Hardened Concrete

a. Strength
b. Durability
c. Impermeability
d. Dimensional change

a. Dimensional changes

Dimensional changes in concrete are caused due to shrinkage (reduction of volume during hardening) of concrete, thermal changes, elasticity and creep (permanent deformation under sustained loading) in concrete. Dimensional changes may induce certain stresses in concrete which may lead to its cracking.

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From research and practical experience, it is observed that the sender the concrete, the greater the strength. Therefore, to obtain the optimum density, it is necessary to compact concrete fully to drive away all entrapped air. For good compaction if fresh concrete, it should be of such plasticity that all particles can easily move with the available external effort to the remotest corner of the mould.

a. Durability

Durability of concrete refers to its resistance to deterioration under the forces of environment such as weathering, chemical attack abrasion, fire and corrosion of steel, etc. Freezing and thawing in cold weather results in disintegration of concrete due to water in its capillary pores. Generally, strong and dense concrete have better durability in extreme weather conditions. To achieve durable concrete in an environment surcharge, special type of cements such as sulphate resisting Portland cement, super sulphate cements, blast furnace slag cements are to be used. Porous concrete brings about corrosion of steel and this can be avoided by reducing soluble chlorides alkalinity of the protective cover.

b. Impermeability

This is the resistance of the concrete to the flow of water through the pore spaces in it. Excess water during concrete manufacture leaves a large number of continuous pored leading to permeability in concrete. To achieve impermeable concrete, a low water cement ratio is used, use of dense and we'll graded aggregate and also ensure full compaction and cure continuously under moist and low temperature conditions, etc. This is very important especially in exposed and water retaining structures such as dams, etc.

c. Strength

Strength of concrete is its resistance to bear the load imposed on it. The strength of concrete plays a very important role in its structural behaviour and design of cement concrete structural members. Its strength can be measured by determining its compressive strength which indicates resistance of concrete to crushing. The compressive strength of concrete is an important property of hardened concrete and can easily be produced for various compressive strengths generally ranging from 5N/mm^2 to 45N/mm^2.

2.8 Factors affecting the strength of concrete

The strength of concrete is usually affected by many factors, in this project work, such factors are discussed with particular reference to the compressive strength. The factors include:

2.8.1 Quality of raw materials

2.8.1.1 Cement

The cement commonly used is Portland cement. It is a cement that hardens under water and is made by heating a slurry of clay and crushed chalk or limestone to clinker in a kiln (Collins, 2021). It is the type of cement usually used in buildings and bridges. Portland cement is so named because of its similarity to Portland stone, which was quarried on the Isle of Portland in Dorset, England. Shatty, (2000) states that water is an important ingredient of concrete as it actively participate in chemical reaction with cement. Since it help to form the strength giving cement gel. Nakhil, et al. (2011) stated that water is an essential ingredient as part of mixing water is utilized in the hydration of cement and the balanced water is required for impacting workability to concrete. Thus the quality and quantity of water is required to be given adequate consideration in the production of concrete.

Nakhil, et al. (2011), also stated that water plays a vital role in the strength of concrete as it helps in the following areas:

a. It wet the surface of aggregate as it helps to develop cohesion thereby enabling the cement paste to adhere quickly and satisfactorily to the wet surface of aggregate than to the dry surface.
b. To prepare a plastic mixture of the various ingredient and to impact workability to concrete so as to facilitate placing in the desired position.
c. Water is also needed for hydration of the cementing material to set and harden during the period of curing.

2.8.1.2. Aggregate

An aggregate is rock like material of various sizes and shapes, used in the manufacturing process of concrete. Generally, aggregate occupy 70 to 80% of the volume of concrete. Type and content of aggregate greatly influence the properties of concrete. The natural rock and gravel sources of aggregates may contain components which are potentially deleterious when the aggregate is used in concrete and mortar. These deleterious materials may be distributed throughout the entire rock or deposit, or confined to only a part of it, or alternatively be present in a particular localized feature within the source rock or deposit.

A geological evaluation of the source combined with a thorough investigation and appropriate testing will minimize the risk of deleterious materials being incorporated into the concrete or mortar. A listing of the most common potentially deleterious materials has been assembled by (Sims and Brown,1998). Conservation of river sand in addition to better ways of disposing wastes from the quarry sites are some of the merits of using crushed granites dusts reported by (Manasseh, 2010). In addition to deleterious materials being incorporated into the aggregate from its source, other components may find their way into an aggregate stockpile as contaminants.

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These may be such materials as metal, wood and plastic fragments introduced during the extraction and processing of the aggregate or as chemical solutions such as salts derived from the capillary use of saline ground waters into the base of aggregate stockpiles, or from salt spray or contamination from adjacent chemical storage facilities. Again, in some rare cases the processed aggregate degrades after it has been processed either in the stockpile, or in the concrete made with it. This indicates that the constituent minerals in the aggregate particles themselves are unstable when exposed to air and water from the atmosphere, (John Newman et al., 2003).

Aggregate is hard, strong, free of undesirable impunities (clean), chemically stable and durable. Aggregate are produced from crushing and processing of mineral quarried stone. According to (ASTM C125-07, 2007) aggregate is defined as a granular material such as sand, gravel, crushed stone or iron blast-furnace slag, used with a cementing medium to form hydraulic-cement concrete or mortar. (Alexander and Mindess, 2005) identified aggregates as mineral constituents of concrete in granular or particulate form, usually comprising both coarse and fine fractions. Aggregates are generally thought of as inert filler within a concrete mix. But a closer look reveals the major role and influence aggregate plays in the properties of both fresh and hardened concrete.

Changes in gradation, maximum size, unit weight, and moisture content can all alter the character and performance of concrete mix (George, 2002). Since aggregates occupy three quarters of the volume of concrete, therefore its performance is of utmost importance. Not only may the aggregate limit the strength of concrete, as weak aggregate cannot produce strong concrete, but the properties of aggregate greatly affect the durability and structural performance of concrete (Neville, 2003). Aggregates exercise important influence on concrete strength and stiffness, providing rigidity to the material that is necessary for engineering use. This simply means that the stronger aggregates are often preferred to be

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used to produce concrete having higher strength with high resistance to all possible attacks (Alexander and Mindes, 2005).

A research work carried out by Jimah et al.(2007) on the influence of aggregate size and type on the compressive strength of concise indicates that, the use of combination of quarry dust and grate aggregates in concrete produce higher strength than concrete containing sand and gravel. For combination of artificial and natural aggregates, the concrete having sand and granite is stronger than the corresponding one with quarry dust and gravel. Also as sizes of course aggregate increases, concrete strength decreases whether the aggregate is natural or artificial.

The rate of decrease in strength with change in aggregate size is highest in concrete with quarry dust and granite and lowest in concrete having combination of sand with gravel This shows that the strength of concrete strength is more sensitive to difference in size when aggregates are granite and quarry dust than similar one with gravel and sand in concrete with gravel and sand, the rate of change in strength with change in aggregate size, is not significant.

According to the research work carried out by Jain and Chouhan, (2011) on effect of shape of aggregate on compressive strength and permeability properties of pervious concrete it may be concluded that for all sizes of aggregates, compressive strength of pervious concrete vary inversely with the angularity number of the aggregate. Similarly, for all types of aggregates, pervious concrete mix prepared using smaller size of aggregates demonstrated higher compressive strength. Also a mix with wet metallic sheen which do not suffer with paste draw down, produce optimum compressive strength. For all the lower as well as higher value of water cement ratio than this optimum value, the compressive strength of the mix is typically lower. It may also be concluded that permeability of pervious concrete varies as a function of water cement ratio, shape and size of aggregate. For all sizes of aggregates, permeability of pervious concrete mixes prepared using aggregates with smaller

2.8.2.3. Fine aggregate (River sand)

Fine aggregates are basically natural sand particles from the land through the mining process, the fine aggregates consist of natural sand or any crushed stone particles that are ¼" or smaller. This product is often referred to as 1/4'" minus as it refers to the size, or grading, of this particular aggregate. Aggregates less than 4.75 mm in size are called fine aggregates; sand falls under the fine aggregate and crushed stone or metal under the coarse aggregates. The maximum size used is 80 mm and the range of 80 mm to 4.75 mm is known as coarse aggregate and 4.75 to 150 µm is called fine aggregate. Size 4.75 mm is common for both fine and coarse fractions.

2.8.2.4 Qualities of fine aggregates

a. Fine aggregate should be clean i.e. it should be free from lumps, organic material, etc.
b. It should be strong and durable.
c. It should not react with cement after mixing.
d. Also, it should have a tough floor.
e. It should not absorb greater than 5% of water.
f. These types of aggregates should not be soft and porous.

2.8.2.5 Types of fine aggregates

a. Fine Aggregates	Size
a. Coarse Sand:	2.0mm – 0.5mm
b. Medium sand:	0.5mm – 0.25mm
c. Fine sand:	0.25mm – 0.06mm
d. Silt:	0.06mm – 0.002mm

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e. Clay: <0.002

2.8.2.6 Properties of fine aggregates

a. **Size of fine aggregates**: The largest size that falls under the limit of the exact set is 4.75 mm. using the largest size will give more dense concrete, but a mixture of all sizes is more desirable and more economical. If cement mortar is prepared for masonry work or plastering work, very fine types of sand of similar size is used.
b. **Strength**: The strength of the aggregate cannot ensure the strength of the concrete. The strength of coarse aggregates are more important.
c. **Shape of fine aggregates**: Irregularly nodular shaped sand is preferable to completely round grained sand. The shape of the aggregate plays a more important role in the coarse aggregate than in the fine aggregate.
d. **Specific Gravity**: The specific gravity of aggregates is the ratio of the density of water to its density. It is used for concrete mix design and if not specified the specific gravity is taken as 2.7 because the specific gravity of most aggregates obtained from different sources falls between 2.6 and 2.8.

2.8.2.7. Coarse Aggregate

Granite is the most common type of igneous rock known to the public. It is widely used in concrete production due to its good engineering properties, which normally refers to the high compressive strength, hard, tough, versatile and durable. Besides, it is a kind of material which is easily accessible. It is a widely occurring type of intrusive igneous rock which usually having medium to coarse grained texture. This is because it hardens deep underground and having relatively slows cooling, which then allows crystallization of the minerals to grow large enough to be easily seen by the naked eye (Chang, 2011).

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Granites are formed of an aggregate of crystals which are moulded together without any interspaces between them or which enclose one another. The magnificent crystalline of granite is a striking characteristic. These minerals occur in different proportions, giving granite its own colour, texture and structural characteristics In addition, bomblende, magnetite, hematite, pyrite, zircon, garnet, corundum and other minerals may be present in smaller amounts, adding to the unique coloration and texture of each granite deposit (Raguin, 1965).

2.8.2.8 Availability of coarse aggregates in Nigeria

According to Foraminifera Market Research (2010), the ever increasing deficit in housing supply and the need for the construction of the other important infrastructure would ensure that granite aggregates (chipping) which is a major raw material in the construction industry to be in constant demand Granite chippings production in Nigeria is very critical to the success of the construction industry in any country owning to the vital role they play in the industry and same could be said of Nigeria The production as evolved over the years from the use of crude implements which are still in use in some part of the country to the use of high tech machinery and equipment. Granite chipping production is not only the most active segment of the mining industry in Nigeria but also one in which high tech equipment is used the most.

Granite chipping are rock aggregates derived from the blasting of rock to derive different sizes of boulders and then the reduction of the boulders to the desired sizes in the primary and secondary crushers. They are basically used in the construction of roads, houses and bridges and other construction activities.

The World Bank study of 2009 did confirm that about 800,000s are meters of dimensions stones were imported into the country on yearly basis and out the whole demand of the economy, the country can only produce less than 5% indicating a large untapped market for the product.

According to geological study in Nigeria, Nigeria is richly endowed with granite stone and other related solid minerals like Marble, Dolomite and Basalt etc. It is found in Enugu, Ebonyi, Kogi, Plateau, Ogun, Oyo, Osun and Ekiti etc. Hence, granite is among the most available and affordable building material Nigeria been a country located in the tropics has these rocks in commercial quantity and it is a means of livelihood for many in some parts of the country.(Foraminifera Market Research, 2013).

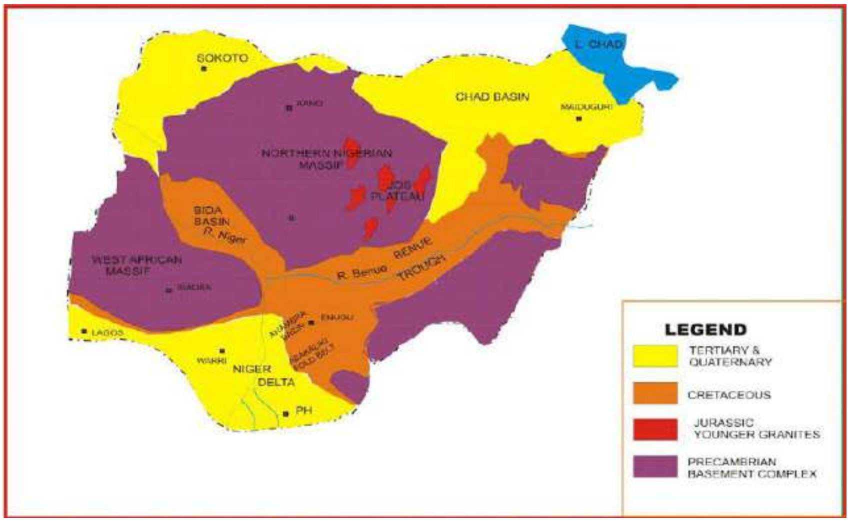

Plate 2.1: Distribution of Granite in Nigeria (Market Research, 2013).

2.8.2.9 Water

Portland cement’s chemistry comes to life in the presence of water. Cement and water form a paste that coats each particle of aggregates. Through a chemical reaction called hydration, the cement paste hardens and gains strength. The quality of the paste determines the character of the concrete.

Nakhil et al. 2011, conducted a research on the impact of water quality on strength properties of concrete using portable water, ground water and sewage water and it was deduced that

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portable water satisfy the requirement of water to be used for construction work as there was significant resulting increase in the flexural, split tensile and compressive strength of the concrete compared to other source of water. Tahir et al. 2020, stated that the quality of water has a significant effect on the strength properties of concrete as treated water produces concrete with comparatively higher strength than groundwater and saline water.

2.8.2 Water to cement ratio

Shatty (2000), stated that the water-cement ratio of concrete must lie within practical limit (0.55-0.6) as this determine the strength of concrete. According to the author,lower cement – water ratio could be used when the concrete is vibrated to achieve higher strength where as higher water-cement ratio is required when the concrete is hand compacted. In other word, the effect of water-cement ratio on strength and durability properties of concrete depends on the type of compaction. But however, regardless of the type of compaction employed during the production of concrete the water-cement ratio falls within the practical limit (0.55-0.6) as any deviation could result to fall in the strength of concrete due to introduction of air voids.

2.8.3 Coarse to fine aggregate ratio

In research on the effects of aggregate content on the behavior of concrete, Ruiz (1966) found that the compressive strength of concrete increases along with an increase along with an increase in coarse aggregate content, up to a critical volume of aggregate , and then decreases. The initial increase is due to a reduction in the volume of voids with the addition of aggregate. So Coarse aggregate is greater than fine aggregate in ratio in other of achieve a greater compressive strength in concrete.

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2.8.4 Aggregate to cement ratio

Aggregate cement ratio is the ratio of weights of aggregate to the weight of cement. If this ratio is more, that implies aggregates are more and cement is less and if this ratio is less, that implies weight of aggregate is less and weight of cement is more (relatively).When the weight of cement is more, i.e. aggregate cement ratio is less, the concrete has more cement paste required to coat aggregates and fill the voids between them. This more cement paste makes the concrete relatively easy to mix, place and compact as it reduces the friction between aggregates and allows its smooth movement. Thus the workability of concrete increases.

When the weight of cement is less, i.e. aggregate cement ratio is more, then there will be very less cement paste to coat aggregate surfaces and fill the voids, thus, mixing, placing and compacting of concrete will be more harder than previous case. This implies, the workability of concrete will be less than previous case.

2.8.5 Age of concrete

Experiments have been made on concretes with varying aggregate/cement and water/cement ratios, with the main object of ascertaining the effects of changes in age and water/cement ratio upon the relation between ultrasonic pulse velocity and the compressive strength of concrete. It was found that the ratio of changes in pulse velocity and compressive strength due to a change in water/cement ratio is not generally the same as that due to a change in age.

Because of this, the relation between pulse velocity and compressive strength cannot be expected to be independent of age and water/cement ratio. It appears, however, that, for compressive strengths up to about 4,000 lb/in^2, the relation may for practical purposes be regarded as being so. For concrete of the same aggregate) cement ratio, it was found that low pulse velocity at an early age predicts low strength at later (Kaplan, 1959).

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2.8.6 Compaction of concrete

The strength versus gel/space ratio relationship has a general application because the amount of gel present in the cement paste at any time is itself a function of age and type of cement. The latter relation thus allows for the fact that different cements require a different length of time to produce the same quantity of gel.

In concrete practice, the strength of concrete is traditionally characterized by the 28-day value, and some other properties of concrete are often referred to the 28-day strength. There is no scientific significance in the choice of the age of 28 days; it is simply that early cements gained strength slowly and it was necessary to base the strength description on concrete in which a significant hydration of cement had already taken place.

Test results revealed that rebound numbers measured on concrete beams compacted by vibrator were found to be higher than those compacted by rod and those produced without compaction irrespective to concrete age. For example, rebound numbers were measured as about 34, 32.5, and 32 for concrete beams compacted by vibrator, compacted by rod, and produced without compaction, respectively (28-day age). Test results has shown that the UPV values measured on concrete beams compacted by vibrator were significantly higher than those measured on concrete beams compacted by rod and those measured on concrete beams produced without any compaction.

2.8.7 Curing of concrete

In concrete technology, the maintenance of the drying and setting process is referred to as curing. The purpose of curing is to keep adequate moisture content and temperature as soon as the concrete is placed and finished.

It is one of the most important (and overlooked) steps and can have the greatest effect on the final outcome.

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Properly cured concrete can have significantly superior properties compared to concrete left to set after finishing. Improperly cured concrete can be subjected to plastic shrinkage cracking (loss of moisture from fresh concrete) and drying shrinkage (loss of moisture from concrete that has set) among other undesired side effects.

Concrete properties and durability are significantly influenced by curing since it greatly affects the hydration of cement. A proper curing maintains a suitable warm and moist environment for the development of hydration products, and thus reduces the porosity in hydrated cement paste and increases the density of microstructure in concrete.

2.9 QUARRY DUST

The quarry dust is the by-product which is formed in the processing of the granite stones which broken downs into the coarse aggregates of different sizes(Mir, 2015). Quarry dusts can include material from aggregate washing or from filtration systems.

Quarry fines below 6 mm are an integral part of many aggregate products, but are sometimes produced in excess quantities that do not match market demand. Where a production/market imbalance exists, aggregate producers need to identify alternative utilisation routes. Often the inclusion of high quantities of dust (particles below 75 μm) requires further processing to remove the unwanted fractions (Petavratzi et al. 2007).

2.10 Effects of Quarry Dust in Concrete

Many researches have been conducted in different parts of the world, to study the effects of incorporation of quarry dust into concrete. Galetakis and Raka, (2004) studied the influence of varying replacement proportion of sand with quarry dust (20, 30 and 40%) on the properties of concrete in both fresh and hardened state (Nevillie, 2003). It was reported that the physical and chemical properties of quarry rock dust as well as the durability of quarry rock dust concrete under sulphate and acid action was better than that of conventional

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concrete. Devi and Kannan (2011), carried out an investigation on strength and corrosion resistance behaviour of inhibitors in concrete containing quarry dust as fine aggregate.

The incorporation of inhibitors as admixture did not show any adverse effects on the strength properties and there was an increase in strength up to certain percentage. The addition of inhibitors as admixture to concrete was found to lower the permeability and water absorption. Nagabhusana and Bai, (2011), reported that crushed stone powder can be effectively used to replace natural sand without reduction in the strength of concrete at replacement level up to 40%. Kumar et al. (2013) reported that there is an increase in strength in concrete containing quarry rock dust (10-12%) more than that of similar mix of conventional concrete. Reddy (2010) reported that stone dust can be used in place of natural sand in concrete. He concluded that by using stone dust as total replacement of natural sand in concrete, higher strength can be achieved.

2.11 REVIEW OF THE EXISTING LITERATURE

According to Nagabhushana et al. (2011), the strength of mortar containing 40% Crushed Rock Powder is much higher than normal mortar containing only sand as fine aggregate. It is concluded that the compressive strength, split tensile strength and flexural strengths of concrete are not affected with the replacement of sand by CRP as fine aggregate up to 40%.

Sivakumar et al. (2010). The 28 days compressive strength of 100% replacement of sand with quarry dust of mortar cube (CM 1:1) is higher than the controlled cement mortar cube. The 56 days maximum Compressive strength, split tensile strength and modulus of elasticity of concrete for 100% replacement of sand with quarry dust of 400 kg/m3 at F/C=0.6, was higher than the reference concrete.

Bhikshma et al. (2010) reported that the stone dust as replacement for natural sand enhances the strength of concrete mix. The rough profile of stone dust provides good interlocking and

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bond between ultra-fine particles of cement paste. The concrete is less permeable and durable than conventional concrete with river sand. The compressive strength increased significantly up to about 20% for concrete with crusher dust compared to conventional concrete.

According to Lohani et al. (2012),the slump valueincreases with increase in percentage replacement of sand with quarry dust. The increase in dust content up to 30% increases compressive strength of concrete, if the dust content is more than 30% the compressive strength decreases gradually. But the compressive strength of quarry dust concrete continues to increase with age for all the percentage of quarry dust contents.

langovan et al. (2008) studied and reported that the strength of Quarry Rock Dust concrete is comparatively 10% to 12% more than that of similar mix of Conventional Concrete. The permeability of Quarry Rock Dust concrete is less compared to that of conventional concrete. The water absorption of Quarry Rock Dust concrete is slightly higher than Conventional Concrete.

The workability of concrete using lateritic sand and quarry dust as fine aggregates was found to have the same trend with normal concrete in a study carried out by Ukpata et al. (2012). The density of hardened concrete using lateritic sand and quarry dust was found to range from 2293-2447 kg/m^3.

2.12 Summary the Review of the Existing Literature

From the foregoing review it can be seen that a general appraisal of the properties of concrete made with quarry dust as partial replacement of fine aggregate has not been fully explored. It can be that a combination of fine aggregate and quarry dust will mobilize the beneficial effects of both materials and yield a concrete with adequate improved strength and durability. Besides, quarry dust has rough, sharp and angular particles and as such causes a gain in strength due to better interlocking. The application of quarry dust will engage stock piles of otherwise waste materials and generate economic revenue to the community where they abound. This study will therefore establish proper justification and generate engineering parameters for increased application of these local materials thereby reducing environmental waste and harnessing local resources for a full economic benefit.

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CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Cement

The type of cement used was Portland-Limestone Cement (PLC). Locally produced ordinary Portland cement was used in the investigation and it conformed to the requirement (BS 12, 1996). The OPC brand used was BUA Portland limestone cement gotten from the market. It was used directly as no chemical analysis was performed to know the constituents of this brand of OPC.

3.1.2 Coarse Aggregate

The coarse aggregate used for this study was sourced from the concrete tech laboratory, IDC Construction Company, Amansea. The coarse aggregates were flushed thoroughly with water to remove any impurity or dirt therein and then it was sun-dried to obtain saturated dry surface condition to ensure that the water-cement ratio is not affected. Some properties of coarse aggregates which affect the workability and bond between concrete matrixes are shape, texture, gradation and moisture content.

3.1.3 Fine Aggregate

The fine aggregate used was gotten from the concrete laboratory, IDC Construction Company, Amansea. The required quantity was first of all, thoroughly washed with clean water to remove any debris, organic matter and impurities present in the sand and then sun dried for at least two days to obtain a dry surface condition and ensure that the water cement ratio is not in any way affected.

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3.1.4 Quarry Dust

Quarry dust where collected from quarry in Abakiliki located in Ebonyi state. And then it was sun-dried to obtain saturated dry surface condition to ensure that the water-cement ratio is not affected.

Plate 3.1: Quarry Dust.

3.1.5 Water

The source of water used for the study is rainwater in Concrete Technology Laboratory, IDC Construction Company, Amansea. According to biological and chemical analysis performed as part of a master's thesis project of Carlos Andrés Medina, Civil Engineer and Specialist in Sustainable Building, indicate that besides using drinking water, rainwater is also viable for making simple concrete mixtures. The quality of this type of water is directly related to the quality of the air.

Therefore it is necessary to carry out an analysis to establish the minimal requirements included in the NTC 3459 (2001) standards, which regulate water issues for concrete mixing. However these parameters are not always fulfilled. The standard says that the liquid destined for this purpose can be obtained from other sources, but also be clear, clean in appearance

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and without damaging amounts of oil, acid, salt, organic material and other substances that may impact the resistance of the concrete.

3.2 METHODS

The main aim of this experiment is to investigate the potential use of quarry dust fines as a partial fine aggregate replacement material. The cube size of 150 x 150x150 mm is used to test the compressive strength of the concrete. The course aggregate used consists of size 16mm crushed granite and the fine sand used was local river sand. Tap water supplied from the lab was used during the study in the mixing, curing and other processes Quarry dust was collected from a quarry located at Abakiliki in Ebonyi state, and it was used as coarse aggregate replacement material. A total of five (5) mixture proportions prepared using water cement ratio of 0.55 were used to achieve this experimental work keeping the coarse aggregate and cement constant in all the mixes except for the variation in the percentage of fine aggregate used with quarry dust.

The first mix is the reference concrete mix or control mix consisting of 100% fine aggregate then the remaining four (4) mixes are prepared by integrating quarry dust by weight. The proportion of fine aggregate replaced ranged from 25% to 50% to 75% and at 100% interval; Steel moulds were used for casting test samples. The inner parts of the moulds were coated with engine oil to ensure easy de-moulding and smooth surfaces finish. Immediately after the mixing of the concrete, the wet mixture was cast into the moulds of size 150 x 150 x150 mm cube using hand trowel. They were filled in three layers and compacted using the compacting rod (25 diameter steel rods).

Each layer was compacted manually by uniformly distributing 25 strokes of the steel rod across the cross section of the mould. The top of each mould was smoothened and levelled and the outside surfaces cleaned. The mould and their contents were kept in the curing room at temperature of 21°C and relative humidity not less than 70. After 24 hours, the specimen were de demoulded and subjected to water curing until the testing date Compressive strength test was determined for 7, 14, 21, and 28 days according to British Standard Institution (2009).

A total of 40 cube specimen were prepared with a water to cement ratio of 0.55 maintained throughout the experiment. The strength and other results on fresh concrete were also compared to specimen that did not contain quarry dust as the control specimen. The laboratory experiments that were carried out to achieve the objective of this research and also, this chapter draw a clear picture and shows how to achieve the stated objective of the research.

3.2.1 Preliminary Calculations

The concrete mix design adopted for this research is as stated below, the design was adopted based on the availability of the material and also the aim of the experiment.

Density of concrete = 2400Kg/m^3

Volume of cube sample = 0.15x0.15x0.15 =0.003375m^3

Mass Density x Volume = 2400Kg/m^3 x 0.003375m^3= 8.1Kg

Water/Cement ratio = 0.55

Using mix ratio = 1: 2: 4; 0.55=1+2+4+0.55 = 7.55

Mass of constituent of cube

Mass of cement= $^1/_{7.55}$ x 8.1Kg = 1.073Kg

Mass of fine aggregate= $^2/_{7.55}$ x 8.1Kg = 2.146Kg

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Mass of coarse aggregate = $^{4}/_{7.55}$ x 8.1Kg = 4.291Kg

Mass of water= $^{0.55}/_{7.55}$ x 8.1Kg = 0.590Kg

Total mass constituents for (8 cubes + 25% of 8 cubes as factor of safety due to hand mixing) = 10 of each mix.

Cement = 1.073 x 10 = 10.73kg

Granite = 4.291 x 10 = 42.91kg

Water = 0.590 x 10 = 5.90kg

Table 3.1: Variation between fine aggregate and quarry dust at interval of 25% Replacement.

S\N	FINE AGGREGATE	QUARRY DUST
1	2.146kg = 100% of fine aggregate 2.146 x 10 = 21.46kg	0% of quarry dust
2	1.6095kg = 75% of fine aggregate 1.6095 x 10 = 16.095kg	0.5365kg = 25% of quarry dust 0.5365 x 10 = 5.365kg
3	1.073kg= 50% of fine aggregate 1.073 x 10 = 10.73kg	1.073kg = 50% of quarry dust 1.073 x 10 = 10.73kg
4	0.5365kg = 25% of fine aggregate 0.5365 x 10 = 5.365kg	0.5365kg = 75% of quarry dust 1.6095 x 10 = 16.095kg
5	0% of fine aggregate	2.146kg = 100% of quarry dust 2.146 x 10 = 21.46kg

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3.2.2 Mixing Process

Mixing was carried out by the conventional hand mixing method. The materials were weighed using a weighing balance. The components were weighed accordingly to achieve the added required mix in the mix design. Since hand mixing was employed, the quarry dust was added after the sand and cement has been properly mixed, after that the coarse aggregate was added and all the components were mixed thoroughly with water to achieve a homogenous constituent.

Procedure

1. Mix the cement and fine aggregate on a water tight non-absorbent platform until the mixture is thoroughly blended and is of uniform colour.

2. Add the coarse aggregate and mix with the cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch
3. Add water and mix it until the concrete appears to be homogenous and of the desired consistency.

Plate 3.2 Hand mixing of the concrete

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Sampling

1. Carefully clean the mould and apply oil.
2. Fill the concrete in the mould in three layers approximately 50mm thick
3. Compact each layer with at least 25 strokes per layer using a tamping rod.
4. Level the top surface and smoothen it with the aid of a trowel.

Plate 3.3: Tamping of concrete with a tamping rod.

3.2.3 Curing

The tests specimen are stored under moist air for 24 hours for it to harden and after this period the specimen are marked and removed from the moulds and kept submerged in clean fresh water until taken out prior to test.

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Plate 3.4: Curing of concrete cubes.

3.3 EQUIPMENT AND TEST PROCEDURES

3.3.1 Tests on Aggregates

1. Sieve analysis of aggregates

A sieve analysis or gradation test is a practice or procedure used commonly in civil engineering to assess the particle size distribution of a granular material. The size distribution is often of critical importance to the way the materials perform in use. A mere analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rocks, clays granite etc.

Apparatus

1. A set of IS sieve sizes, 31.5mm, 26.5mm, 19mm, 14mm, 12.5mm, 10mm,4.75mm,2mm, 1.18mm, 0.6mm, 0.425mm, 0.3mm, 0.15mm, 0.075mm and tray
2. Sensitive weighing balance
3. Mechanical sieve shaker

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4. Wire brush and other miscellaneous apparatus

Procedures

1. A representative weighed sample is poured in the sieve
2. The sample is sieved using a set of IS sieve agitated by the mechanical shaker
3. On completion of sieving, the material on each sieve is weighed
4. Cumulative weight passing through each sieve is calculated as a percentage
5. Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100

2. Specific gravity and water absorption of aggregates

The test is done to determine the specific gravity and water absorption of fine grained particles by pyconometer method as per IS:2720 (partIII/sec.1). Specific gravity is the ratio of the weight in air of a given volume of a material at a standard temperature to the weight in air of an equal volume of distilled water at the same stated temperature.

Apparatus

1. A pyconometer
2. Wash bottle
3. Stirring rod
4. Enamel tray
5. Funnel and filter paper
6. Thermostatically controlled oven
7. Electronic weighing balance

Procedure to determine the specific gravity of fine grained particle

1. The pyconometer along with the stopper should be washed and dried in a thermostatically controlled oven at a temperature of 105^0C to 110^0C, cooled to the desiccator and weighed to the nearest 0.01g
2. Weigh about 400g of the saturated surface dry sample and record as C
3. Pour the sample into the pyconometer, add little amount of water, above the level of the sample and stir thoroughly
4. Add extra water to fill to the brim of the pyconometer, cover the pyconometer and with the aid of the wash bottle, fill the pyconometer to the brim until there is no void left in the particle
5. Weigh the mixture and record as A
6. Pour the mixture into an enamel tray and filter using the filter paper and the funnel
7. Place the drained sample in the oven and allow drying for 24hrs.
8. Weigh the oven dried sample and record as D
9. Wash the pyconometer thoroughly with distilled water, fill distilled water into the pyconometer and record the weight of pyconometer and distilled water as B
10. Take at least two of the observation for the same sample.

3.3.2 Tests on concrete

1. Concrete slump test

Principle

The slump test result is a measure of the behaviour of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the workability of concrete.

Apparatus

1. Slump cone
2. Scale for measurement
3. Tamping rod

Procedure

The mould for the slump test is a frustum of a cone, 300mm of height. The base is200mm in diameter and it has a smaller opening at the top of 100mm.

1. The base is placed on a smooth surface and the container is filled with concrete in three layers, whose workability is to be tested.
2. Each layer is tamped 25 times with a standard 16mm diameter steel rod, rounded at the end.
3. When the mould is completely filled with concrete, the top surface is struck off by means of screening and rolling action of the tamping rod.
4. The mould must be firmly held against a base during the entire operation so that it did not move during the pouring of concrete and this can be done by means of handles and foot rests brazed to the mould.
5. Immediately after filling is completed and the concrete is levelled, the come is slowly and carefully lifted vertically, the unsupported concrete will now slump.
6. The decrease in height of the centre of the slumped concrete is called slump.
7. The slump is measured by placing the cone just beside the slumped concrete and the tamping rod is placed over the cone so that it should also come above the area of slumped concrete.
8. The decrease in height of concrete to that of mould is noted with scale. Usually measured to the nearest 5mm.

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Note the slumped concrete takes various shapes and according to the profile of slumped concrete, the slump is termed as collapse slump, shear slump and true slump.

Plate 3.5: Slump test.

2. Compressive strength test

The compressive strength test was carried out using the compressive strength test machine a find in the test method BS 1881 pant 116, 1983. An increasing compressive strength was plat to the cube specimen until failure occurred to obtain the maximum compressive load.The specimen dimension was taken before testing. The testing was carried out for 7, 14, 21 and 28 days after curing.

$$\text{Compressive strength} = \frac{CompressiveLoad, P\ (N)}{SurfaceArea, A\ (mm^2)} = \text{N/mm}^2\text{……Eq. 1}$$

Procedure

1. Remove the specimen from water after specified curing time and wipe out excess water from the surface.
2. Take the dimension of the specimen to the nearest 0.2m.
3. Clean the bearing surface of the testing machine.

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4. Place the smoothest side of the specimen in the machine in such a way that the loads shall be applied to the opposite sides of the cube.
5. Align the specimen centrally on the base plate of the machine.
6. Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
7. Apply the loads gradually without shock and continuously at the rate of 140Kg/cm/minute till the specimen fails.
8. Record the maximum load and note any unusual features in the type of the failure.

Plate 3.6: Crushing of concrete cubes.

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CHAPTER 4

RESULTS AND ANALYSIS

4.1 SIEVE ANALYSIS

The result of the particle size distribution carried out in accordance with BS 812-103.1 [15] is presented. The tables of the particles of the particle size distribution of the three materials used in the investigation; River sand, quarry dust and coarse aggregate are shown in the appendix. Also the graphical analysis of the materials is also plotted below.

Table 4.1 Coarse aggregates particle size distribution.

Sieve Size (mm)	Weight retained (g)	Percentage weight retained (g)	Cumulative percentage passing (%)
31.5	0	0	100
26.5	10.78	1.08	98.93
19	37.88	3.79	95.14
14	293.46	29.35	65.79
12.5	610.44	61.04	4.75
10	47.45	4.75	0
4.75	0	0	0

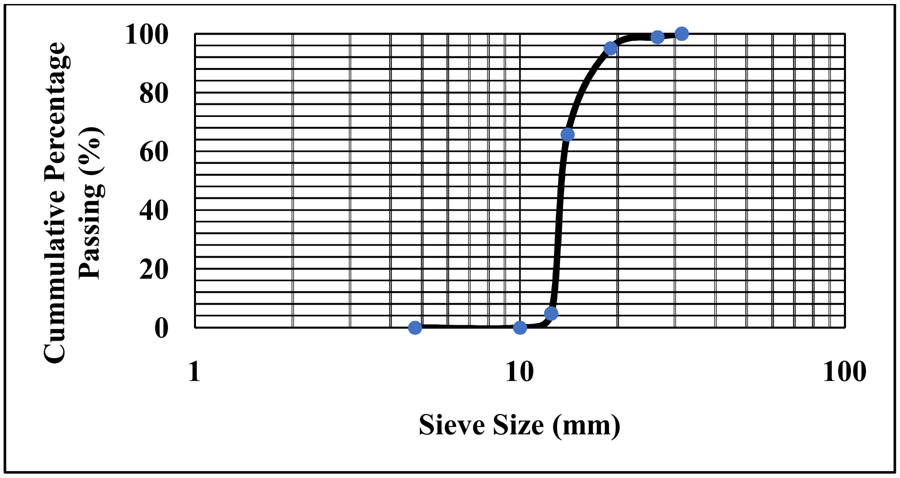

Figure 4.1: Particle size distribution of coarse aggregates.

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From Figure 4.1 it shows that the coarse aggregate consists of 100% gravel size aggregate which consists of about 6% medium gravel size and 94% fine gravel size. The coarse aggregate has a coefficient of uniformity (Cu) of 1.23 and coefficient of curvature (Cu) of 1.01.

Where;

D60= 16, D30= 14.5, D10= 13.

Coefficient of uniformity, Cu=$\frac{D60}{D10}=\frac{16}{13}$= 1.23 …………eq. 1

Coefficient of curvature, Cc=$\frac{D30\text{^}2}{D60\times D30}=\frac{14.5\text{^}2}{13\times 16}$ = 1.01 ……….eq. 2

Table 4.2: Fine aggregates particle size distribution.

Sieve Size (mm)	Weight retained (g)	Percentage weight retained (g)	Cumulative percentage retained (%)	Cumulative percentage passing (%)
2	4.73	0.95	0.95	99.05
1.18	21.86	4.37	5.32	94.68
0.6	86.72	17.34	22.66	77.34
0.425	112.57	22.51	45.18	54.83
0.3	162.86	32.57	77.75	22.25
0.15	97.80	19.56	97.31	2.69
0.075	4.86	0.97	98.28	1.72
0	8.61	1.72	100	0

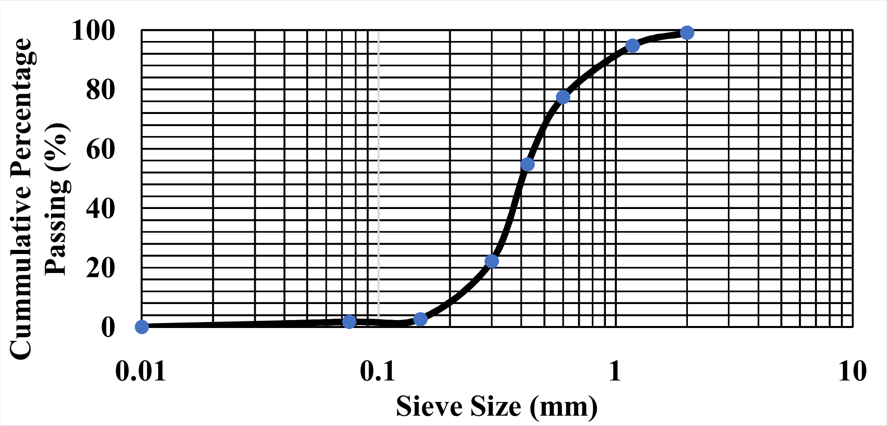

Figure 4.2: Fine aggregate size distribution.

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From Figure4.2,it shows that the fine aggregate consists of about 10% sand about 85% silt. The coefficient of uniformity, Cu is 2.14 and the coefficient of curvature, Cc is 1.15.

Where;

D60= 0.45, D30= 0.33, D10= 0.21.

Coefficient of uniformity, $Cu=\frac{D60}{D10}=\frac{0.45}{0.21}=2.14$ ……….eq. 1

Coefficient of curvature, $Cc=\frac{D3\ \ \hat{}2}{D60\times D30}=\frac{0.33\hat{}2}{0.21\times 0.45}=1.15$ ……….eq. 2

Table 4.3: Quarry dust particle size distribution.

Sieve Size (mm)	Weight retained (g)	Percentage weight retained (g)	Cumulative percentage retained (%)	Cumulative percentage passing (%)
4.75	24.72	4.943	4.943	95.056
2	89.86	17.971	22.911	77.085
1.18	88.47	17.693	40.604	59.392
0.6	60.34	12.067	52.671	47.325
0.425	54.44	10.887	63.558	36.437
0.3	30.86	6.171	69.729	30.266
0.15	35.84	7.167	76.896	23.099
0.075	44.83	8.965	85.861	14.133
0	70.67	14.133	100	0

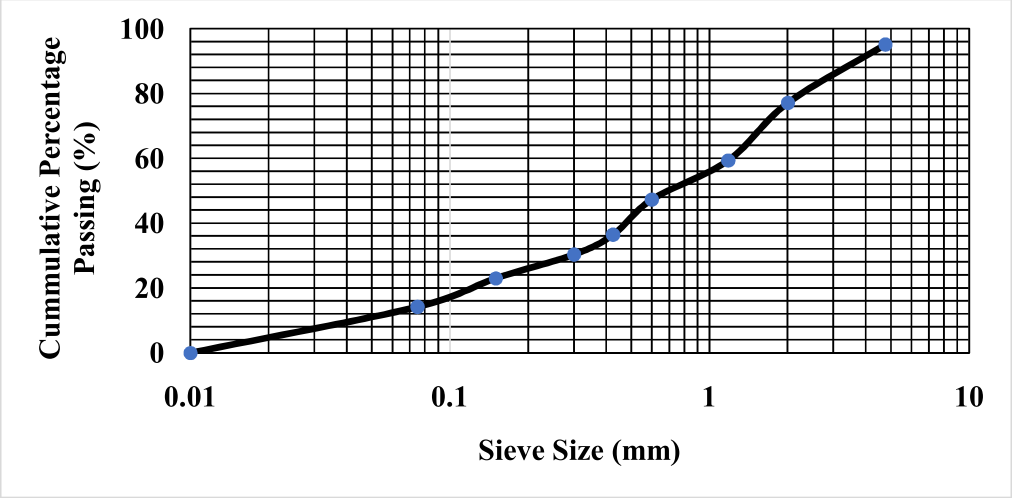

Figure4.3: Quarry dust particle size distribution.

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From Figure4.3, it shows that the quarry dust which is the main material of this work consists of about 65% sand and about 35% silt. The coefficient of uniformity, Cu is 31.43 and the coefficient of curvature, Cc is 1.37.

Where;

D60= 1.4, D30= 0.29, D10= 0.044.

Coefficient of uniformity, Cu=$\frac{D60}{D10}$=$\frac{1.4}{0.044}$= 31.82 …………eq. 1

Coefficient of curvature, Cc=$\frac{D30{}^\wedge 2}{D6\ \times D30}$= $\frac{0.29{}^\wedge 2}{1.4\times 0.044}$ = 1.37 ………..eq. 2

4.2 SPECIFIC GRAVITY AND WATER ABSORPTION

The specific gravity and water absorption of the coarse aggregates, fine aggregates and quarry dust are shown in the table 4.4 below;

Table 4.4 Specific gravity and Water Absorption

Sample type	**Coarse aggregate**	**Fine aggregate**	**Quarry dust**
Mass of empty jar, M_1 (g)	34.70g	24.40g	24.40g
Mass of empty jar + soil sample, M_2 (g)	82.70g	50.64g	58.29g
Mass of jar + soil sample + water, M_3 (g)	176.80g	140.55g	145.40g
Mass of jar + water, M_4 (g)	146.50g	124.47g	124.48g
Mass of oven dried soil, M_5 (g)	47.42g	25.43g	31.55g
$G_s = \frac{M2-M1}{(M2-M1)+(M4-M3)}$	2.71	2.58	2.61
Water absorption = $\frac{M2-M1-M5}{M2-M1}\times 100$	1.2%	3.1%	6.9%

`

From the results obtained from Table 4.4; the specific gravity G_s for Coarse aggregates, Fine aggregates and Quarry dust is 2.7, 2.58 and 2.61 respectively. From the results the coarse aggregate (Granite) has the highest specific gravity 2.7 while the Fine aggregates (Sand) has the lowest value at 2.58, there wasn't much difference between the specific gravity of the samples. From the water absorption results above the quarry dust has the highest percentage at 6.9% followed by the fine aggregate at 3.1% while the least is the coarse aggregate at 1.2%.

4.3 SLUMP TEST

Table 4.5: Slump test result

Percentage of quarry dust (%)	Height of collapse (mm)	Slump (mm)
0	215	85
25	235	65
50	255	45
75	270	30
100	280	20

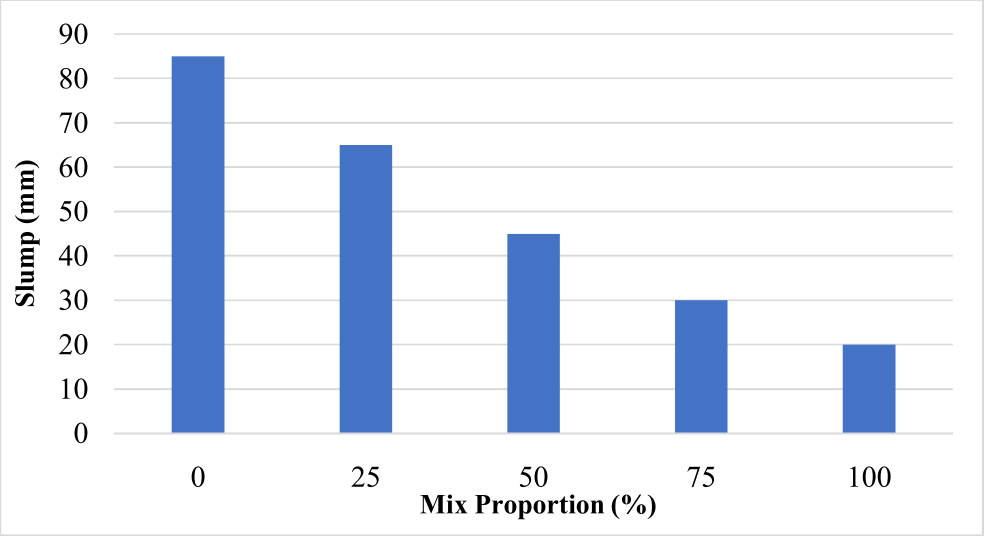

Figure 4.4: Slump test at different quarry dust percentage replacement

The variation of workability of fresh concrete is measured in terms of slump and reported in Table 4.5 and in Figure 4.4. For the given water/cement ratio of 0.55, the highest slumps were recorded for the mixes. The overall workability values with the increase in quarry dust replacement are less compared to the 0% replacement. It is observed that workability of the concrete decreases with the increase in percentage of quarry dust.

The slumps obtained are in the medium range of 20mm-95mm rounded up to the nearest 5mm. The highest slump was obtained with concrete made with 0% quarry dust. This indicates that quarry dust has a significant effect in the workability of concrete.

4.4 COMPRESSIVE STRENGTH CONCRETE

The Compressive Strength of the concrete cubes at different curing ages; 7 days, 14 days, 21 days and 28 days, made with BUA cement is tabulated in Table 4.6 below.

Table 4.6: Compressive strength result

Specimen	**Curing Time (days)**	**Cross Sectional Area (150×150) (mm^2)**	**Average Weight (kg)**	**Average Crushing Load (KN)**	**Average Compression Strength (N/mm^2)**
0% Quarry dust (Control)	7	22500	8.20	364.50	16.20
	14	22500	8.25	387.00	17.20
	21	22500	8.29	468.00	20.80
	28	22500	8.37	506.25	22.50
25% Quarry dust	7	22500	8.11	364.50	16.20
	14	22500	8.30	416.25	18.50
	21	22500	8.32	481.50	21.40
	28	22500	8.41	535.50	23.80
50% Quarry dust	7	22500	8.13	402.75	17.90
	14	22500	8.19	459.00	20.40
	21	22500	8.12	486.00	21.60
	28	22500	8.24	564.75	25.10
75% Quarry dust	7	22500	8.18	360.00	16.00
	14	22500	8.24	391.50	17.40
	21	22500	8.32	468.00	20.80
	28	22500	8.45	528.75	23.50

`

100% Quarry dust	7	22500	8.13	344.25	15.30
	14	22500	8.19	371.25	16.50
	21	22500	8.12	445.50	19.80
	28	22500	8.24	490.50	21.80

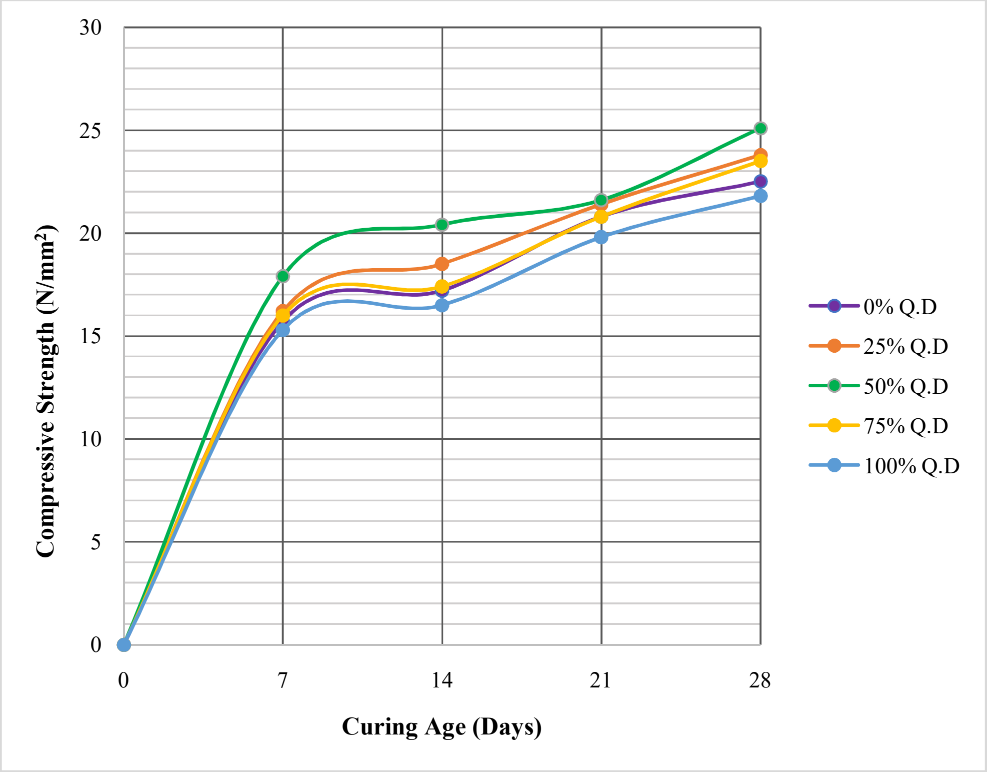

Figure 4.5: Graph of compressive strength against age of concrete.

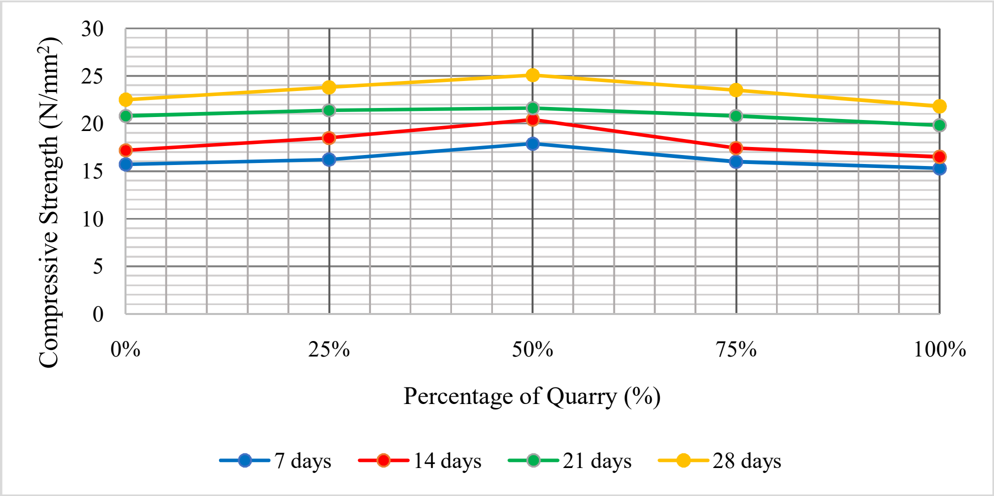

Figure 4.6: Graph of compressive strength against percentage of quarry dust

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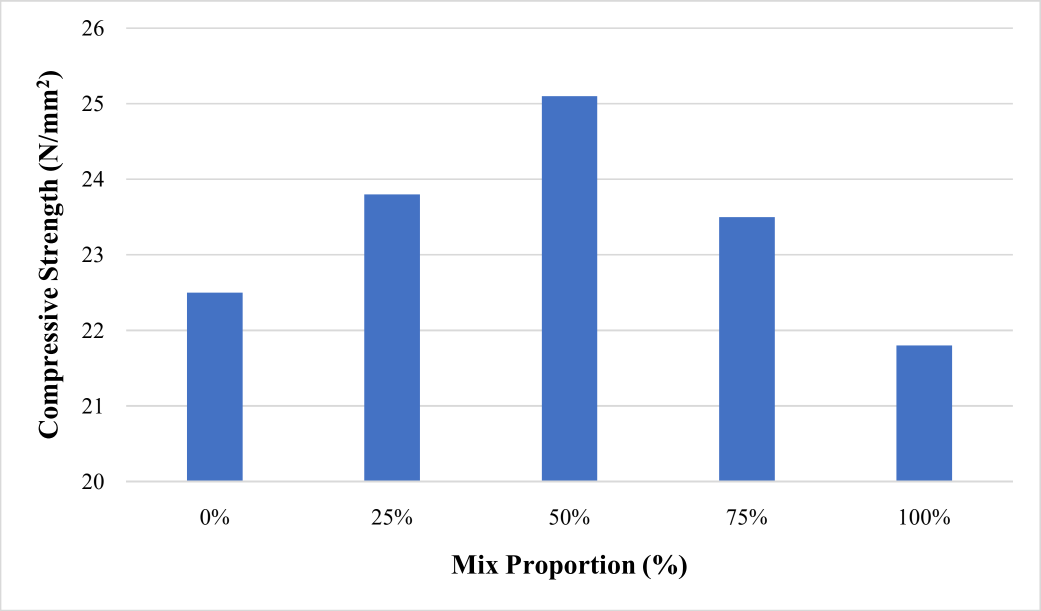

Figure 4.7: Effect of quarry dust on the compressive strength of concrete at the 28th day

From Figures 4.5, 4.6 and 4.7, the highest Compressive strength which is 25.1 N/mm^2 occurred at the 50% replacement of the concrete with quarry dust. While 100% quarry dust replacement concrete specimens gave the lowest compressive strength of 21.8 N/mm^{2}on the 28th day. So for a concrete that strength of 20N/mm^2 is required, quarry dust can be used as a fine aggregate and at 28 days of curing the result would be satisfactory. For the various percentages of quarry dust replacement it was observed that the compressive strength increases with curing age.

The growth pattern of strength is progressive for all the test mixes and specimen from 7days to 28 days. There is little strength growth between 21 days and 28 days. The variation shows that the compressive strengths at age 7 days, 14 days, 21days constitute average values of 70%, 80% of the 28 days cube strength. These values are comparable to 67%, 80%, and 95% obtained by Ephraim and Ode (2006) and other related studies on concrete with gravel and quarry dust as aggregates.

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Figure 4.7 is the graph of 28 days strengths achieved at different replacement levels of the fine aggregates with quarry dust. Concrete with varied percentages of quarry dust shows a varying compressive strength. In other words, compressive strength of concrete made with replacement of fine aggregates with quarry dust ranges from 21.8 N/mm^2 to 25.1N/mm^2 for BUA cement. Its maximum is at 50% replacement and the compressive strength is 25.1N/mm^2. Other replacements have a lower compressive strength.

The concrete specimen with 50% quarry dust replacement gave the highest compressive strength at all the curing age when compared with the control and other percentage quarry dust replacements. This specimen gave compressive strengths of 17.9 N/mm^2, 20.4 N/mm^2, 21.6 N/mm^2 and 25.1N/mm^{2}at 7, 14, 21 and 28 days respectively, which were higher than the compressive strengths obtained in the conventional concrete (0% replacement) which had compressive strengths of 15.7, 17.2, 20.8 and 22.5N/mm^2 at 7, 14, 21 and 28 days respectively.

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CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

From the analysis of the results obtained, the following conclusions were made accordingly:

1. The higher the percentage replacement of fine aggregate with quarry dust, the less the workability of concrete. Hence, the workability of concrete is inversely proportional to the percentage content of quarry dust in concrete.
2. The specific gravity Gs is relatively the same for the coarse aggregate, fine aggregate and quarry dust with gave 2.71, 2.58 and 2.61 respectively.
3. The water absorption of quarry dust which was determined as 6.9% was very high compared to the fine aggregate that is 3.1%. The concrete mix prepared with higher proportion of quarry dust has very low workability because of the high water absorption of the quarry dust.
4. An optimum compressive strength of 25.10 N/mm^2 on the 28th day of curing was achieved in concrete specimens with 50% partial replacement of quarry dust.
5. The lowest compressive strength of 21.80 N/mm^2 on the 28th day of curing was achieved in concrete specimens with 100% replacement of quarry dust.
6. The compressive strength of the concrete specimens is directly proportional to the curing time for all the mix proportions.
7. The compressive strength of the concrete specimens increases with an increase in percentage content of quarry dust but up to a certain content.
8. All the mix proportions of quarry dust gave a compressive strength which was more than the design mix ratio strength of 20 N/mm^2 on the 28th of curing.

9. In conclusion, quarry dust is a good replacement of sand as a fine aggregate in concrete production of 1:2:4 mix ratio with 0.55 w/c.
10. The utilization of quarry dust as partial replacement of fine aggregates in concrete will preserve the global natural resource base as well as save construction costs significantly.

5.2 RECOMMENDATIONS

1. The water to cement ratio should be increased as the percentage of replacement of fine aggregate with quarry dust is increased, this is to improve the workability of the concrete this might reduce the strength of concrete so, the use of Superplasticizers as an admixture can improve flowability of concrete and alternatively at the same flowability requirement, the water/cement (W/C) ratio can be reduced to improve the strength and durability of concrete (Kwan and Fung, 2012).
2. The use of hand mix was not quite efficient; the use of mechanical mixers (machines) would be more efficient because the aggregates will mix well with the cement after series of turns.
3. The mix ratio should be varied for instance for the 50% quarry dust replacement a mix ratio of 1:3:6 can be varied with 1:2:4 and a reasonable strength of 20 N/mm^2 can be achieved.
4. The ratio of the quarry dust and sand can be varied between 0% and 40% for effective compressive strength and workability to be achieved.

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STRUCTURAL ANALYSIS AND DESIGN OF BOX CULVERT ALONG ISUANIOCHA/MGBAKWU ROAD USING EURO CODE 2.

BY

OKPARA DANIEL IFEANYI

(NAU/2016224048)

SUBMITTED TO
THE DEPARTMENT OF CIVIL ENGINEERING
FACULTY OF ENGINEERING
NNAMDI AZIKIWE UNIVERSITY AWKA.

IN PARTIAL FUFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN CIVIL ENGINEERING

SUPERVISOR: ENGR. PROF. C.H. AGINAM

FEBUARY, 2021

CERTIFICATION

This is to certify that this project topic titled "Structural Analysis and Design of Single and Triple Cell Box Culvert along Mgbakwu/Isuaniocha Road using Euro code 2" was carried out by Okpara Daniel Ifeanyi with registration number (NAU/2016224048) in the Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

Okpara Daniel Ifeanyi **Date**

(student)

APPROVAL PAGE

This research work "Structural Analysis and Design of Single ad Triple Cell Box Culvert along Mgbakwu/Isuaniocha Road using Euro code 2 " has been assessed and approved by department of civil engineering Nnamdi Azikiwe university.

Prof. C.H. Aginam **Date**

(Project Supervisor)

Engr. Dr. C.A Ezeagu **Date**

(Head of Department)

Engr. Prof. D.O. Onwuka **Date**

(External Examiner)

DEDICATION

This work is dedicated to Almighty God for the gift of life and also for guiding me through school. I also want to dedicate this work to my lovely mother Mrs Okpara Ngozi who served as a real source of inspiration toward my academic pursuit and my dear brother Dr. Muna for his sincere support.

ACKNOWLEDGEMENT

Special thanks go to Almighty God for giving me the strength to complete this work and also for His guidance and protection throughout my stay in Nnamdi Azikiwe University.

Also I will like to express my profound gratitude to my mum; Mrs Okpara Ngozi for her moral support, constant prayers throughout my stay in school, special thanks goes also to my siblings Dr. Muna and Miss Gift for their encouragement during trying times of my academic pursuit.

I want to thank in a very special way, my project supervisor in the person of Prof. C. H. Aginam for his time and guidance in the accomplishment of this project. May the lord rain blessing from heaven for him and his family and may he also protect your family.

Special thanks go to the Head of Department of Civil Engineering in the person of Engr. Dr. C.AEzeagu.He has been more like a father to us all and I appreciate him so much.

I will also like to extend my heartfelt appreciation to all the staff (academic and non-academic) of the Department of Civil Engineering for their invaluable tutorship and professional guidance.

Finally, I will like to appreciate everyone who has in one way or the other contributed to making me a better person, may the Lord Almighty reward you all greatly

ABSTRACT

This study was conducted to evaluate the structural reliability of EC2 in the analysis and design of hydraulic structures. The structural analysis and design of single and triple cell box culvert along Mgbakwu/Isuaniocha road using EC2, focuses essentially on load assemblage and estimation, calculation and analysis of moment using hardy cross method of moment distribution, calculation of shear force, design and provision of area of steel required. From the loading analysis, the ultimate design load for top slab, vertical walls and bottom slab are 78.07KN/m, 41.88KN/m and 140.69KN/m, 122.79KN/m, 48.6KN/m and 159.6KN/m when both culverts is empty and 12.37KN/m, 93KN/m and 99.8KN/m, 10.69KN/m, 76.5KN/m and 41.99KN/m when both culvert is full. The fixed end moment and free end moment generated for the structural members of the single and triple cell box culverts are 27.84KNm, 58.61KNm and 58.61KNm, 76.51KNm, 25.43kNm and 90.08KNm, 189.2kNm, 12.81kNm and 246.2kNm, 283.8kNm, 13.31km and 369.34kNm respectively while the design moment are 48.67KNm, 58.61KNm and 58.61KNm, 154.83kNm, 178.85kNm and 190.49kNm respectively. The maximum shear forces are 53.96KN, 128.69KN and 63.77KN, 63.05KN, 529.3KN and 73.85KN respectively. The design suggest that minimum area of steel of 1200mm^2 was required for all structural members (Top slab, Vertical walls and Bottom slab) of the single cell box culvert and area of steel provided was 1340mm^2 while the triple cell box culvert suggested an area 1600mm^2 as the area of steel required for all structural members, 1800mm^2 as area provided for top slab, 2090mm^2 as area provided for the two vertical walls and bottom slab respectively. The type, size and spacing of reinforcement specified by the design for all structural members are Y16@ 150mmc/c U-bars as main bars and Y12@ 200mmc/c as distribution bars in both faces for the single cell box culvert and Y20@ 150mmc/c U-bars as main bars and Y12@ 150mmc/c as distribution bars in both faces for the triple cell box culvert respectively. The bar bending schedule prepared indicate that seventy-five length of Y16 was required as main bars and forty length of Y12 was required as distribution bars for the single cell box culvert and three hundred and seventy-two length of Y20 was required as main bars and one hundred and fifty-one length of Y12 was required as distribution bars for the triple cell box culvert. The shear design carried out for the critical shear generated (128.69KN and 529.3KN) was satisfactory as the design concrete shear stress exceed the design shear stress in magnitude. The study encourages the use of EC2 in the design of concrete structures as it is logical, organized and structurally reliable, this code is gaining more credence globally and should therefore be adopted by Nigerian Engineers.

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LIST OF SYMBOL & ABBREVIATION

A- cross sectional area.

Ac -area of concrete section.

Ac -gross area of concrete at a cross-section.

As- -area of tension reinforcement.

Asc--´ area of compression reinforcement.

As’prov-- area of compression reinforcement.

Asc ---area of compression reinforcement, per unit length of wall.

Asmin - minimum area of steel.

*A*sreq--- area of tension reinforcement required.

BT—bottom

TP--- Top

VT—Vertical

c/c---center to center

Y--- high yield

BF---both face

FF----far face

NF---near face

EC2--- Euro code 2

Gk--- Characteristic dead Load

Qk--- Characteristic Imposed Load

b—breadth of slab

h---- thickness of culvert

M---ultimate design moment

N---shear force or axial pull

ULS------ultimate limit state

SLS----serviceability limit state

Γc--- factor of safety for concrete.

γf ---partial safety factor for load.

γm ---partial safety factor for strength of materials.

Γs--- factor of safety for steel.

P--- Reinforcement ratio for longitudinal reinforcement.

Φ--- diameter of steel.
Ω-- ultimate load.

DCSS---- design concrete shear stress

DSS---- design shear stress

FEM--- finite element model

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

A hydraulic structure is a structure submerged or partially submerged in any body of water, which disrupts the natural flow of water. They can be used to divert, disrupt or completely stop the flow of water. A hydraulic structure can be built in river, sea or any body of water where there is a need for a change in the natural flow of water (Ola, 2018).

Culvert is a hydraulic structure that allows water to flow under a road, railway, trail or similar obstruction from one side to the other side. Typically embedded so as to be surrounded by soil. Culverts can be constructed from a variety of materials including cast-in-place or precast concrete. Precast reinforced concrete (RC) culverts are very common and usually constructed as single or multi-cell culverts. Precast reinforced concrete (RC) culverts offer advantages such as enhanced quality control, use of higher strength concrete, relatively lower cost due to mass production and shorter installation time.

Culverts are commonly used both as cross-drains for ditch relief and to pass water under a road at natural drainage and stream crossing. A culvert may be a bridge-like structure designed to allow vehicle or pedestrian traffic to cross over the waterway while allowing adequate passage for water (Ola, 2018). Culverts come in many sizes and shapes including round, elliptical and box- like construction. The type and shape selection are based on a number of factors including requirements for hydraulic performance, limitation on upstream water, surface elevation and roadway embankment height.

In the 1970s, there was a significant boom in culvert bridge construction in many countries (Alkhrdaji and Nanni, 2014). Most of the culverts, made of corrugated metal or reinforced concrete after approaching 10-15 years of age are deteriorating at a high ratio. This deterioration have been attributed to poor structural analysis and design coupled with aggressive environment (e.g, exposure to high moisture and temperature and heavy traffic load) leading eventually to loss of serviceability. The structural design of culvert involves consideration of load cases (empty box, full and surcharge load e.t.c) and factors like live load, effective width, braking force, dispersal of load through fills, impact factors, coefficient of earth pressure e.t.c. The standard elements are required to be designed so as to withstand maximum bending moment and shear force with relevant code required to be referred.

This study therefore presents the structural analysis and design of single and triple box culverts along Isuaniocha/Mgbakwu road using Euro code 2.

1.2 Statement of Problem

Most of the culverts made of corrugated metal or reinforced concrete after approaching 10-15 years are deteriorating at a high rate. This has been largely attributed to poor structural analysis and design which have consequently resulted to loss of serviceability.

This study therefore tackles the problem associated with the deterioration in the design life of single and triple box culverts along Isuaniocha/Mgbakwu road through accurate structural analysis and design using Euro code 2.

1.3 Aim and Objectives of Study.

The aim of the study is to carry outthe structural analysis and design of single and triple box culverts along Isuaniocha/Mgbakwu road using Euro code 2 and the objectives includes:

1. Determine the total design loads (dead and imposed) acting on the various part of the single and triple box culverts.
2. Generate the internal stresses (maximum bending moment and shear force).
3. Design the single and triple box culvert using Euro code 2.
4. Detail the design structural elements of the culverts.
5. Prepare bar bending schedule of structural elements.

1.4 Scope of Study.

This study is essentially centered at improving the design life condition of single and triple box culverts along Isuaniocha/Mgbakwu road through accurate and efficient structural analysis, design and detailing using Euro code 2. This process involves estimation of load (dead and live load), generation of internal stresses (bending moment and shear force), design and specification of sizes, types, numbers and spacing of reinforcement steel to be employed.

1.5 Significance of Study.

Most of the culverts constructed and installed in Anambra State particularly in Isuaniocha/Mgbakwu road Anambra State have been characterized by deteriorating design life which have resulted to high maintenance cost after construction and installation.

This study will therefore address the problem associated with the decline in design life of single and triple box culverts along Isuaniocha/Mgbakwu road through accurate and efficient structural analysis and design using Euro code 2. This would be extremely beneficial to the host communities through the following:

1. Increase the design life of the culverts thereby reducing post maintenance cost.
2. Reduce the occurrence of accident as a result of poorly designed culverts.
3. Specify materials for construction of culverts with good hydraulic characteristics.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General

Culverts are widely used as cross-drains for ditch relief and to pass water under natural drainage and stream crossings. Culverts are made of concrete or metal (corrugated steel or aluminum), and plastic pipe is occasionally used, as well as wood and masonry. The type of materials used depends on cost and availability of these materials. Generally, concrete and metal pipes are more durable compared with plastic pipes. The culverts are commonly used in different shapes, namely round pipes, arch pipes, structural arch, and box depending on the site, the required span and permissible height of backfill soil (Keller and Sherar, 2003). Culverts need to be properly sized and installed, and protected from erosion and scour. The key factors in culvert selection are that the culvert has adequate flow capacity, fits the site, and that the installation is cost effective (Montana State University, 1992).

Box Culvert is the arrangement made to cross an obstacle in the form of a stream, a river or a road to pass without closing the way beneath (Sagar and Roshan, 2019). A Culvert is defined as standard specifications as any structure whether made up of single and multiple cell construction with a clear span of 6m. Box Culvert which has got its name due to its shape & orientation and looks like a hollow rectangular box with two slab & two vertical walls which connects monolithically. Box culverts are easy to design and easy to construct economically. It is designed to carry all the loads comes from top slab and transferred with help of vertical walls to bottom slab which rest generally where the bearing capacity of soil is low. Box Culverts are economical due to their rigidity and monolithic action no separate foundation is required when bottom slab is rest on hard soil. The structure is designed such as rigid frame adopting moment distribution method for obtaining final distributed moments on the basis of the vertical walls and slabs. Box Culverts are generally found in three locations, the first is at the bottom of depressions where no natural water course exist, second is where natural stream intersect the roadway and third is at locations required for passing surface water carried in the ditches beneath roadways and driveways to adjacent property. There are many general problem occur with box culvert such as serviceability and strength, abrasion and deterioration of concrete. For masonry culverts there will be major cause due to sedimentation and blockage by debris. There are two types of culverts which are rigid culvert for example concrete and flexible culvert for example steel. Rigid culverts are made to bear the bending moments where the flexible culverts are not.

This Eurocode underpins all structural design irrespective of the material of construction. It establishes principles and requirements for safety, serviceability and durability of structures. (Note, the correct title is Eurocode not Eurocode 0.). The Eurocode uses a statistical approach
to determine realistic values for actions that occur in combination with each other. The series of European standards commonly known as "Eurocodes", EN 1992 (Eurocode 2, in the following also listed as EC2) deals with the design of reinforced concrete structures – buildings, bridges and other civil engineering works. EC2 allows the calculation of action effects and of resistances of concrete structures submitted to specific actions and contains all the prescriptions and good practices for properly detailing the reinforcement.
EC2 consists of three parts:
1. EN 1992-1 Design of concrete structures - Part 1-1 General rules and rules for buildings,
Part 1-2 Structural fire design (CEN, 2002)
2. EN 1992-2 Design of concrete structures - Part 2: Concrete Bridges – Design and Detailing rules (CEN, 2007).
3. EN 1992-3 Design of concrete structures - Part 3: Liquid retaining and containmentstructures (CEN, 2006).

2.2 Culverts and Classification.

Generally, culverts are cast in situ, but it depends on the country you are because some countries they preferred due to economic and low cost with having fast workmanship. There are different types of culvert; it depends on its shape; also, it uses as a small bridge. Culvert spans generally are 6m-10m length so it can control all the water coming from the canals, river, and all the stormwater and floodwater to pass under the road safely. Reinforced concrete box culvert has four sides that monolithically connected. Some box culverts have three sides because there's raft or mat foundation in the bottom and two vertical wells in the sides. There are different types of culvert, and they are,

1. Pipe Culverts
2. Box Culverts

3. RCC Solid Slab Culverts
4. Pipe Arch Culverts
5. Arch Culverts

1. **Pipe Culvert**

Pipe culvert may be a single or multiple pipes; therefore, if it's used a single culvert, then a large diameter culvert is required if the width of the water channel becomes greater than multiple pipe culvert is going to use in that place. The multiple pipe culvertsare suitable to use for a large water channel. The diameter size of the pipe culverts is between (1m to 6m). Pipe culverts are generally widely used and they look rounded in shape. The shape varies from circular, elliptical and pipe arch. Generally, their shape depends on site conditions and constraints. Some of it advantages includes: ease of construction to any desired strength by proper mix design, thickness and reinforcement, they are economical, the pipes can withhold any tensile stresses and compressive stresses and the crossing of water is under the structure.

Plate 2.0 Multiple Pipe Culvert (Source: metal-culvert.com).

Plate 2.1 Single cell Pipe Culvert with Filter (Source: metal-culvert.com).

2.0 Box Culvert

Box culvert is always in a rectangular shape, and the type of materials used to make the box culvert are (cement, sand, reinforcement, gravel). This type of culvert is used to drain the rainwater, river water, and storm water under the road embankment. Also, box culvert is useful in the dry period because they can help the animals as a passage cross of the railroad or highways. Rectangular cross-section culverts are easily adaptable to a wide range of site conditions including sites that require low profile structures. Due to the flat sides and top, rectangular shapes are not as structurally efficient as other culvert shapes. In addition, box sections have an integral floor. This culvert is made up of concrete and especially Reinforced concrete (RCC). The most challenging part in constructing a box culvert is that the dry surface is needed for installing it. However, due to the strength of the concrete floor, water direction can be changed when a large amount of water is expected. This feature makes box culverts one of the most commonly found types of culverts. Some of the advantages include: simplicity of construction, suitable for non-perennial streams where scrub depth is not significant but the soil is weak, reduces substantial amount of pressure on the soil through it bottom slab, they are economical due to their rigidity and monolithic action and separate foundation are not required.

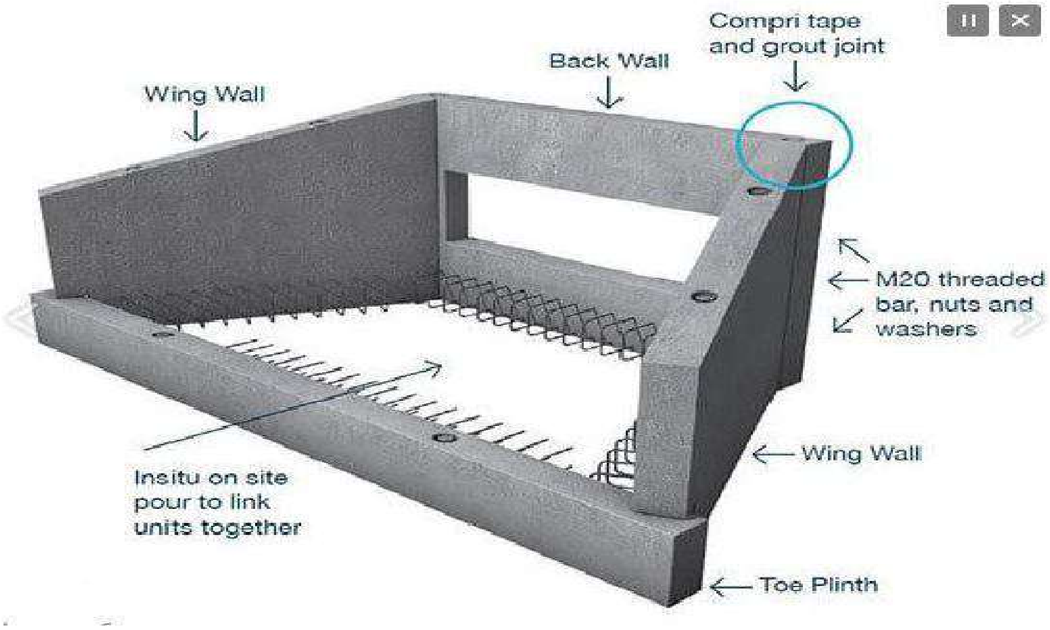


Plate 2.2 Front of Box Culvert (Source: metal-culvert.com).

Plate 2.3 Single Concrete Box Culvert (Source: miller-miller-inc.com).

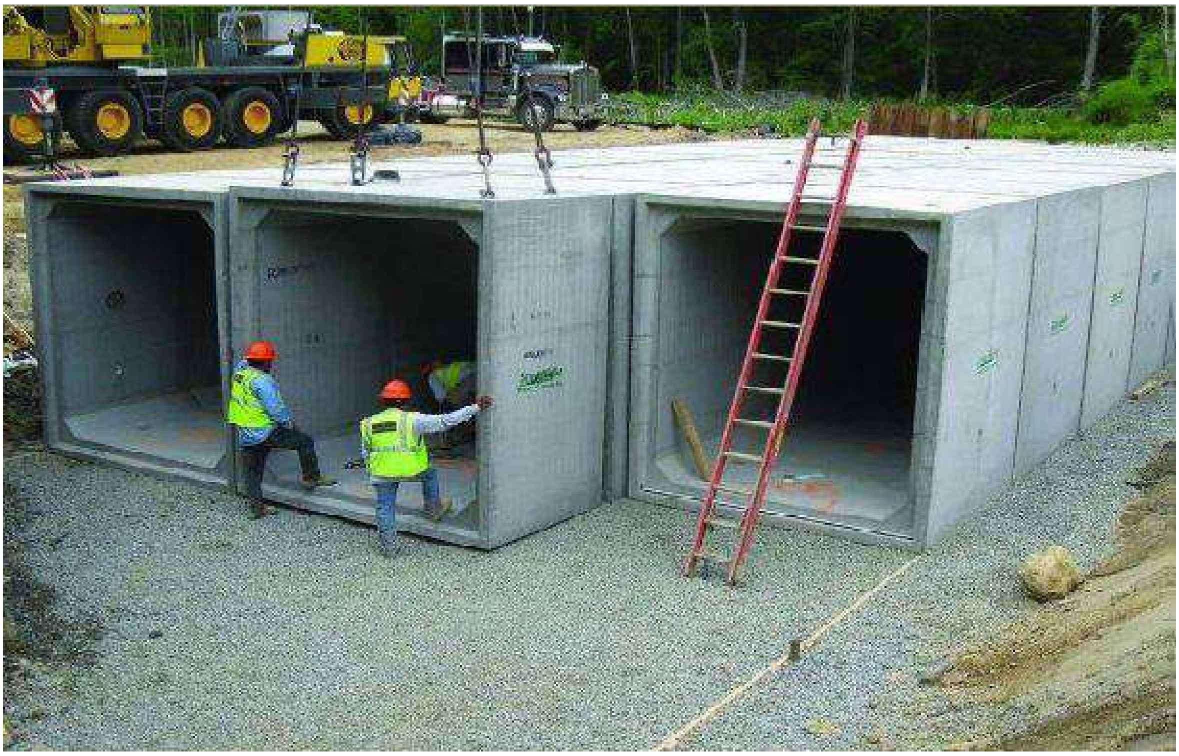


Plate 2.4 Multiple Concrete Box Culvert (Source: miller-miller-inc.com).

3. RCC Solid Slab Culverts

Solid slab culverts are provided where the big canals and the rivers also are used as a small bridge in road vehicles. In these types of culverts, the foundations are laid under the ground surface. A series of box culvert is laid in the ground, then pavement is put on the top surface.

Plate 2.5 RCC Solid Slap Culverts. (Source: http://www.visitgrey.ca).

4. Pipe Arch Culvert.

Pipe Arch Culvert means that they look like a half-circle and half arch culvert. This type of culverts are suitable for the places of the large water flow or waterway opening where fishes can be provided with a greater hydraulic advantage but the flow capacity should be stable. Pipe arch culverts are good for the sewages and fishes because they can use drainage easily without stocking the flow at the bottom. These types of the culvert are very useful so you can see in many places; also, these culverts have a very beautiful appearance. Some of their advantages include: limited headroom condition, improved hydraulic capacity at a low flow, aesthetic shape and appearance, lightweight and ease of installation.

Plate 2.6 Single Concrete Pipe Arch Culverts (Source: http://www.visitgrey.ca).

Plate 2.7 Single Concrete Pipe Arch Culvert with a small Channel (Source: http://www.visitgrey. ca).

5. Arch Culvert.

These types of the culvert are similar to pipe arch culvert, but in this culvert, there is mat provided below the arch. The passage of this culvert is very wide and can transmit a large flow of water. The material made of this culvert is made of concrete or steel.Arch culvert is made up of metal, stone, masonry, concrete. Construction does not take a lot of time unlike box culvert, water diversion is not necessary as it can be installed without disturbing the water current. Thus, it can be termed as low profile culvert. This type of culvert maintains the natural integrity of the wash bed. Some of its advantages include: greater hydraulic efficiency, accelerated construction schedule, cost saving, pleasing aesthetics and design-build advantage.

Plate 2.8 Reinforced Concrete (RCC) Arch Culvert (Source: http://www.visitgrey. ca).

Plate 2.8.1 Steel Arch Culvert (Source: http://www.visitgrey. ca).

2.3 Principle of Culvert Installation

Culvert installation for drainage crossings is quite important process for sustainability of the culvert (Kellar and Sherar, 2003). Important installation details include install culverts at natural stream grade, using quality, well compacted bedding and backfill material, using inlet, outlet, and stream bank protection measures (Normann et al. 1998). However, any soil of low moisture, mud, roots, expansive clay, and boulders can be used. Bedding material beneath the pipe should not have rocks larger than 3.8 cm (Magdi and Zumrawi, 2016). Clay soil can be used if it is carefully compacted at a uniform near optimum moisture content (Montana State University, 1992).

The following guidelines provide specific considerations and details for various conditions in a step-by-step installation sequence according to (NCSPA, 2003), this includes:

1. Check alignment in relation to the plans as well as the actual site conditions.
2. Make certain that the box or pipe length and necessary appurtenances are correct.
3. Excavate to the correct width, line and grade.
4. Provide a uniform, stable foundation—correct site conditions as necessary.
5. Unload, handle and store the box correctly.
6. Assemble the box or pipe properly—check alignment, follow special procedures for the connecting bands, gaskets, and other hardware used.
7. Use a suitable (granular) backfill material as required in the plans and specifications.
8. Maintain proper backfill width.
9. Haunch the box or pipe properly.
10. Place and compact the backfill in 6 to 8 inches (150 to 200 millimeters) of thickness of compacted lifts.
11. Install the necessary end treatment quickly to protect the pipe and your efforts.
12. Protect the structure from heavy construction equipment loads, other heavy loads and hydraulic forces.

2.4 Scouring of Culvert

Eroding of the downstream of a culvert as a result of debris accumulation upstream is referred to as scoring. This occurs when this debris, through crossing hydraulic structures cause the upstream water level and the downstream scour depth to increase, which can lead to failure of the structure. Local scour downstream of culverts involves the removal of granular bed material through the action of hydrodynamic forces. As the maximum scour depth downstream of the culvert increases, the stability of the foundation of the structure may be threatened with a consequent risk of damage and failure (Sarathi, et al 2008). Scour characteristics downstream are affected by many factors, below are previous studies on factors affecting scour characteristics downstream.

2.4.1 Previous Studies on Scour Characteristics Downstream.

Many previous studies have studied the factors affecting the scour hole characteristics downstreamof the culverts. (Abt et al. 1987a: Abt et al. 1987b), experimentally studied the effect of culvert shape on scour hole dimensions.Different culvert sections such as square, arch and rectangular culvert shapes were investigated withuniform graded sand (D50 at 1.86 mm). The results revealed that culvert cross-section shape had alimited effect on outlet scour. (Chen, 1970) and (Ruffet al. 1982) observed that under equivalent dischargeconditions, a square culvert with a height equal to the diameter of a circular culvert would reducescour. (Abt et al. 1985) studied the culvert slope influence on the maximum scour depth, experimental testswere performed on a circular pipe with various slopes (0, 2, 5, 7 and 10%), and uniform graded sand(D50 at 1.86 mm) was used. The results showed that the maximum scour depth increased as the culvertslope increased within the range of the slopes tested.

Doehring and Abt (1994) studied culvert drop height effects on the maximum scour depth.Experimental tests were performed in a 4-inch diameter circular culvert and uniform sand with D50 at 1.86 mm. Drop heights of 0, 1, 2 and 4 times the culvert diameter above the bed were investigated.The results showed that the depth of scour was directly proportional to discharge intensity. As the relative drop height increased, the maximum scour depth increased proportionally, the width of scour increased, the scour length decreased, and scour hole volume increased. Abt et al. (1984) investigated the effects of varying non-cohesive bed material on local scour geometry at circular culvert outlets. Five non-cohesive bed materials were tested downstream of a four-inch diameter circular culvert. The results produced a single expression for estimating the relative scour depth. Aderibigbe and Rajaratnam, (1998) investigated the effects of sediment gradation on scour hole shape deformed by wall jets. Three sediment mixtures were investigated withD50 at 6.75, 1.32 and 1.62 mm, and geometric gradations (∂) of 1.32, 2.02 and 3.13, respectively. The results demonstrated that sediment non-uniformity had a significant effect on the scour hole dimensions deformed by the jets. There is good correlation between the effective sediment size D95 and scour depth at more than D50 for estimation.FdAbidaand Townsend, (1991) investigated experimentally the effects of bed material properties on scour hole patterns downstream of a box culvert. The results showed that the maximum scour in uniform sands was greater than in well-graded mixtures. Sarathi et al. (2008) studied sediment grain size effects on scour hole dimensions in a non-cohesive sand bed.

One of the problems affecting crossing structures such as culverts is debris accumulation upstreamor inside them, which becomes an obstruction in the waterway. Floating or submerged debris causeshigher velocities and vortices, which increase the scour depth downstream of the culvert as well asraising the upstream water level, which increases the possibility of the structure failure during aflood event (Hemdan et al. 2016). Yasser Abdallah et al. (Hemdan et al. 2016: Moussa et al. 2018) studied experimentally the effects of partial blockagepermeability on scour characteristics in front of bridge piers and found that partial blockage occurrencein front of a bridge pier had considerable interest due to its influence on the stream flow and the formedscour around the neighboring bridge supports. (Sorourian et al. 2014: Sorourian, 2015: Sorourian and Keshavarzi, 2016) experimentally investigatedblockage ratio effects on scour characteristics downstream of a square culvert under steady flow,the results showed that blockage had a significant effect on the flow structure and scouring holedimensions at the culvert outlet. The velocity distribution was rapidly increased in the culvertbarrel in blocked condition and the average turbulent intensity was three times greater than thenon-blocked condition.

It may be concluded from the above studies that culvert shape, culvert slope, soil properties,tail-water depth and culvert blockage are the main factors affecting downstream scour deformation.

2.4.2 Minimizing Scour Downstream Characteristics.

Local scour downstream the box culverts outlet may cause a complete failure of the culvert structure. New research is employed to reduce the max scour depth downstream the outlet of the box culvert under a different flow conditions based on an experimental investigation. (Abdel et al. 2019) suggest a sharp edge sill proposed on a rigid bed to dissipate the excess flow energy. Consequently, a great reduction of the scour hole dimensions is obtained by using the sharp edge sill. The experimental study was carried out using a different positions, heights and shapes of the sharp edge sill with different flow rates as well as tail water depths. The results indicate that the sharp edge sill is a promising tool to reduce the scour dimensions. The reduction of the scour depths by using the sharp edge sill are 60%, while the reduction in the scour depths are 64%, on account of using of rigid apron of length 7 times the height of culvert, compared to previous results without rigid bed. (Abt et al. 1984) suggest that Protection against scour at culvert outlets varies from limited riprap placement to complex and expensive energy dissipation devices. At some locations, use of a rougher culvert material may alleviate the need for a special outlet protection device.

2.4.3 Other Causes of Failures on Culvert.

Various reasons of failure on culvert including lack of maintenance, environmental, and installation-related failures, capacity related failures. Those failures causing erosion of the soil around and under the culvert, and structural or material failures that causes culverts to fail due to collapse or corrosion of the materials from which they are made (Architectural Record, 2013).

Capacity related failures of culvert in some cases is accelerated by floating trees that blocks the inlet of culvert in some cases which causes high pressure. Overflow water on the embankment and through the foundation of pipe culvert is the main contributor to the wear and damages of culverts (Magdi and Zumrawi, 2016).

Failures on culverts may occur suddenly. Sudden road collapses are often the result of poorly designed and engineered culvert crossing sites or unexpected changes in the surrounding environment cause design parameters to be exceeded. Water passing through undersized culverts will scour away the surrounding soil over time. This can cause a sudden failure during medium-sized rain events. Accidents from culvert failure can also occur if a culvert has not been adequately sized and flood event overwhelms the culvert or disrupts the road or railway above it. Ongoing culvert function without failure depends on proper design and engineering considerations being given to load, hydraulic flow, surrounding soil analysis, backfill and bedding compaction, and erosion protection. Improperly designed backfill support around culverts can result in material collapse or failure from inadequate load support (Architectural Record, 2013).

For constructed culverts which have sustainable degradation or loss of structural integrity, rehabilitation using a reline pipe maybe preferred instead of replacement. Sizing of a reline culvert uses the same hydraulic flow design criteria as that of a new culvert, however as the reline culvert is meant to be inserted into an existing constructed culvert, reline installation requires the grouting of the annular space between the host pipe and the surface of reline pipe so as to prevent or reduce seepage and soil movement. Grouting also serves as a means in establishing a structural connection between the liner, host pipe and soil. Depending on the size and annular space to be filled as well as the pipe elevation between the inlet and outlet, grouting maybe required to be performed in multiple stages. As the diameter of the reline pipe will be smaller than the host pipe, the cross-sectional flow area will be smaller.

Failure of pipe culvert may occur due to deformation of pipes which results from load of transportation. Such failure occurs when the soils above pipe culvert are not capable to support transportation loads. Soils above pipe culvert should have suitable strength and compaction and should be of thickness not less than 30cm.

2.5 Efficiency of Culvert Design.

The efficiency of a culvert design is affected by so many factors and according to Flaherty, (1987) different factors are to be considered are as follows:

1. **The depth of water pond:** For a given design, the depth of the pond formed at the entrance is a function of the size and shape of the culverts. Conversely, the manner in which flow takes place in the culvert is affected by the head of water available at the inlet.
2. **Types of entrance:** If the culvert has poorly designed entrance, then considerable turbulence will occur at the inlet and energy will be dissipated which would otherwise be available for moving the water through the culvert.
3. **The roughness of interior walls:** Rough textured culverts which run full will discharge less water than a smooth one also running full, since much of the energy head is used up in overcoming the resistance to flow.
4. **Basic culverts characteristics:** The length of the culvert dictates whether or not the type of entrance and roughness of the interior walls are major or minor feature of the hydraulic design, if the culvert is properly designed, it adequately drain road grades. The structural

and hydraulic design of culverts is substantially different from that of the bridges as are the construction, maintenance, repair and replacement procedures. Culverts are usually designed to operate at peak flows with a submerged inlet to improve hydraulic efficiency. The effects of pounding and flow on appurtenant structures, embankment and abutting properties are important considerations in the design of culverts (Rigby andBarthelmess, 2011). Structural culverts are buried in soil and are designed to support the dead load of soil over the culverts as well as live load of traffic. Either the live load or the dead load may be the most significant load element depending on the type of culvert, type and thickness of the cover and amount of live load. However, live loads on culverts are generally not as significant as dead load unless the cover is shallow.

5. **Maintenance:** Routine maintenance for culverts primarily involves the removal of obstructions and repairs of erosion and scour. Other defects from weathering loads and age will occur and require routine maintenance.
6. **Traffic Safety:** A significant safety of many culverts as compared to bridges is the elimination of construction in the road way. Culvert can economically be extended so that the standard roadway cross section can be carried over the culvert.
7. **Construction:** One of the most significant factors is that culverts are constructed in and through the roadway embankment. The trench width, bedding, composition and amount of fill over the culvert are important factors that influence the ability of the culvert to carry the design load. Thus, the construction techniques and quality control of workmanship are critical to the ultimate serviceability and life expectancy of culvert.
8. **Durability:** Durability of materials is a significant problem in culverts and other drainage structures. In hostile environments, corrosion and abrasion can cause deterioration of all commonly available culvert materials.

2.6 Analysis and Design of Box Culverts.

The structural and hydraulic design of box culvert is different from the bridge design for construction, maintenance, replacement and repair procedure. The basic characteristics of box culverts the first is on hydraulics in which the culvert are designed for highest flood level or peak value with a submerged inlet to improve hydraulic efficiency. Second is load carrying capacity where structural culverts are used to bear all dead load, live load, and load due to pressure, Impact load and braking forces that can safely be resisted by structure and soil. The third one is maintenance; there is a problem with the blockage by debris and sediment, especially when the culvert is subjected to seasonal flow. The fourth one is the construction in which culvert are made to take the vehicle load bycombined strength of box and surrounding embankment. The fifth one is durability of materials which are major problem in box culverts and other drainage structure. Counteractive environment can cause corrosion and abrasion of the available materials. The culvert are divided into categories according to type of materials used in which first is concrete materials which the culvert are made either precast or cast in situ. The selection is depending on the size, type, flexibility etc. Precast concrete are easy to handle and install. Cast in situ culverts are made on site that requires more days for construction. Second is corrugated steel made by factory named as corrugated steel sheet, this culverts are made by steel pipe sections. This is used in steel pipe culverts with steel sheet for greater span. Third is corrugated aluminum, corrugated aluminum culverts are constructed by factory made of corrugated aluminum pipe and this are available as the conventional structure plate for box culvert and long span structure. Fourth is plastic pipe are made from various materials and have a good strength and properties which depend on the base resin made by formulation of chemicals and final resin is used to produce the pipe. According to the shapes of box, the first one is circular pipes and this is the most common shape for pipe culverts. It is structurally and hydraulically efficient under many conditions for smaller opening. Second is pipe arch or elliptical shape which is generally used when distance from channel invert to pavement surface limited to pipe arch and elliptical shape are not structurally efficient as compared to as a circular shape. It is used in the areas with limited vertical clearance. Third is arch culvert which offers less obstruction to the waterway than pipe arches, the structure is also safe for scour design requirements. Fourth is box section or square and rectangular section used generally nowadays due to angular corner of the structure. Fifth one is the multiple cells used where flow channel is wide, span having more length are used to give proper channel to waterways and also where no problem of clogging when the discharge is more.

2.6.1 Previous Studies on Analysis and Design of Box Culverts.

Patil and Galatage (2016) had carried out study on the design and analysis of factors of box culvert done with cushioning and without cushioning the maximum bending moment in each and every loading. The result is that, load combination was found very critical for all aspect ratio, bending moments for different ratio or aspect is varying or constant for with and without cushion. The effect of water ratio 1:1.5 is negligible and for 2:3 is empty. Afzal Hamif Sharif (2016)had done study by using moment distribution method and Staad pro software, compared them and check out all the structural elements for safety of bridge. The results are the advantage of box culvert and their design critical and span length according by ratio of cell and number of cell.

Ajay, Chandreshaand Parikh (2017), had done the analysis and comparison by using design consideration in mind of box coefficient of earth pressure, cushion, width or angle of dispersion and load case for design. The result is without cushion or with cushion and angle of dispersion been zero, there will be maximum live load and greater stresses are created without cushion.

Ayush, et al (2017), had done study of solid slab and R.C.C Box which is evaluated by estimation of quantities, specifications and detailing of each work. The result shows that reinforced box culvert of span up to 9m should be implemented after which the solid slab should be preference for the span range up to 15m.

Sravanthi et al. (2015), had manually design and check all the design factor and coefficients by using codes IRC& IS Codes somewhat using Staad pro software also. Result suggests the advantages of box culvert either single or double depending on the span length and some other factors.

Ketan et al. (2015), had studied the analysis and design of culvert using software hydraulic parameters, graphs, charts, tables showing variations in test result for different ratio which are bending moment, shear force, discharge capacity, loads etc. Result was declared on the basis of the software analysis tables for hydraulic parameter, bending moment for bottom slab, side walls and top slab are shown in tables for different aspect ratio of cell.

Mahesh et al. (2017), had studied the analysis and design of culvert using FEM (ANSYS) Software and IRC guidelines. The internal stresses for the 3m×3m box culvert where the braking force, design moments, total loads all calculated and check for deformation normal stress, principle stress, Von miss stress for without and with cushion conditions. The result obtained was that deformation without cushion is more, maximum principle stress without cushion is more, and also normal stress, shear stress, and equivalent stress are more without cushioning.

Bilal and Parvez, (2015), conducted hydraulic design of box culvert which include catchment area, maximum HFL, longitudinal area, cross section, velocity observation and estimation of discharge by rational method empirical formula (dickens formula), critical depth and height of jump also decides the area and length of apron. The culvert is designed by manual calculations which give size and shape of box according to discharge and depth of scour

Nehaet al. (2014), had studied the analysis and design of box culvert by using manual calculation and IRC code for bridges and roads taken all the design considerations factors. The findings was that box culvert are economical than the pipe drain and also it have various advantage and design factor may be affected if it is done properly.

Saurav and Pandey (2017), had done comparative analysis study and analysis of conventional method using Staad pro software and FEM using ANSYS Software. The result obtained by using both model conclude that 16.8% FEM through ANSYS Software saves large amount of money and gives the more economical design.

Sujata et al. (2013), had find out the coefficients for moment, shear and thrust of single and two cell box culvert by using Staad Pro software. The result for the design of box culvert includes the information regarding the effect different ratio L/H=1.0, L/H=1.25 etc. Also moments and loads were obtained.

Vaishali, and Ashish (2016), had studied the Berackeven Method / Pay Back period cost, time, labor and material by analytic method. The result obtained by using both methods conclude that cost and time of precast structure is less than the cost in situ structure.

Vasu et al. (2018), had studied the analysis and design of box culvert by using Staad Pro software. The culvert are subjected to certain cases and providing the values in the form of graph and tables in which reduction in displacement and reduction in bending moment are shown. The result obtained using software suggests that the bending moment and displacements decline to minimum value taken in percentage.

Vasu et al. (2018), suggested from study that the stress value increases in the flared portion and shear values decreased on increment of flared portion. Principle stresses decline and give a positive response for structural change. The result obtained from manual design shows the graph and their variations in values with respect to stress by using the flared portion and the stress value were dropped for different cases.

Virendra et al. (2017), provided information regarding the skew box culvert of any angle which shows how reinforcement changes analytical and experimental study of skew bridge model, seismic response, dynamic response and different aspect inspections. The result shows that the longitudinal moment decrease in skew approach as compared to straight approach deflection deck slab, which decrease with increase in skew angle, abutment stiffness and also increases with increase in skew angle which significantly contribute to stiffness of the bridge.

Zengabriel et al. (2018), performed the modeling and analysis of precast reinforcement box culvert with FEM and using ABAQUS and tested the stress, deflections and check the box behaviour by plotting the load deflection graph and loads stress graph. The result obtained from the Modeling and analysis of prefabricated box, knowing the steel requirements, load and deflection curve and load stress curve indicate that there is warning of structure before failure of structure is getting.

Bolden, et al. (2016) stated that the culvert design begins when the structure design unit receives the culvert hydraulic design report. This report shall be used to contain the culvert length, design fill, and other items that lead to the completed culvert plans.

Garg, (2007) reported that box culverts are typically designed similar to bridges, and the new design concepts for bridges are based on the Load and Resistance Factor Design (LRFD) which were developed by AASHTO. Box culvert's four sides are built monolithically and also provide haunch at corners to decrease the water pressure effect. In this type of culvert there is no need of extra foundation since bottom slab act as mat foundation.

2.7 Structural Element of Box Culverts

Kumar and Srinivas (2015) stated that box Culverts consist of top slab, bottom slab and two vertical side walls. Reinforced concrete rigid frame box culverts are used for square or rectangular openings. The top of the box section can be at the road level or can be at a depth below road level with a fill depending on site conditions.

Pencol Engineering Consultants (1983) assumed the thickness of the box culvert and later checked in conventional method. However, this may lead to uneconomical design therefore an attempt is made to evaluate optimum thicknesses for economical design.

2.7.1 Applied Design Loads.

Kumar and Srinivas (2015) classified loads subjected to box culvert to dead load and live load. Dead load comprising of self-weight of top and bottom slab of the culvert and two side walls of the structure which is calculated based on clear dimensions of the culvert and thickness of the culvert. Super imposed dead load depends on the typed road constructed above the culvert and is calculated from standards and specifications code of practice. Live load on culvert is vehicular loading. The vehicular live load consistsof wheel loads moving on top slab of culvert. These loads are distributed through the top slab of the culvert. Earth can exert pressure as active and passive, minimum is active and maximum is passive earth pressure and the median is rest.

Chandrakant and Malgonda (2014) concluded that, since box culvert carries earth embankment which is subjected to same traffic loads as the road carriestherefore; it is required for the box culvert to be designed for such loads. The structural elements are required to be designed to withstand maximum bending moment and shear force. Analysis of box culvert is carried out for various load conditions and structural design is suggested for critical cases.

Kim and Yoo, (2002) conducted an investigation for deeply buried structures, the dead weight of soil itself is the main design load and the effect of live loads is not considered significant. AASHTO LRFD Bridge Design Specifications stipulate the computation of the design load on the top slab of the box culvert based primarily on the effective density of the concrete box culverts can be dependent on the installation method and trench installation.

2.8 Design Fundamental.

The successful completion of any structural design project is dependent on many variables, however, there are a number of fundamental objectives which must be incorporated in any design philosophy to provide a structure which throughout its intended lifespan:

1. Will possess an acceptable margin of safety against collapse whilst in use,

2. is serviceable and perform its intended purpose whilst in use,

3. is sufficiently robust such that damage to an extent disproportionate to the original cause will not occur,

4. is economic to construct, and

5. is economic to maintain

Historically, structural design was carried out on the basis of intuition, trial and error, and experience which enabled empirical design rules, generally relating to structure/member proportions, to be established. These rules were used to minimize structural failures and consequently introduced a margin-of-safety against collapse. In the latter half of the 19th century, the introduction of modern materials and the development of mathematical modeling techniques led to the introduction of a design philosophy which incorporated the concept of factor-of-safety based on known material strength, e.g. ultimate tensile stress; this is known as permissible stress design. During the 20th century two further design philosophies were developed and are referred to as load-factor design and limit state design; each of the three fundamental is discussed separately in Sections below.

2.8.1 Permissible Stress Design

When using permissible stress design, the margin of safety is introduced by considering structural behaviour under working/service load conditions and comparing the stresses under these conditions with permissible values. The permissible values are obtained by dividing the failure stresses by an appropriate factor of safety. The applied stresses are determined using elastic analysis techniques, i.e.

Stress induced by working load $\leq \frac{\text{Failure Stress}}{\text{Factor of Safety}}$

2.8.2 Load Factor Design

When using load factor design, the margin of safety is introduced by considering structural behaviour at collapse load conditions. The ultimate capacities of sections based on yield strength (e.g. axial, bending moment and shear force capacities) are compared with the design effects induced by the ultimate loads. The ultimate loads are determined by multiplying the working/service loads by a factor of safety. Plastic methods of analysis are used to determine section capacities and design load effects. Despite being acceptable, this method has never been widely used.

Ultimate design load effects due to ≤ ultimate capacity based on the failure stress of the material (Working load × factor of safety)

2.8.3 Limit State Design

The limit state design philosophy, which was formulated for reinforced concrete design in Russia during the 1930s, achieves the objectives set out in Section 2.3 by considering two 'types' of limit state under which a structure may become unfit for its intended purpose. They are,

1. The Serviceability Limit State in which a condition, e.g. deflection, vibration or cracking, occurs to an extent, which is unacceptable to the owner, occupier, client etc.

2. The Ultimate Limit State in which the structure, or some part of it, is unsafe for its intended purpose, e.g. compressive, tensile, shear or flexural failure or instability leading to partial or total collapse.

2.9 Eurocode 2

The basis of the approach is statistical and lies in assessing the probability of reaching a given limit state and deciding upon an acceptable level of that probability for design purposes. The method in most codes is based on the use of characteristic values and partial safety factors.

In the Eurocode series of European standards (EN) related to construction, **Eurocode 2: Design of concrete structures** (abbreviated **EN 1992** or, informally, **EC 2**) specifies technical rules for the design of concrete, reinforced concrete and prestressed concrete structures, using the limit state design philosophy. It was approved by the European Committee for Standardization (CEN) on 16 April 2004 to enable designers across Europe to practice in any country that adopts the code.

Concrete is a very strong and economical material that performs exceedingly well under compression. Its weakness lies in its capability to carry tension forces and thus has its limitations. Steel on the other hand is slightly different; it is similarly strong in both compression and tension. Combining these two materials means engineers would be able to work with a composite material that is capable of carrying both tension and compression forces.

Eurocode 2 is intended to be used in conjunction with

1. EN 1990: Eurocode - Basis of structural design;
2. EN 1991: Eurocode 1 - Actions on structures;
3. **hENs**, **ETAGs** and **ETAs**: Construction products relevant for concrete structures;
4. ENV 13670: Execution of concrete structures;
5. EN 1997: Eurocode 7 - Geotechnical design;
6. EN 1998: Eurocode 8 - Design of structures for earthquake resistance, when concrete structures are built in seismic regions.

Eurocode 2 is subdivided into the following parts:

Part 1-1: General rules, and rules for buildings
Part 1-2: Structural fire design
Part 1-3: Precast Concrete Elements and Structures
Part 1-4: Lightweight aggregate concrete with closed structure
Part 1-5: Structures with unbonded and external prestressing tendons
Part 1-6: Plain concrete structures
Part 2: Reinforced and prestressed concrete bridges
Part 3: Liquid retaining and containing structures

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

The study was conducted in Mgbakwu and Isuaniocha communities in Awka North Local Government Area of Anambra State, Southeast Nigeria. The study communities lies between latitude 6^o 26^1 N/4^o 05^1N and longitude 7^o 03^1 E/7^o 30^1E. The area is within the tropical rain forest zone and has marked wet and dry season. The wet season (march-october) is about 8 months while the dry season (October-February) is about 4 months with an average relative humidity of 70%. The length of the road is 16m and the chainage points for both the single and triple box culverts are 0 + 525m and 0 + 725m respectively. The area has a landmass of 1.347km^2 and 1.426km^2 with a population of 5920 and 6450 (2009-2015) respectively. The study area located in Awka North is surrounded by neighboring places like Awba, Ofemili, Ugbene, Ebenebe, Achalla, Urum, Amansea, Amanuke and Ugbenu.

3.2 Hydraulic Design Information

The hydraulic design information for the as-built single and triple box culvert along Mgbaukwu/Isuaniocha road is presented in Table 3.0 below. The measurement of the as-built culvert structure was done with the aid of a measuring tape and recording material. It is however worthy of note that the dimensions of the respective culverts obtained after measurement is relatively different, the findings obtained from the design will be applicable to the respective culverts from different location. Information on chainage was sourced through the structural department situated under ministry of works Awka, Anambra State.

Table 3.0 Hydraulic Design Information for the Proposed Culvert.

Relevant Design Codes	**EN, 1992-1-1, Euro code 2-Part 1-1, Design of Concrete Structure.** **EN, 1992-1-2, Euro code 2-Part 1-1, Design of Concrete Structure.**
General Loading Condition	**HB Loading Units (30 and 45 units).** **Specific Density of Concrete = 25KN/m^3** **Density of active earth pressure = 18KN/m^3** **Water Pressure = 10KN/m^3** **Unit Weight of asphalt concrete = 22.5kN/m^3** **Characteristic Strength of Concrete = 30Mpa** **Characteristic Strength of Steel = 500Mpa** **Effective Pressure for Wheel Load = 1.1N/mm^2** **Factor of horizontal active pressure = 0.33** **Concrete cover = 50mm**
Factor of Safety	**Dead Load (G_k) = 1.35** **Imposed Load (Q_k) = 1.5** **Ultimate design load = 1.35 G_k + 1.5 Q_k**
Design Data	**Fixed End Moment = $\frac{wl2}{12}$** **Free End Moment = $\frac{wl2}{8}$** **Minimum area of steel = 0.4%bh** **Design parameters for moment and Shear force (Axial Pull) for Top Slab, Vertical walls and Bottom Slab = $\frac{N}{bh}$ and $\frac{M}{bh2}$**
Single Cell Box Culvert Details	**Width of Culverts = 2500mm (2.5m)** **Depth of Culverts = 2700mm (2.7m)** **Thickness of Culverts = 300mm (0.3m)** **Length of Culvert = 7500mm (7.5m)** **Depth of Earth fill = 140mm (1.4m)** **Chainage point for the single culvert: 0 + 525m** **Thickness of foundation = 150mm (0.15m).** **Wing wall dimension at both ends = 760mm and 120mm respectively.**
Triple Cell Box Culvert Details	**Width of Culvert = 3950mm (3.95m)** **Depth of Culverts c/c of Top and Bottom Slab = 1600mm (1.6m)** **Thickness of Earth fill = 1200mm (1.2m)** **Thickness of Asphalt = 100mm (0.1m)** **Thickness of all Element = 350mm (0.35m)** **Chainage Points for Triple Cell Culverts = 0 + 725m** **Length of Culvert = 1600mm (1.6m)** **Thickness of Foundation = 150mm (0.15m)**

	Wing wall dimension at both ends = 1000mm and 1200mm respectively.

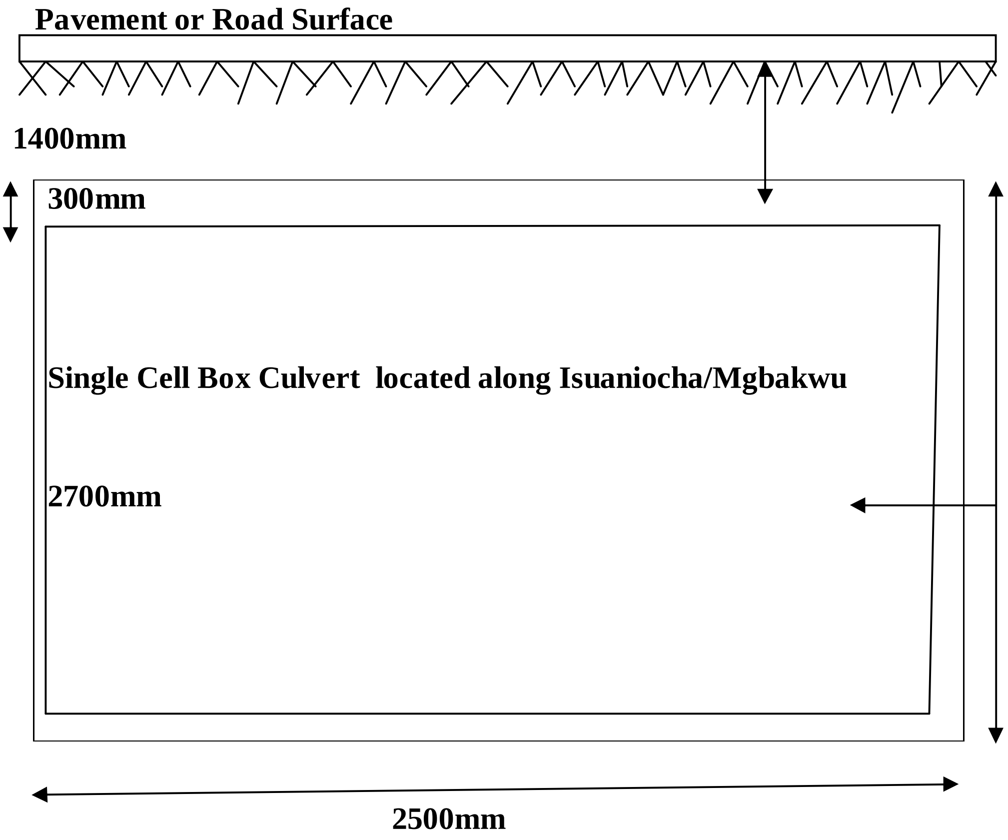


Figure 3.0 Details of Single Cell Box Culvert

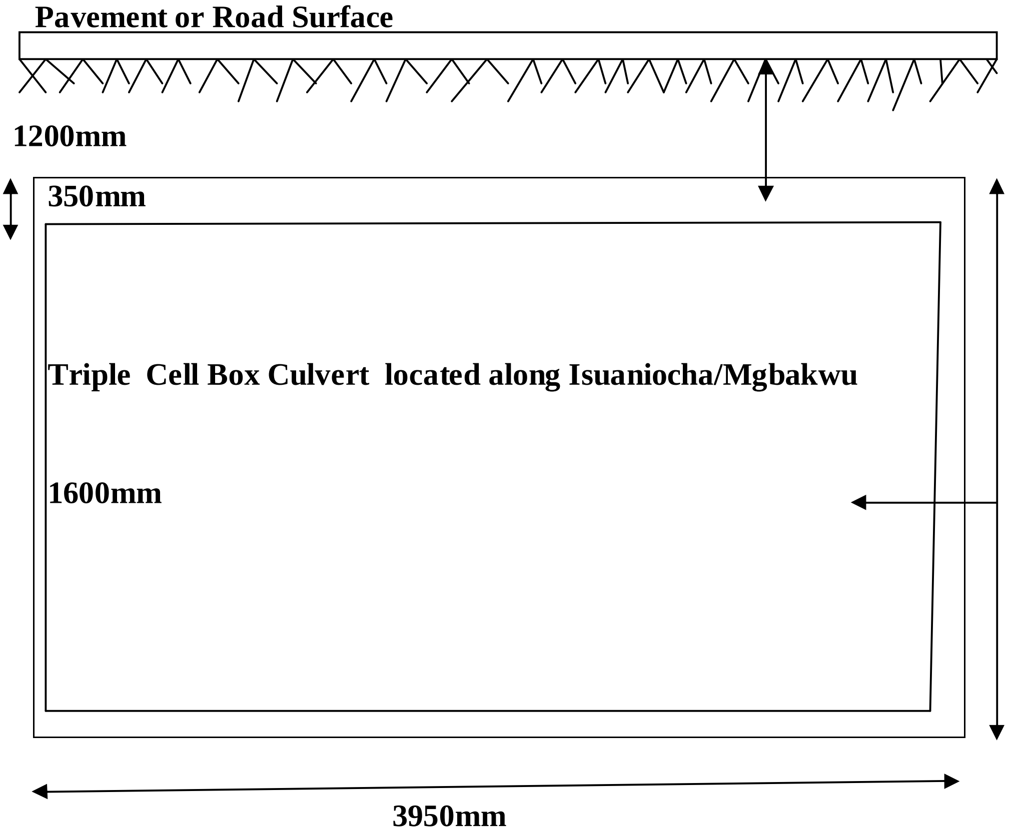


Figure 3.1 Details of Triple Cell Box Culvert.

3.3 Design Consideration for Structural Members

The design is carried out for 7.5m and 16m length of the single box culvert was based on theobtained dimensions from the hydraulic design. The culvert was designed as a hydraulic structure with moment occurring at the four corners. Mainly, the load cases for boxculvert design are: -

1. Box empty, live load surcharge on top slab of box and superimposed surchargeload on earth fill. Active earth pressure, self weight on walls, Top slab and its entire imposed load together with the wall load on bottom slab.
2. Box inside full with water, live load surcharge on top slab and superimposedsurcharge load on earth fill. Water pressure on inside walls and also water pressure and self weight of wall on bottom slab.

3. Box inside full with water, no live load surcharge on top slab and superimposedsurcharge on earth fill. Full water pressure on inside walls and full water pressure and self weight of wall on bottom slab.

Oyenuga (2001) proven that the first load case gives the higher value of moments,because when the box culvert inside full with water, the resultant force ofhydrostatic water pressure on the inside and resultant of superimposed surchargeload on the outside, the sum of the two resultants yields a lesser resultant forceacting on the culvert wall. But however, the analysis and design will be done with due consideration to both cases with the higher value of internal stresses developed used for the final design.

3.4 Analysis and Design of Structural Elements using Euro code2

3.4.1 Top Slab

The method adopted for analysis and design of top slab include:

1. Load assemblage and estimation
2. Calculation of Fixed and Free end moment from ultimate design load calculated in 1.
3. Analysis of fixed end moment using hardy cross method of moment distribution.
4. Generation of final design moment through the principle of superimposition of free end moment with consideration of higher value.
5. Calculation of shear force (Axial pull) from design load.
6. Selection of final shear force to be used for design.
7. Design proper.
8. Provision of reinforcement size, type and spacing.
9. Preparation of bar bending schedule.

3.4.2 Vertical Walls

The method adopted for analysis and design of vertical walls include:

1. Load assemblage and estimation
2. Calculation of Fixed and Free end moment from ultimate design load calculated in 1.
3. Analysis of fixed end moment using hardy cross method of moment distribution.
4. Generation of final design moment through the principle of superimposition of free end moment with consideration of higher value.

5. Calculation of shear force (Axial pull) from design load.
6. Selection of final shear force to be used for design.
7. Design proper.
8. Provision of reinforcement size, type and spacing.
9. Preparation of bar bending schedule.

3.4.3 Bottom Slab

The method adopted for analysis and design of bottom slab include:

1. Load assemblage and estimation
2. Calculation of Fixed and Free end moment from ultimate design load calculated in 1.
3. Analysis of fixed end moment using hardy cross method of moment distribution.
4. Generation of final design moment through the principle of superimposition of free end moment with consideration of higher value.
5. Calculation of shear force (Axial pull) from design load.
6. Selection of final shear force to be used for design.
7. Design proper.
8. Provision of reinforcement size, type and spacing.
9. Preparation of bar bending schedule.

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 Results

During the course of the research, certain analysis were conducted which would be of immense importance in the design of the proposed culverts. The results of the analysis are summarized in Table 4.1 below:

Table 4.1 Summary of Result obtained through analysis of Single Cell Box Culverts along Mgbakwu/Isuaniocha road.

STRUCTURAL MEMBERS	PARAMETERS	EURO CODE 2(EC2)
Top Slab	Load Assemblage (KN/m) When Culvert is empty.	
	Slab own load	10.13
	Wheel load on Slab	30.14
	Earth Load on Slab	37.8
	Ultimate design load	78.07
	Load Assemblage (KN/m) When Culvert is full.	
	Water load	22.5
	Slab own load	-10.13
	Ultimate design load	12.37
	Internal Stresses	
	Moment (KNm)	
	Fixed End Moment	27.84
	Free End Moment	76.51
	Design Moment	48.67
	Shear Force (KN)	53.96
	Area of Steel (mm^2)	
	Area of Steel required	1200
	Area of Steel Provided	1340
	Reinforcement	Y16@150mmc/cT&B
Vertical Walls	Load Assemblage (KN/m) When Culvert is empty.	
	Wall own load	10.13
	Earth fill on wall (W1)	12.47
	Earth fill on wall (W2)	41.88
	Design load	64.48
	Load Assemblage (KN/m) When Culvert is full.	

	Water pressure at Top Slab	**22.5**
	Water pressure at Bottom Slab	**70.5**
	Total load	**93**
	Internal Stresses	
	Moment (KNm)	
	Fixed End Moment	**58.61**
	Free End Moment	**30.51**
	Design Moment	**58.61**
	Shear Force (KN)	**128.69**
	Area of Steel (mm^2)	
	Area of Steel Required	**1200**
	Area of Steel Provided	**1340**
	Reinforcement Provided	**Y16@ 150mmc/c (BF)**
Bottom Slab	**Load Assemblage (KN/m) When Culverts is empty**	
	Top Slab load	**218.60**
	Load from vertical walls	**175.34**
	Unit design load	**140.69**
	Load Assemblage (KN/m) When Culverts is full	
	Load due to Top Slab and Walls	**-38.35**
	Water pressure on walls	**306.9**
	Wall own load	**60.78**
	Unit design load	**99.8**
	Internal Stresses	
	Moment (KNm)	
	Fixed End Moment	**58.61**
	Free End Moment	**90.08**
	Design Moment	**58.61**
	Axial Pull (KN)	**63.77**
	Area of Steel (mm^2)	
	Area of Steel required	**1200**
	Area of Steel provided	**1340**
	Reinforcement provided	**Y16@150mmc/c (BF)**

Table 4.1.1 Summary of Result obtained through analysis of Triple Cell Box Culverts along Mgbakwu/Isuaniocha road.

STRUCTURAL MEMBERS	PARAMETERS	EURO CODE 2(EC2)
Top Slab	Load Assemblage (KN/m) When Culvert is empty.	
	Slab own load	11.81
	Wheel load on Slab	75.54
	Earth Load on Slab	32.4
	Ultimate design load	122.79
	Load Assemblage (KN/m) When Culvert is full.	
	Water load	22.5
	Slab own load	-11.81
	Ultimate design load	10.69
	Internal Stresses	
	Moment (KNm)	
	Fixed End Moment	189.2
	Free End Moment	283.8
	Design Moment	154.83
	Shear Force (KN)	63.05
	Area of Steel (mm^2)	
	Area of Steel required	1600
	Area of Steel Provided	1800
	Reinforcement	Y20 @150mmc/cT&B
Vertical Walls	Load Assemblage (KN/m) When Culvert is empty.	
	Wall own load	11.81
	Earth fill on wall (W1)	16.2
	Earth fill on wall (W2)	48.6
	Design load	76.61
	Load Assemblage (KN/m) When Culvert is full.	
	Water pressure at Top Slab	22.5
	Water pressure at Bottom Slab	54
	Total load	76.5
	Internal Stresses	
	Moment (KNm)	
	Fixed End Moment	12.81
	Free End Moment	13.31
	Design Moment	178.85
	Shear Force (KN)	529.3

	Area of Steel (mm^2)	
	Area of Steel Required	**1600**
	Area of Steel Provided	**2090**
	Reinforcement Provided	**Y20@ 150mmc/c (BF)**
Bottom Slab	**Load Assemblage (KN/m) When Culverts is empty**	
	Top Slab load	**528**
	Load from vertical walls	**159.16**
	Unit design load	**159.8**
	Load Assemblage (KN/m) When Culverts is full	
	Load due to Top Slab and Walls	**-49.71**
	Water pressure on walls	**175.95**
	Wall own load	**54.33**
	Unit design load	**41.99**
	Internal Stresses	
	Moment (KNm)	
	Fixed End Moment	**246.2**
	Free End Moment	**369.34**
	Design Moment	**190.49**
	Axial Pull (KN)	**73.85**
	Area of Steel (mm^2)	
	Area of Steel required	**1600**
	Area of Steel provided	**2090**
	Reinforcement provided	**Y20@150mmc/c (BF)**

4.2 Discussion on Result obtained.

4.2.1 Culverts Loading

The results obtained from the load analysis of structural members of the single and triple cell box culverts using Euro code2 at their respective ultimate limit state indicate that the design loads of the single cell culvert for the top slab, two vertical side walls and bottom slab when the culvert is empty are 78.07, 12.47, 41.88 and 140.69 while when the culvert is full are 12.37, 93 and 99.8 respectively while that of the triple cell box culvert suggest that for the top slab, two vertical side walls and bottom slabs when the culvert is empty are 122.79, 16.2, 48.6 and 159.8 while when the culvert is full are 10.6, 76.5 and 41.99 respectively. The aforementioned results, implies that the bottom slab produces comparatively higher loading than the top slab and walls for both the single and triple cell box culvert respectively, this is evident from the fact that both the load from the top slab and walls is borne by the bottom slab. Comparative deduction with respect to the load estimation of both the single and triple cell box suggest that the triple cell box culvert generate relatively higher magnitude of load when the culvert is considered than when it is considered full.

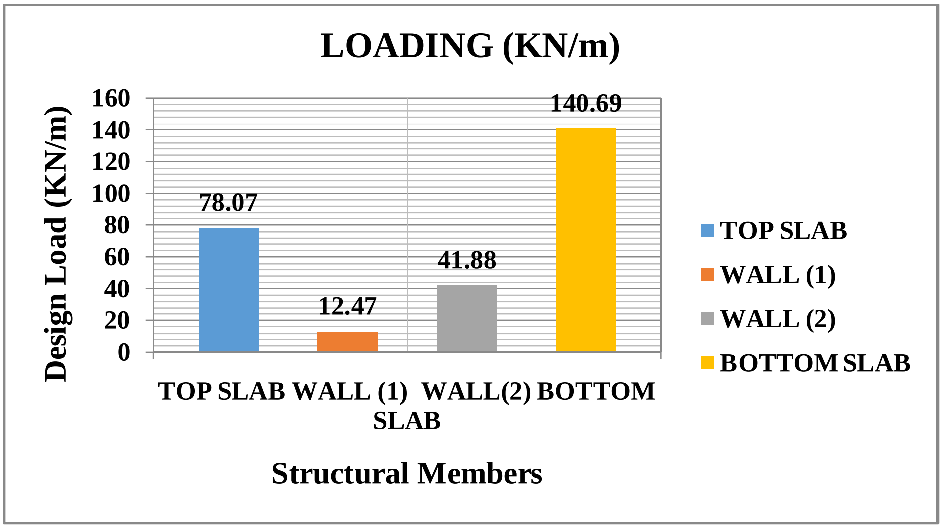


Figure 4.0a: Loadingon Structural Members of Single Cell Box Culvert when Culvert is Empty.

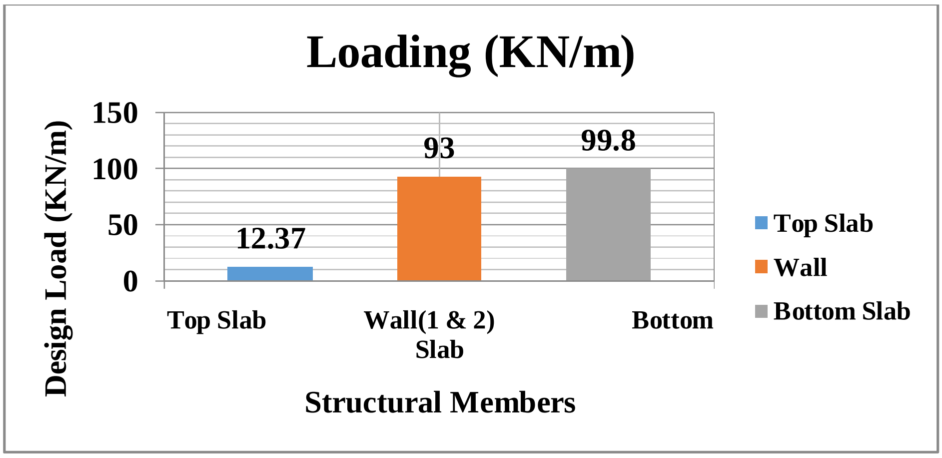


Figure 4.0b: Loading on Structural Members of Single Cell Box Culvert when Culvert is full.

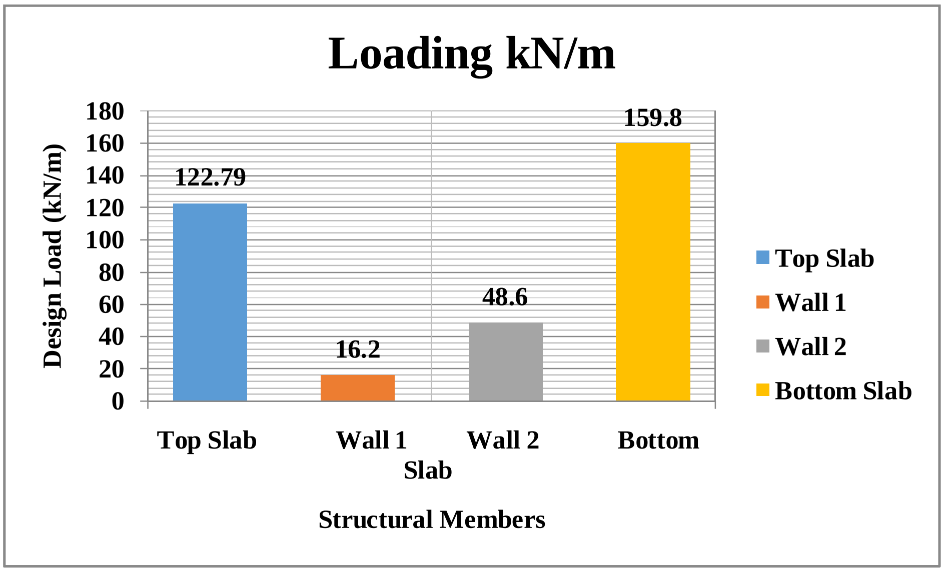


Figure 4.0c: Loading on Structural Members of Triple Cell Box Culvert when Culvert is Empty.

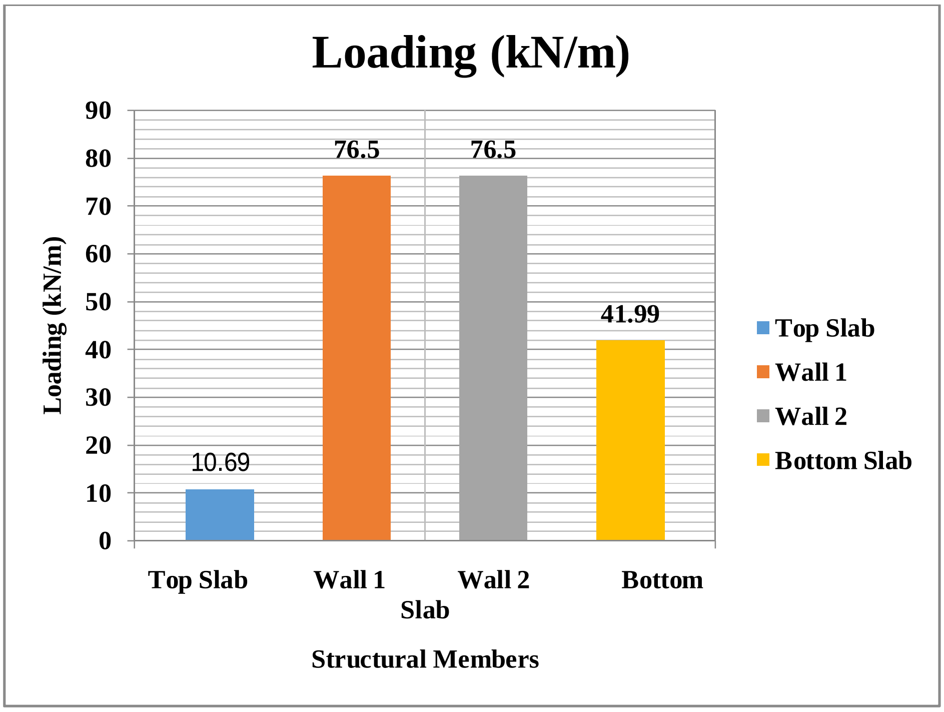


Figure 4.0d: Loading on Structural Members of Triple Cell Box Culvert when Culvert is full.

4.2.2 Fixed and Free End Moment

The fixed and free end moment obtained from the structural analysis of the single and triple cell box culverts members (top slab, walls and bottom slab) using Euro code2 shows thatfor the single cell box culvert, the fixed end moment are 27.84, 58.61, 58.61 and 58.61 while the free end moment are 76.51, 5.48, 25.43 and 90.08 respectively while for the triple cell box culvert, the fixed end moment are 189.2, 11.06, 12.81 and 246.2 while the free end moment are 283.8, 5.66, 13.31 and 369.34 respectively The above results indicate that the fixed end moment of the two vertical side walls and bottom slab are the same for the single cell box culvert with the top slab producing comparatively lower value of fixed end moment while for the free end moment, the bottom slab produces higher value followed by the top slab and the vertical walls. Comparison between the value of both fixed and free end moment generated by both the single and triple cell box culvert suggest that the triple cell box culvert produces comparatively higher value of fixed and free end moment for both the top and bottom slab and this can be attributed to the higher geometry of the triple cell box culvert compared to the single cell box culvert.

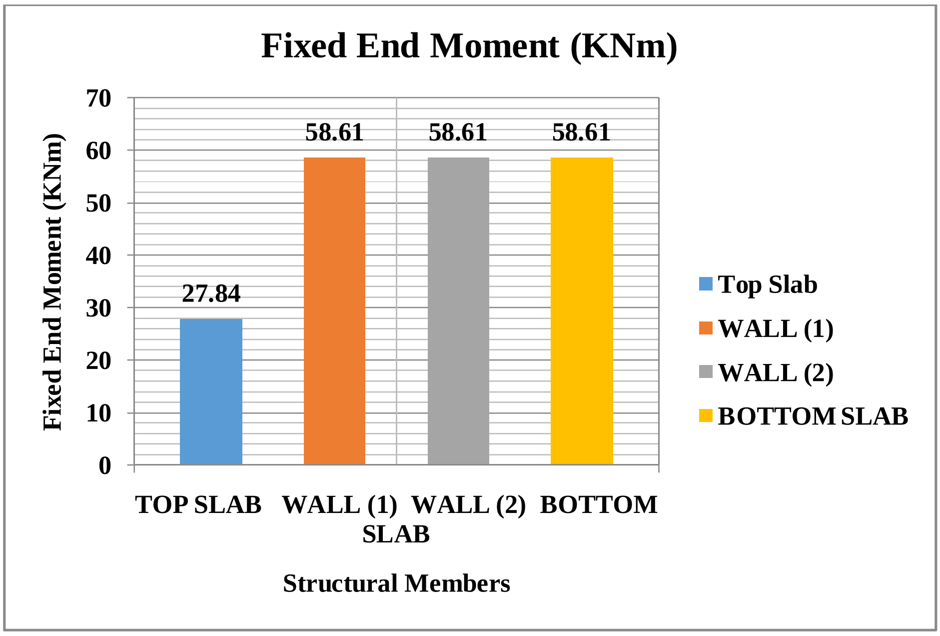


Figure 4.1a: Fixed End Moment for Structural Members of Single Cell Box Culvert.

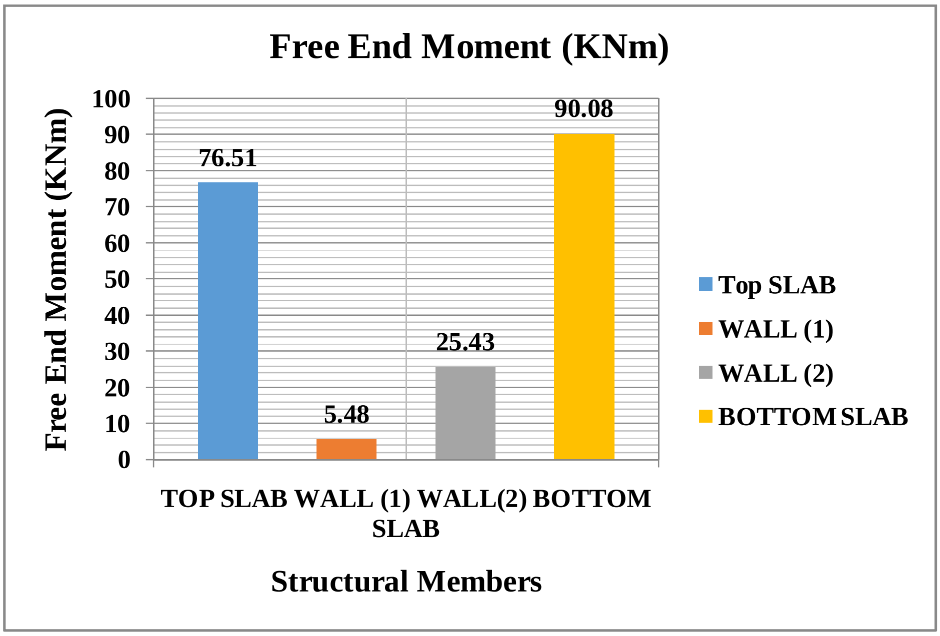


Figure 4.1b: Free End Moment for Structural Members of Single Cell Box Culvert.

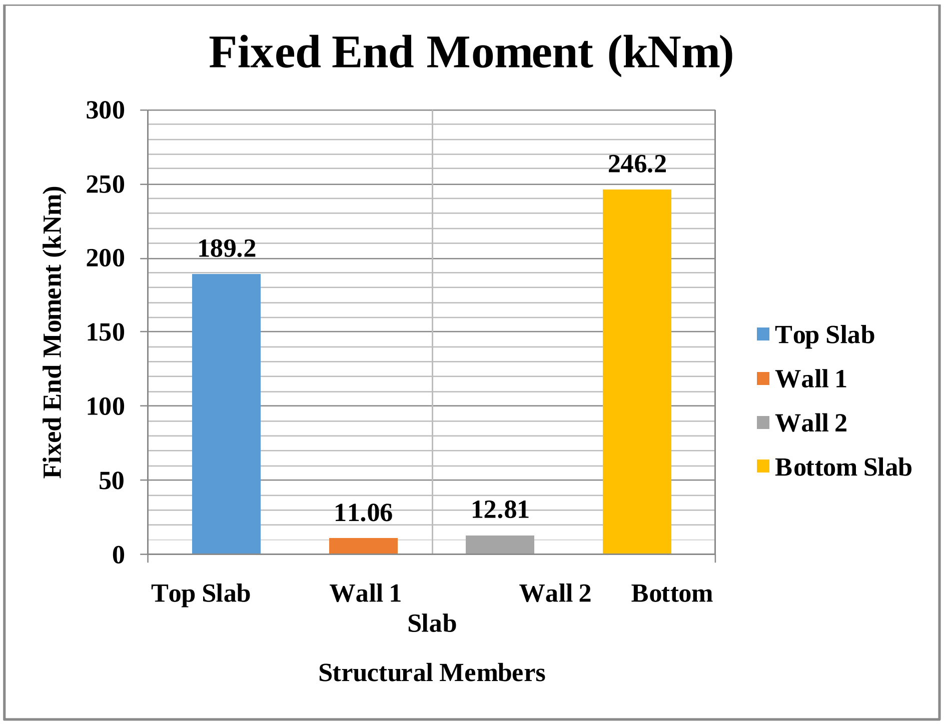


Figure 4.1c: Fixed End Moment for Structural Members of Triple Cell Box Culvert.

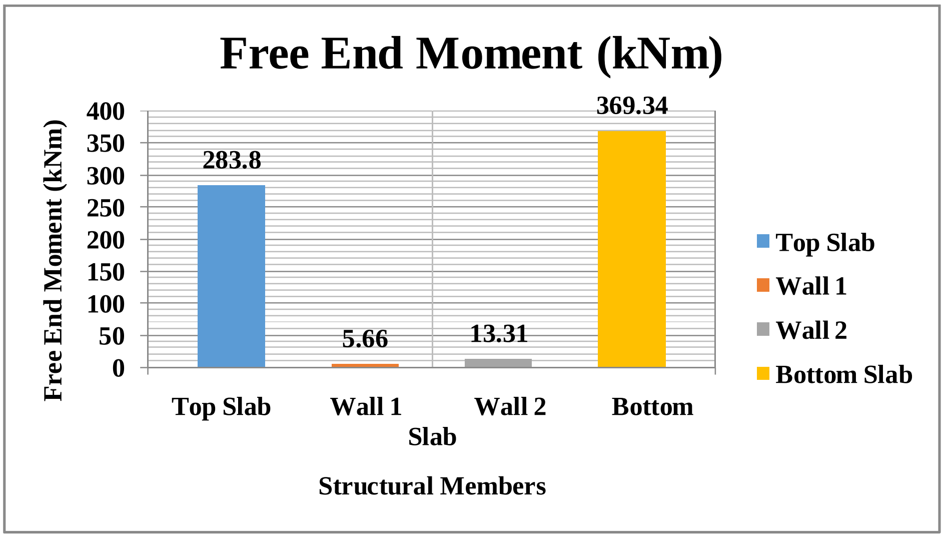


Figure 4.1d: Free End Moment for Structural Members of Triple Cell Box Culvert.

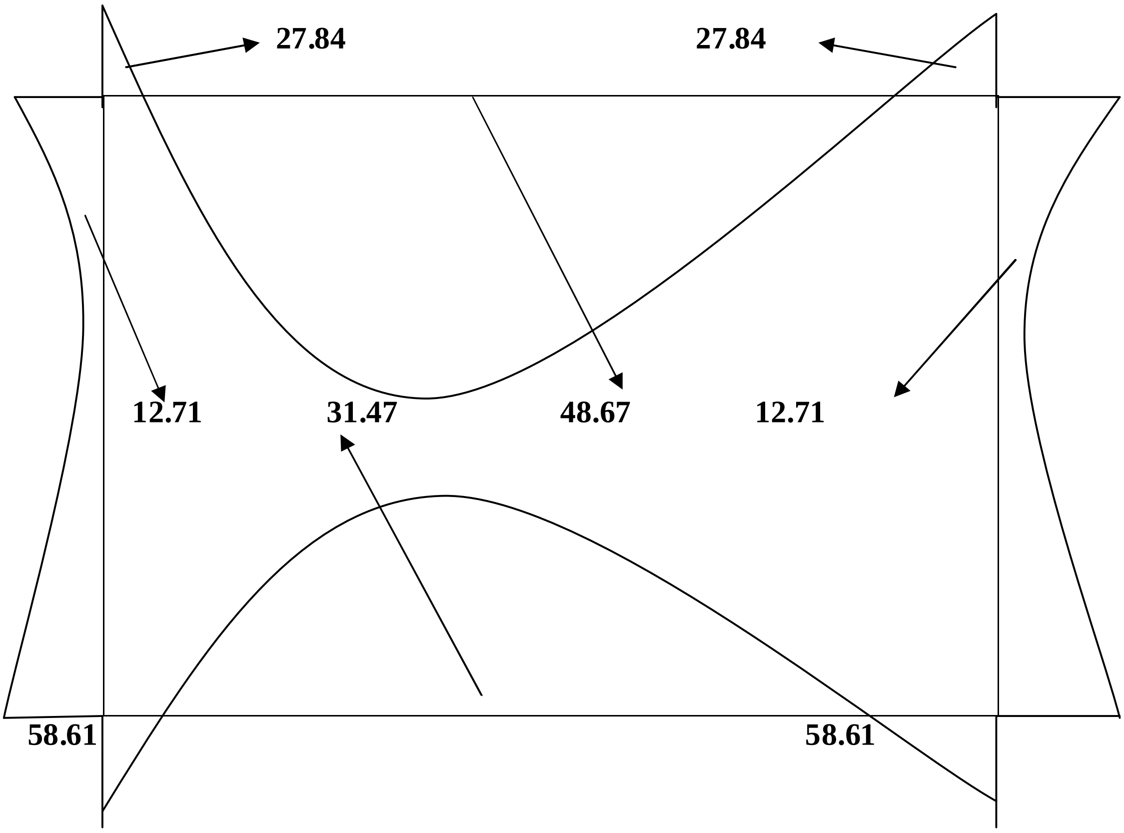
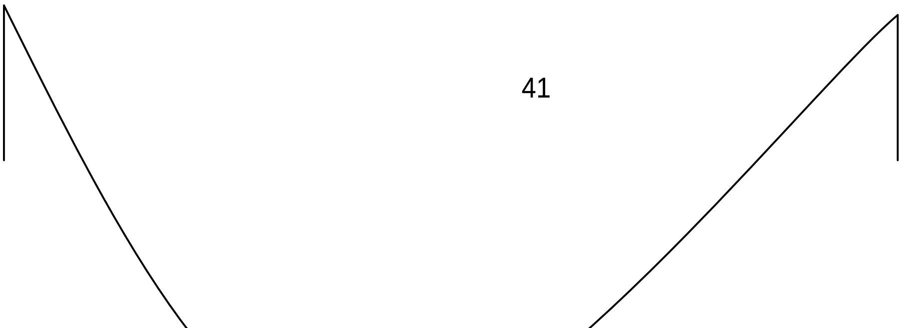


Figure 4.1e Bending Moment Diagram for Structural Members of Single Cell Box Culvert.



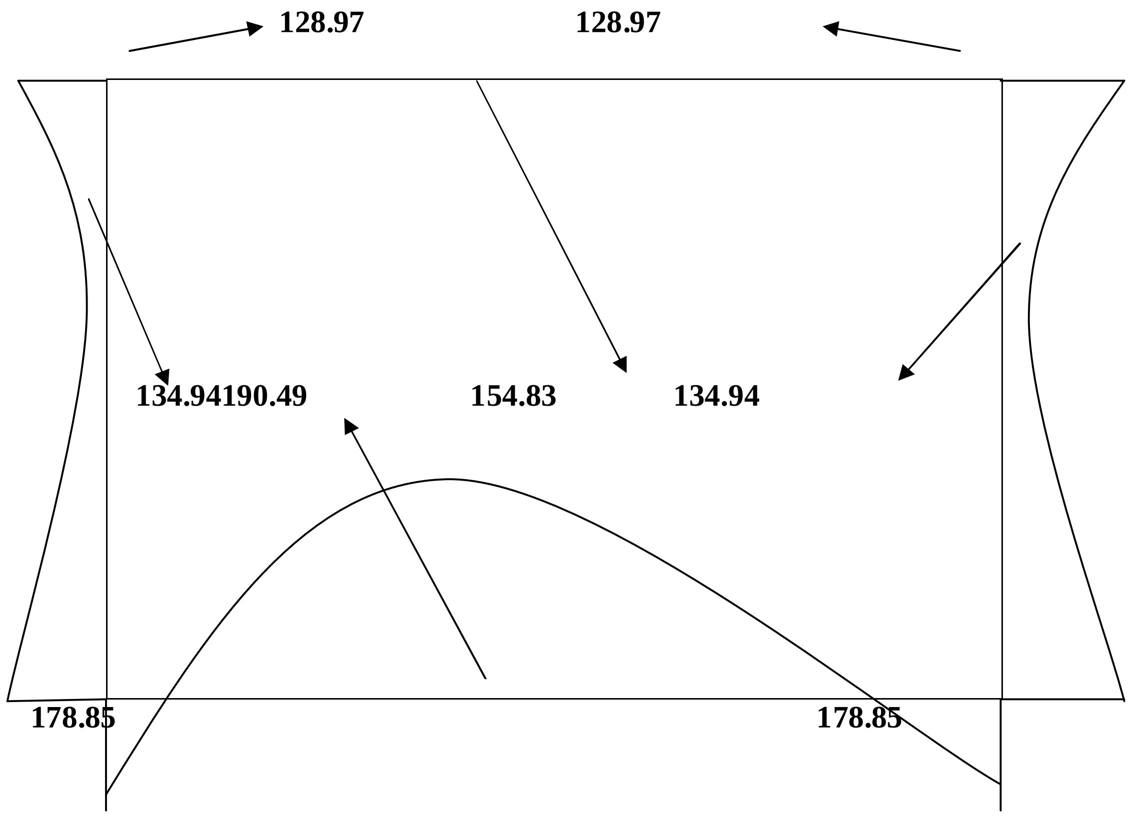


Figure 4.1f: Bending Moment Diagram for Structural Members of Triple Cell Box Culvert

4.2.3 Design Moment

The design moment was obtained after superimposing the free end moment for the respective structural members and considering the highest value of moment as the design moment. The result obtained indicate that the design moment of the two vertical side walls and bottom slab are the same for the single cell box culvert with the top slab producing comparatively lower value of fixed end moment. Comparative inference extracted from both culverts shows that the triple cell box culvert produces relatively larger magnitude of design moment for all structural members with the bottom slab producing the highest value, this can be attributed to the culvert geometry and also due to the fact the a larger magnitude of the load from the top slab and two vertical side walls is borne by the bottom slab which transfers this load safely to the underlying soil.

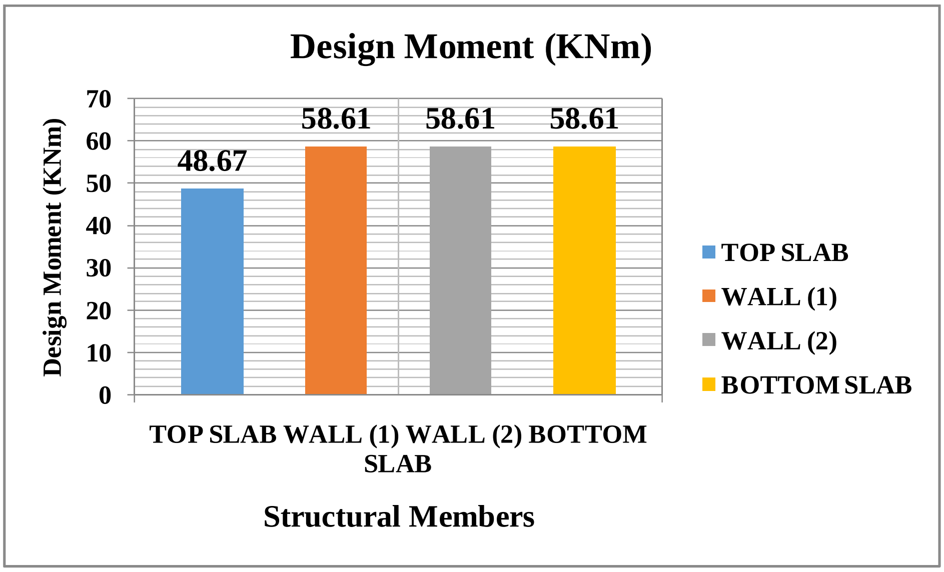


Fig 4.2a: Design Moment for Structural Members of Single Cell Box Culvert.

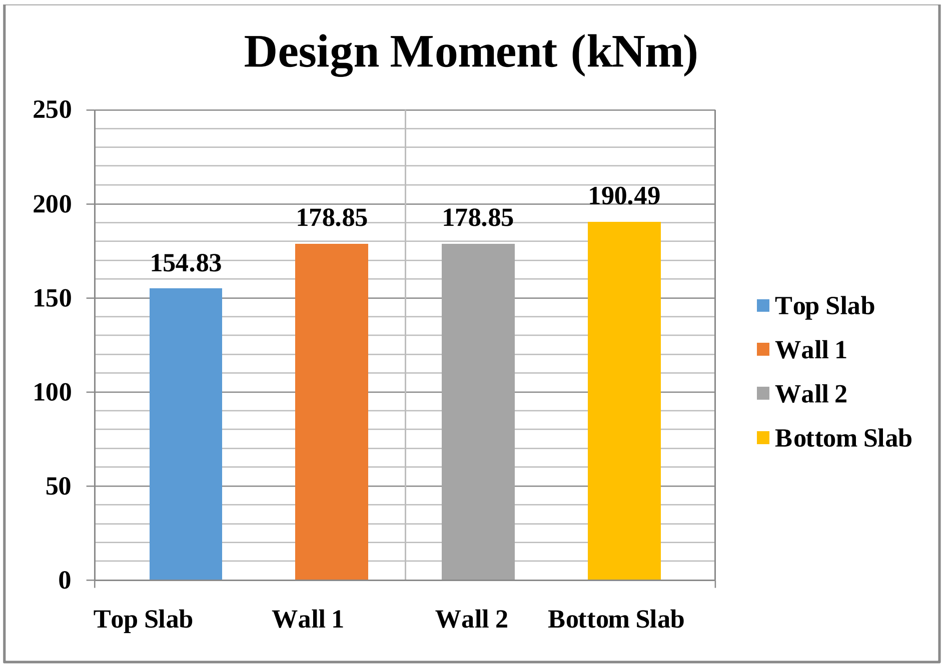


Fig 4.2b: Design Moment for Structural Members of Triple Cell Box Culvert.

4.2.4 Shear Force (Axial Pull).

The shear force generated for the structural members (top slab, vertical walls and bottom slab) of both the single and triple cell box culverts are 53.96, 128.69 and 63.77, 63.05, 529.3 and 73.85 respectively. This result implies that the highest shear generated for the walls of both the single and triple box culverts would be considered for design purpose because of it relatively higher value.

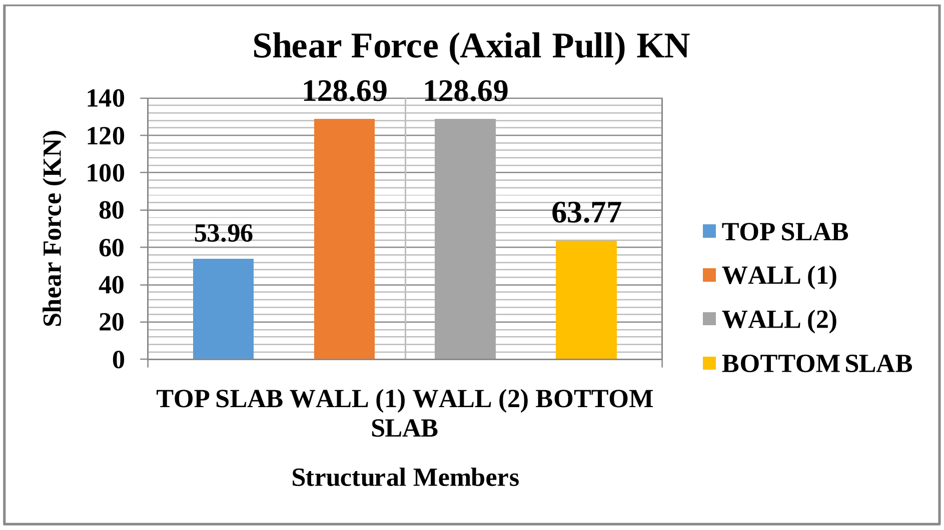


Fig 4.3a: Shear Force Value for Structural Members of Single Cell Box Culverts.

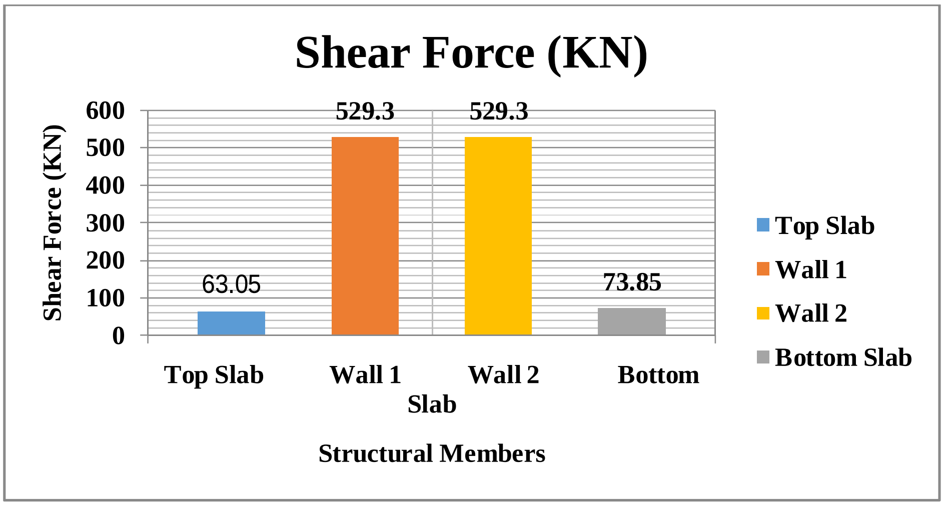


Fig 4.3b: Shear Force Value for Structural Members of Triple Cell Box Culverts.

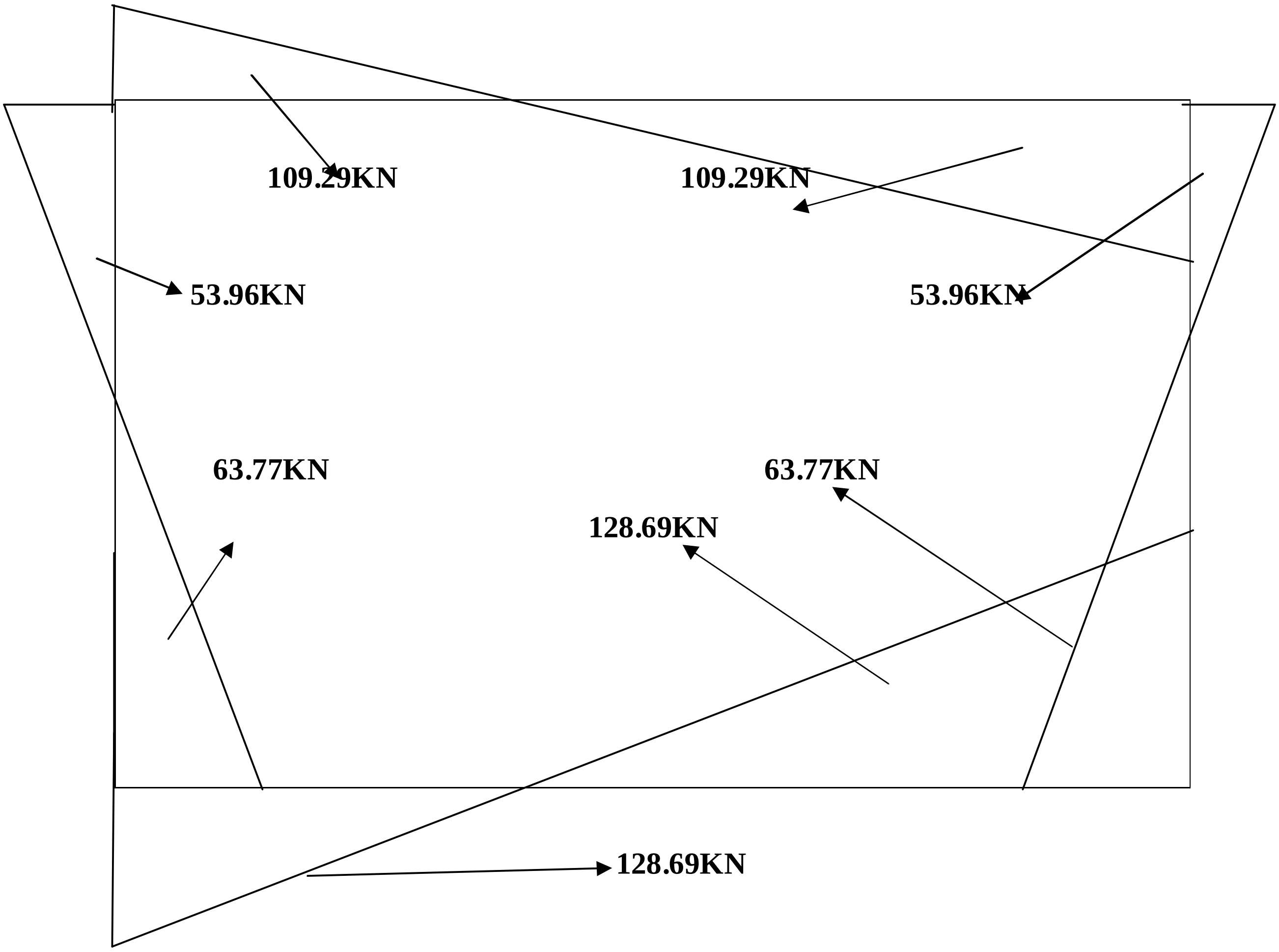
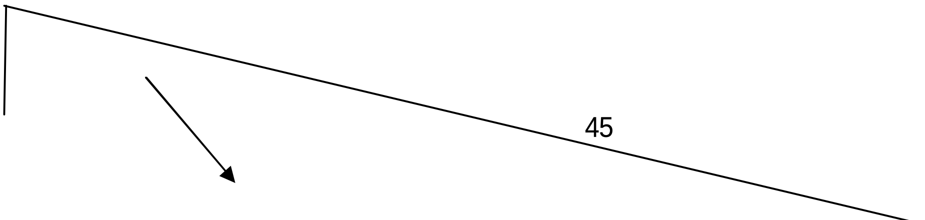


Fig 4.3c: Shear Force diagram for Structural Members of Single Cell Box Culvert.



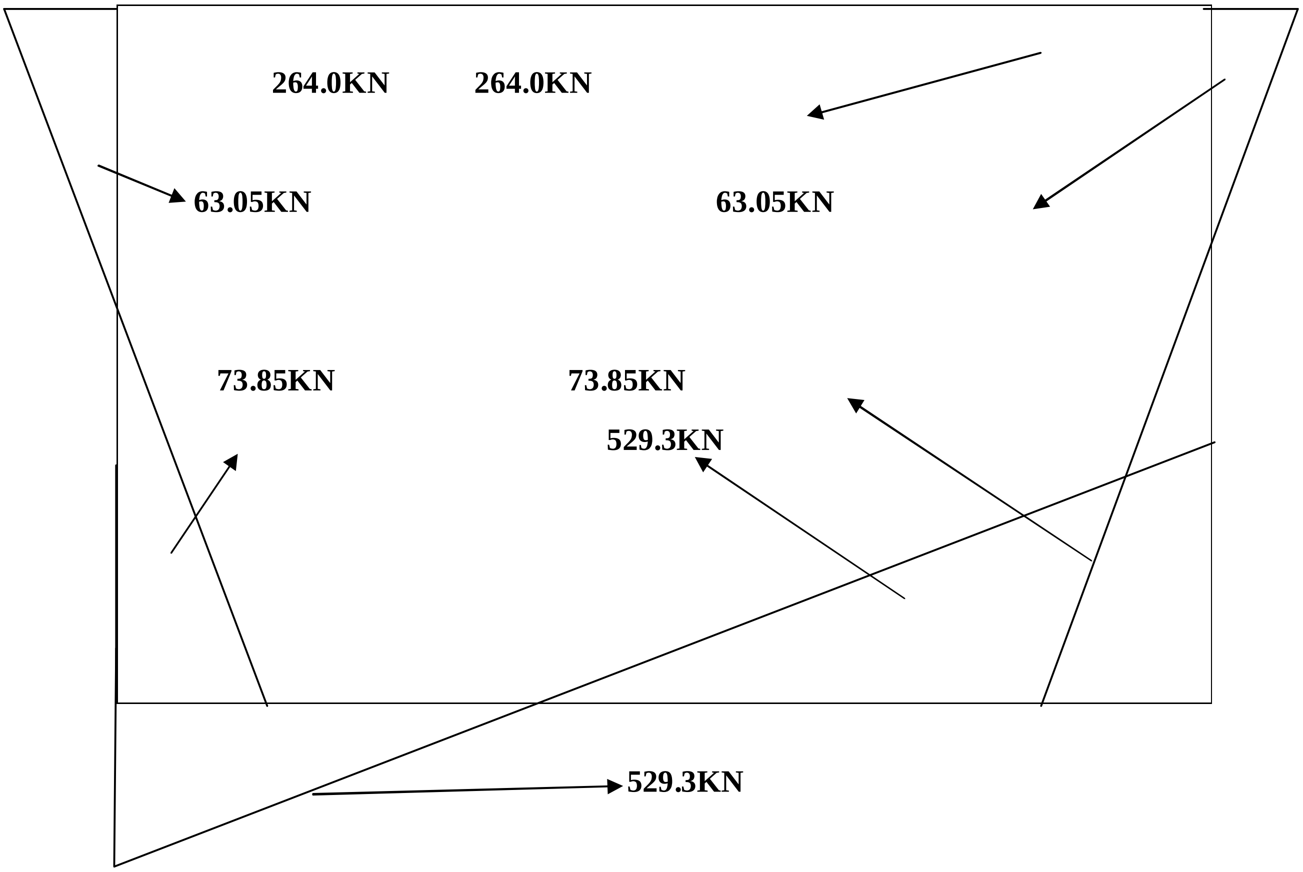


Fig 4.3d: Shear Force diagram of Structural Members for Triple Cell Box Culverts.

4.2.5 Area of Steel

The area of steel required and provided for all structural members (top slab, walls and bottom slab) are the same for the single cell box culvert because the design outcome shows that minimum reinforcement was provided for all members with area of steel required at 1200mm^2 and the area provided at 1340mm^2 respectively. The triple cell box culverts give a required area of 1600mm^2 for all structural members and area provided as 1800mm^2 for top slab and 2090mm^2 for both the two vertical side walls and bottom slab respectively. Comparison between the two culverts suggests that the triple cell box culvert required and provided more area of reinforcement than the single cell box culvert; this can be attributed to the magnitude of moment generated as the triple cell box culvert generated relatively higher magnitude of moment than the single cell box culverts as depicted in the Figure shown below:

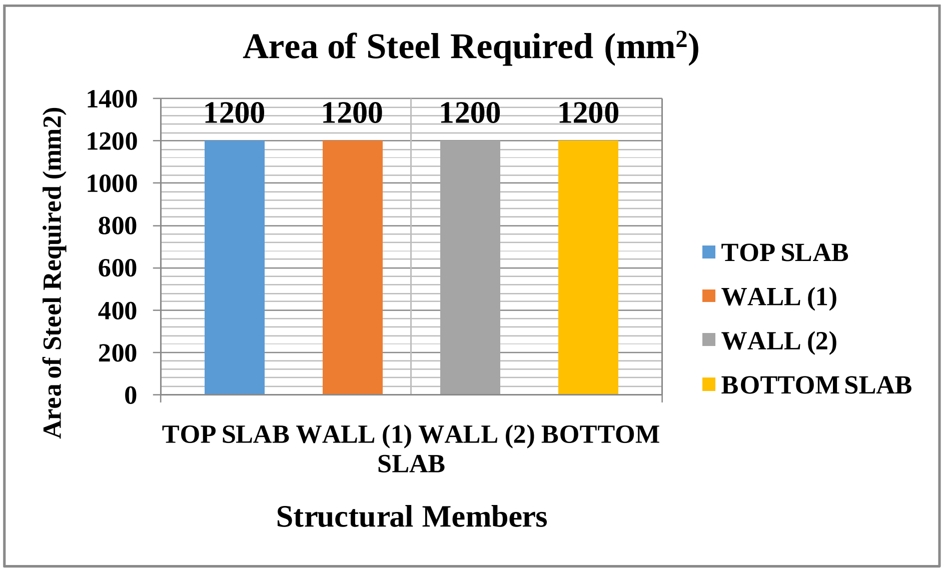


Fig 4.4a: Area of Steel Required for Structural Members of Single Cell Box Culvert.

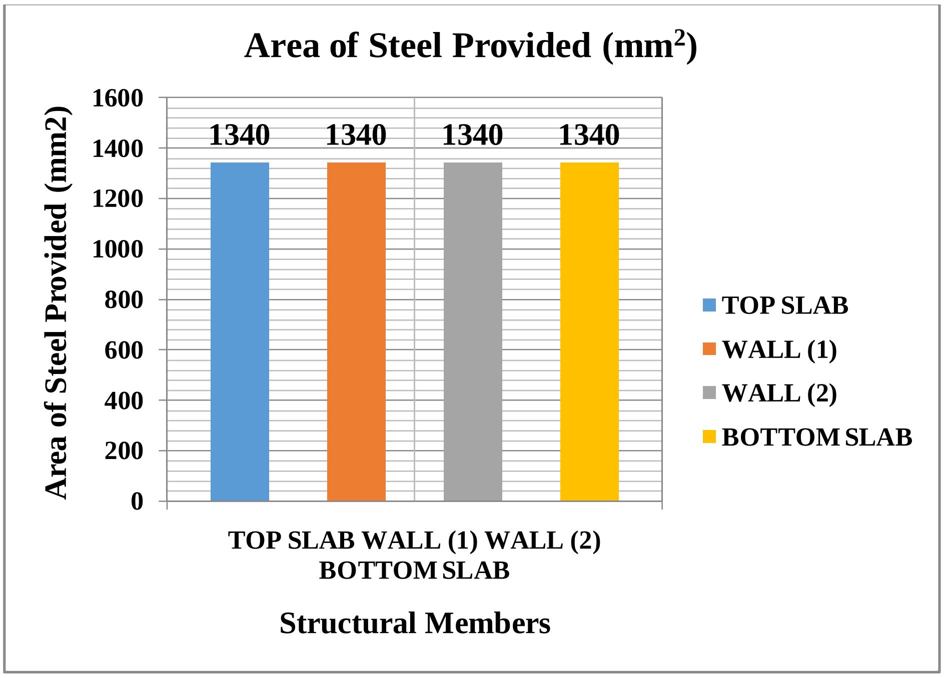


Fig 4.4b: Area of Steel Provided for Structural Members Single Cell Box Culvert.

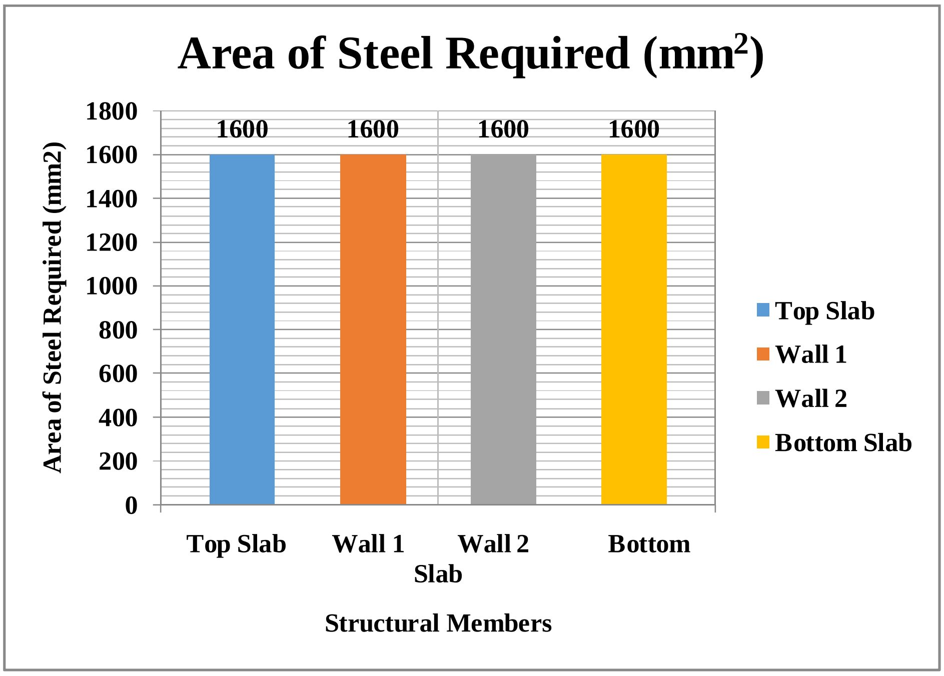


Fig 4.4c Area of Steel Required for Structural Members of Triple Cell Box Culvert.

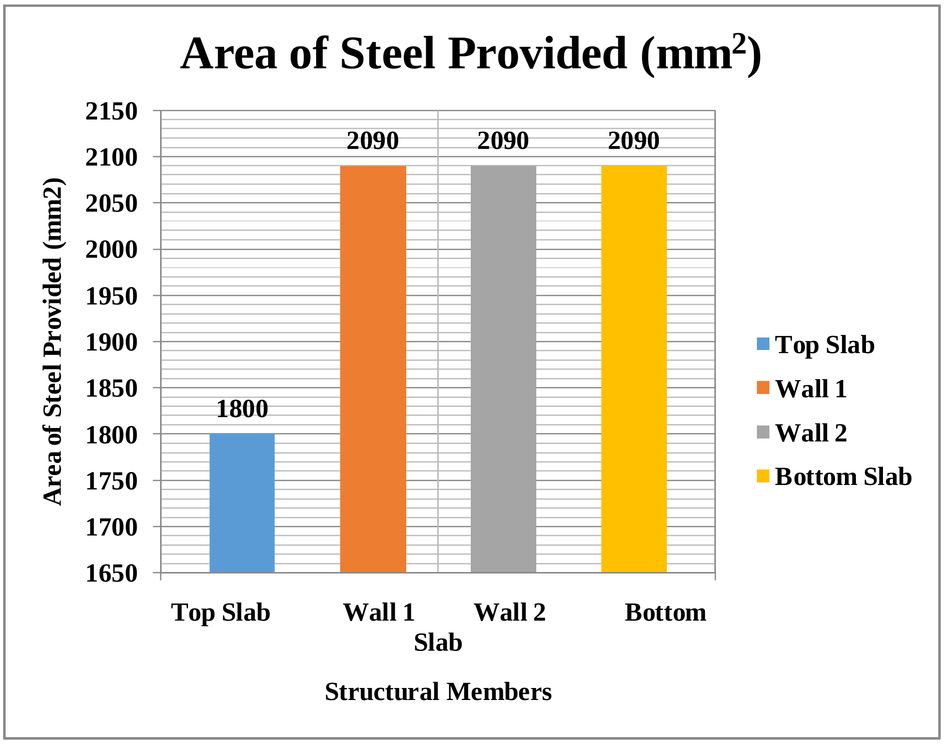


Fig 4.4d Area of Steel Provided for Structural Members of Triple Cell Box Culvert.

4.2.6 Reinforcement Details

The reinforcement details shows that Y16@ 150mmc/c U-bars both face is required as the main bars while Y12@ 200mmc/c both face is required as the distribution bars for the single cell box culvert while Y20@ 150mmc/c U-bars both face is required as the main bars while Y12@ 150 mmc/c both face is required as the distribution bars for the Triple cell box culvert and this applies for all structural members.

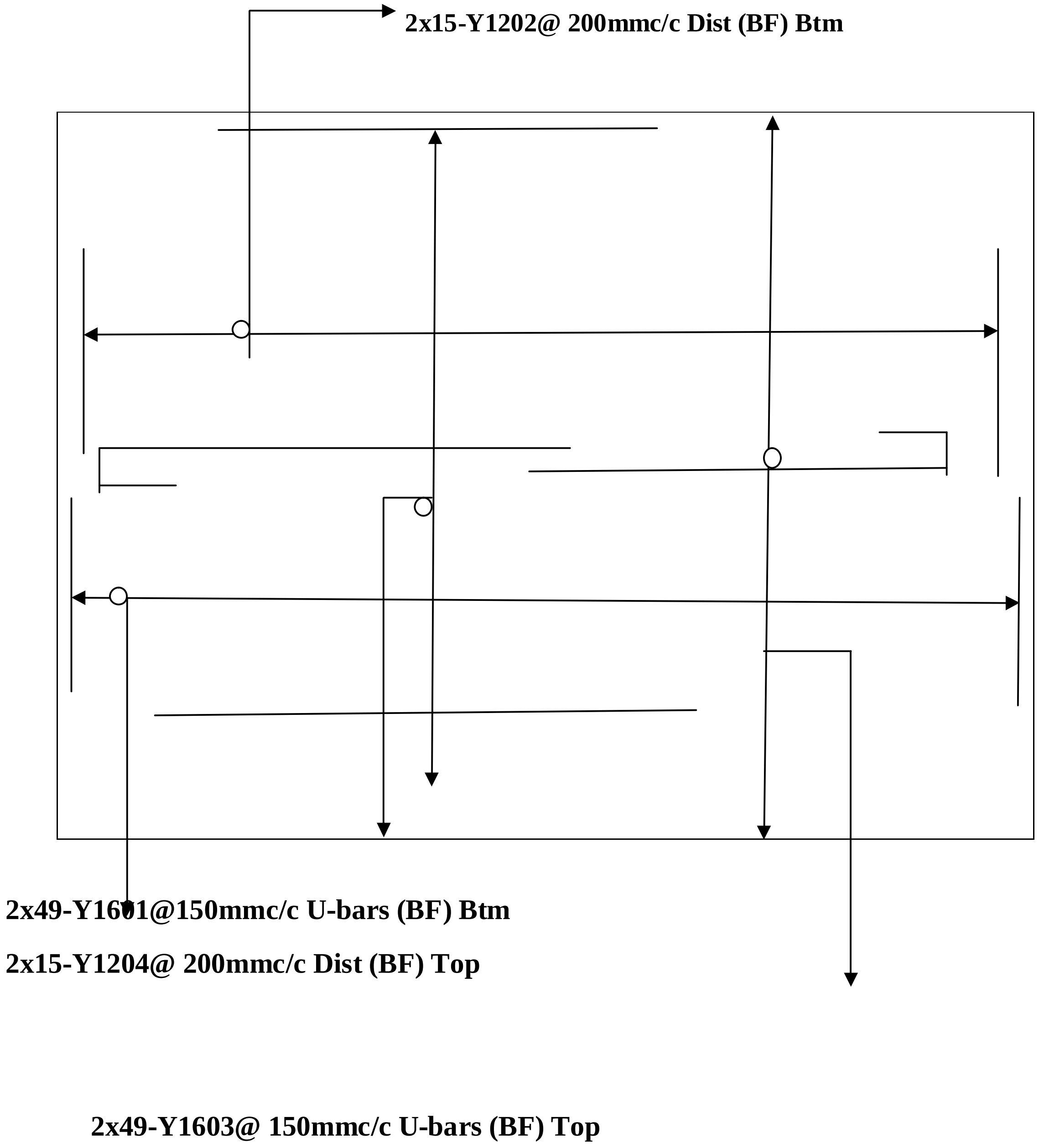
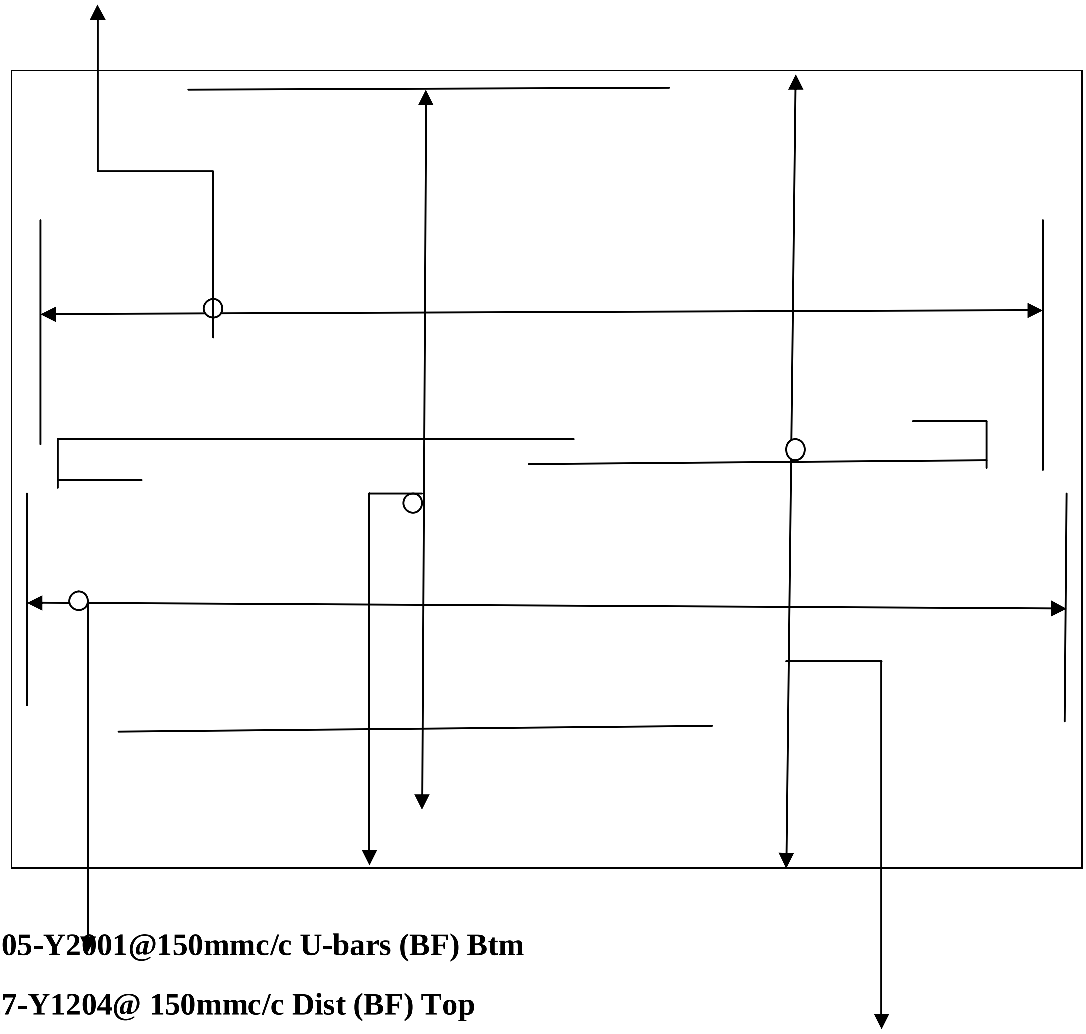


Fig 4.5a: Reinforcement details of Single Cell Box Culverts.

2x27-Y1202@ 150mmc/c Dist (BF) Btm



2x105-Y2001@150mmc/c U-bars (BF) Btm

2x27-Y1204@ 150mmc/c Dist (BF) Top

2x105-Y2003@ 150mmc/c U-bars (BF) Top

Fig 4.5b: Reinforcement details of Triple Cell Box Culverts.

Table A1 Bar Bending Schedule for Structural Members of Single Cell Box Culvert.

SECTION	BAR MARK	SIZE & TYPE	NO OF EACH	NO OF MEMBER	SHAPE CODE	LENGTH OF EACH	TOTAL LENGTH OF

						(mm)	EACH (mm)
SLAB/WALL SECTION	**01**	**Y16**	**49**	**2**	**U-Shape**	**4300**	**421,400**
	02	**Y12**	**15**	**2**	—	**7500**	**225,000**
	03	**Y16**	**49**	**2**	**U-Shape**	**4300**	**421,400**
	04	**Y12**	**15**	**2**	—	**7500**	**225,000**

Total Length of Y16 = 421,400 + 421,400 = 842,800

Total Length of Y12 = 225,000 + 225,000 = 450,000

Conversion

Y16

1 Length = 11,500mm

842,800mm

$= \frac{842,800}{11,500}$ **= 75 Length**

Y12

1 Length = 11,500mm

450,000mm

$= \frac{450,000}{11,500}$ **= 40 Length**

Table A2 Bar Bending Schedule for Structural Members of Triple Cell Box Culvert.

SECTION	BAR MARK	SIZE & TYPE	NO OF EACH	NO OF MEMBER	SHAPE CODE	LENGTH OF EACH (mm)	TOTAL LENGTH OF EACH (mm)
SLAB/WALL SECTION	**01**	**Y20**	**105**	**2**	**U-Shape**	**10200**	**2,142,000**

	02	**Y12**	**27**	**2**	———	**16000**	**864,000**
	03	**Y20**	**105**	**2**	**U-Shape**	**10200**	**2,142,000**
	04	**Y12**	**27**	**2**	———	**16000**	**864,000**

Total Length of Y20 = 2,142,000 + 2,142,000= 4,284,000

Total Length of Y12 = 864,000 + 864,000 = 1,728,000

Conversion

Y20

1 Length = 11,500mm

4,284,000mm

$$= \frac{4,284,000}{11,500} = 372 \text{ Length}$$

Y12

1 Length = 11,500mm

1,728,000mm

$$= \frac{1,728,000}{11,500} = 151 \text{ Length}$$

4.2.7Bar Bending Schedule

The computation done for the bar bending schedule shows that seventy –five (75) length of Y16 are required as main bars while 40 length of Y12 are required as distribution bars for the single cell box culvert and one three hundred and seventy-two (372) length of Y20 are required as main bars while one hundred and fifty-one (151) length of Y12 are required as distribution bars for the triple cell box culvert.

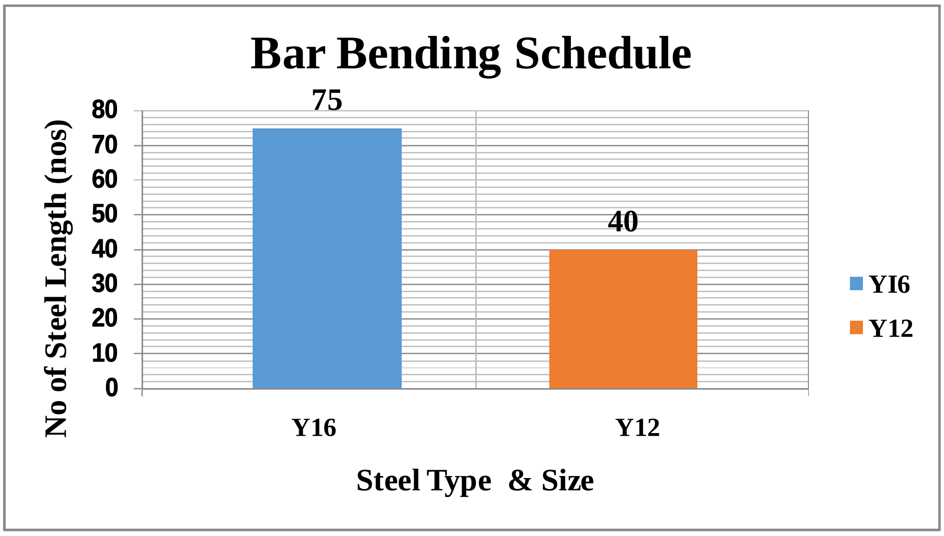


Fig 4.6a: Schedule of Reinforcement for Single Cell Box Culverts.

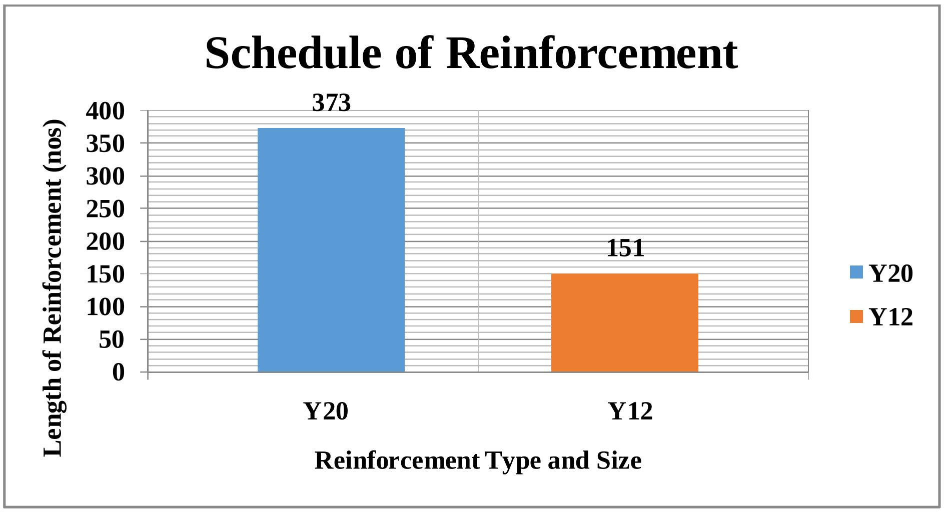


Fig 4.6b: Schedule of Reinforcement for Triple Cell Box Culverts.

4.2.8 Shear Force Design

The shear force design carried out after taking cognizance of the critical shear force (128.69KN) obtained after thorough analysis suggest a design shear stress of 0.536N/mm^2 and a design concrete shear stress of 0.58N/mm^2. From this findings, it can be deduced that the shear design is satisfactory as the design concrete shear stress exceed the design shear stress in value and as a result, the thickness of the as-built culvert satisfies all practical purposes for it construction. This same findings applies for the triple cell box culverts.

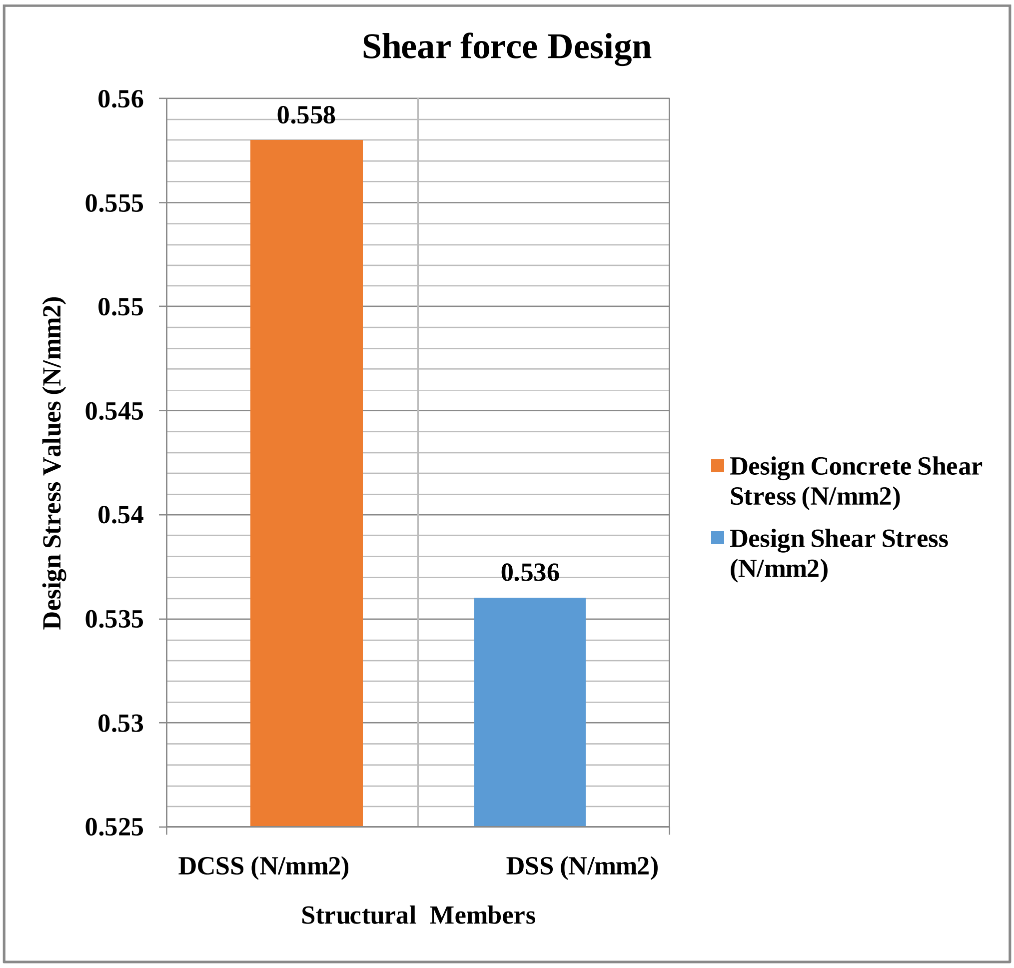


Fig 4.7a: Shear Force Details for the Single Cell Box Culvert.

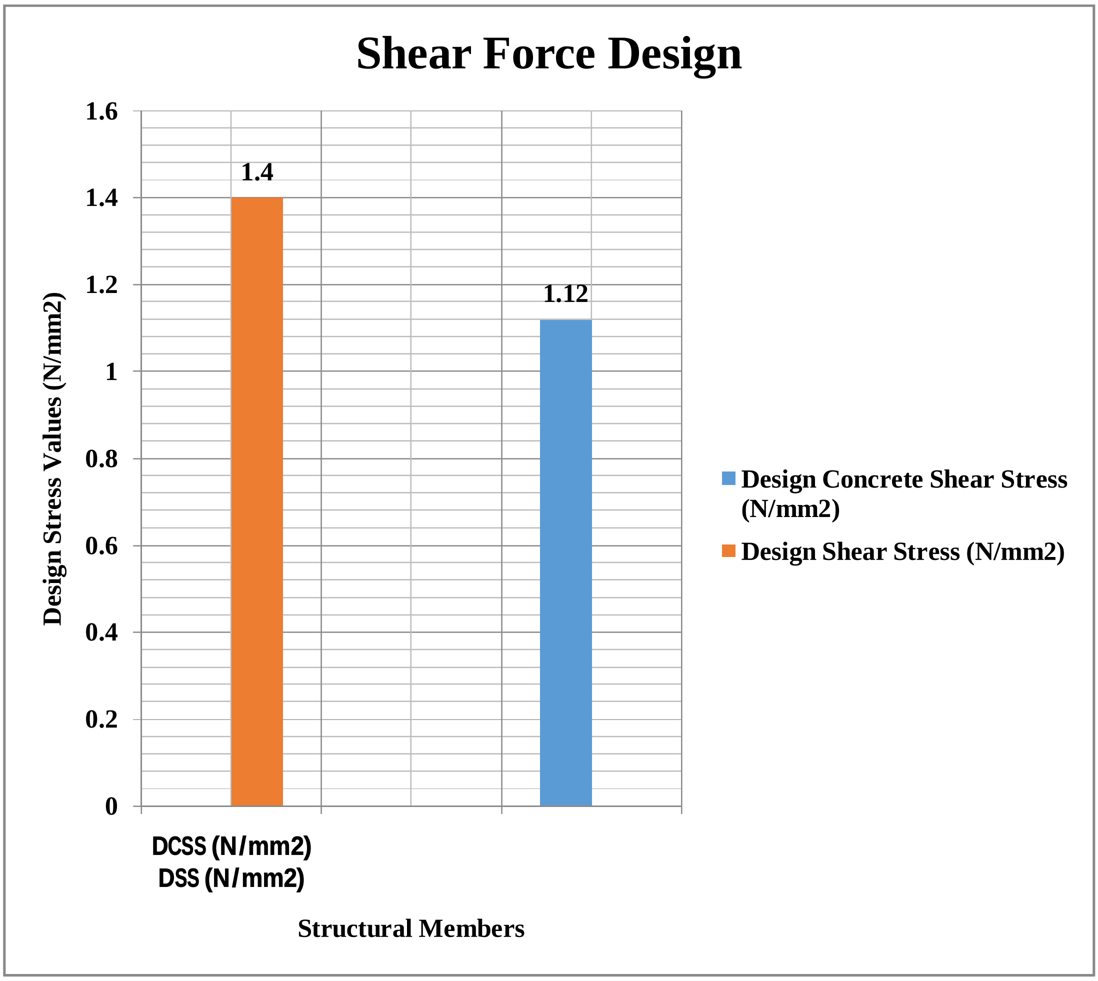


Fig 4.7b: Shear Force Details for the Triple Cell Box Culverts.

STUDY AREA

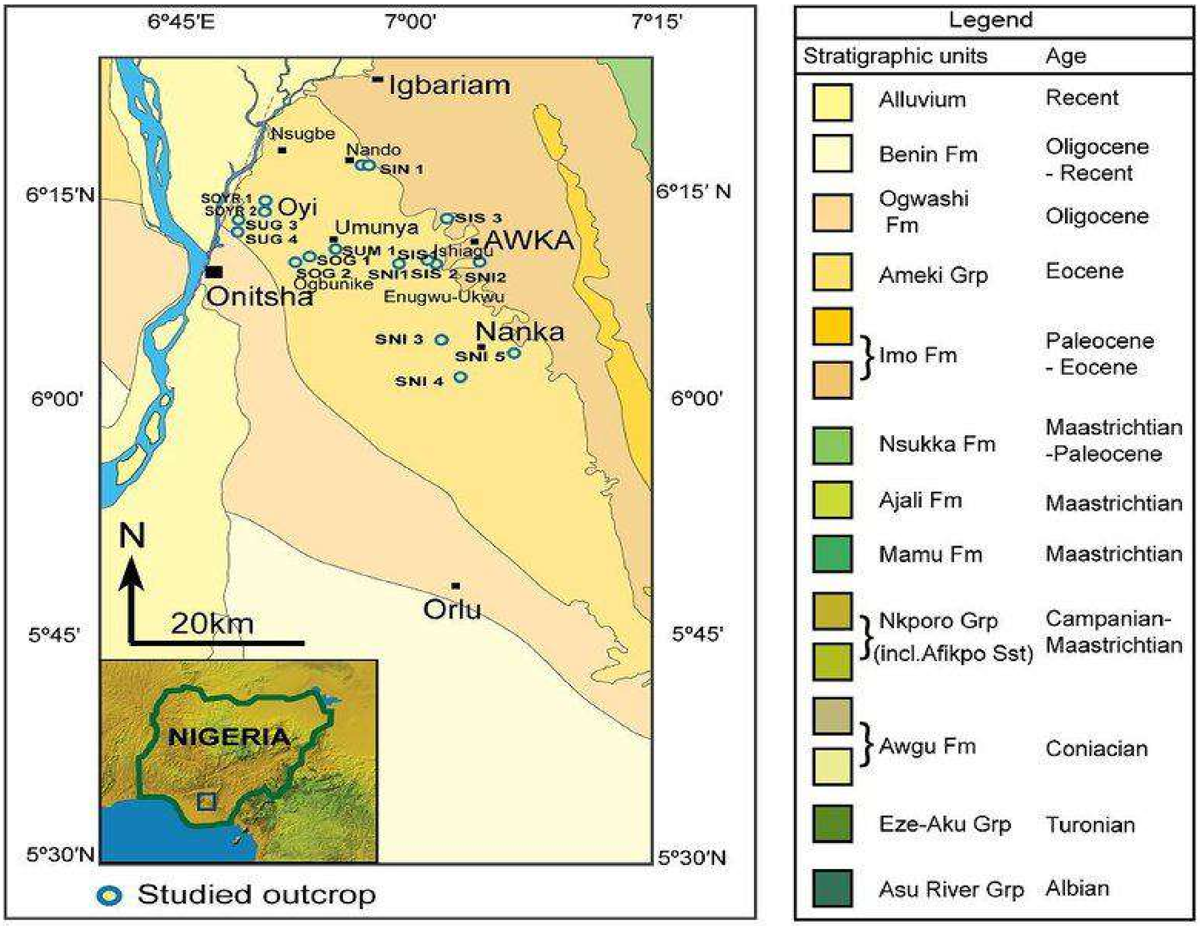


Plate C1 Geologic Map of Study Area.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the structural analysis of members of single and triple box culvert along Isuaniocha/Mgbakwu using Euro code2, the following deduction can be made:

1. The ultimate design load obtained for the bottom slab when the culvert is empty and also when the culvert is full is comparatively higher the other structural members (top slab and vertical walls) for both culverts. This can be attributed to the load from both wall and top slab borne by the bottom slab.
2. The fixed end moment obtained for the bottom slab and vertical walls are the same with that of the top slab been comparatively lower while for the free end moment, the bottom slab is comparatively higher followed by the top slab and walls. Comparison between the fixed and free end moments of both culverts shows that the triple cell box culverts produces relatively higher value of moment than the single cell box culvert.
3. The moment adopted for the design referred to as design moment for both culverts are the same for walls and bottom slab with the top slab producing relatively low value of design moment.
4. The shear force generated for the structural members shows that the walls produces a higher magnitude of shear force (128.69KN) than the other structural members and would be considered for design.
5. The area of steel required for all the structural members are the same with reinforcement comprising of Y16@150mmc/c U-bars used as main bars in both faces and Y12@200mmc/c used as distribution bars in both faces for the single cell box culvert and Y20@150mmc/c U-bars used as main bars in both faces and Y12@150mmc/c used as distribution bars in both faces for the triple cell box culvert
6. The schedule of reinforcement suggest that seventy-five (75) length of Y16 is required as main bars and 40 length of Y12 is to be required as distribution bars for the single cell box culvert and three hundred and seventy-two (372) length of Y16 is required as main bars and one hundred and fifty-one (151) length of Y12 is to be required as distribution bars for the single cell box culvert.

7. The shear force design suggests a satisfactory result as the design concrete shear stress exceed the design shear stress in magnitude.
8. The outcome of the structural analysis and design of members of the culvert suggest that the adopted code for the design (Euro code 2) is structurally reliable for concrete structures and should be given due consideration.

5.2 Recommendation

From the design result obtained using Euro code2 it is recommended that:

1. Design of reinforced concrete structures using Euro code 2 should be given thorough consideration on account of its structural integrity and reliability.
2. More awareness on the use of Euro code 2 should be strongly intensified through its incorporation and use by institution of higher learning and professional bodies (NSE, NIStructE, ACEN) for professional assessment.

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APPENDICES

APPENDIX A

BAR BENDING SCHEDULE

Table A1 Bar Bending Schedule for Structural Members of Single Cell Box Culvert.

SECTION	BAR MARK	SIZE & TYPE	NO OF EACH	NO OF MEMBER	SHAPE CODE	LENGTH OF EACH (mm)	TOTAL LENGTH OF EACH (mm)
SLAB/WALL SECTION	**01**	**Y16**	**49**	**2**	**U-Shape**	**4300**	**421,400**
	02	**Y12**	**15**	**2**	———	**7500**	**225,000**
	03	**Y16**	**49**	**2**	**U-Shape**	**4300**	**421,400**
	04	**Y12**	**15**	**2**	———	**7500**	**225,000**

Total Length of Y16 = 421,400 + 421,400 = 842,800

Total Length of Y12 = 225,000 + 225,000 = 450,000

Conversion

Y16

1 Length = 11,500mm

842,800mm

$= \frac{842{,}800}{11{,}500} =$ **75 Length**

Y12

1 Length = 11,500mm

450,000mm

$= \frac{450{,}000}{11{,}500} =$ **40 Length**

Table A2Bar Bending Schedule for Structural Members of Triple Cell Box Culvert.

SECTION	BAR MARK	SIZE & TYPE	NO OF EACH	NO OF MEMBER	SHAPE CODE	LENGTH OF EACH (mm)	TOTAL LENGTH OF EACH (mm)
SLAB/WALL SECTION	**01**	**Y20**	**105**	**2**	**U-Shape**	**10200**	**2,142,000**
	02	**Y12**	**27**	**2**	———	**16000**	**864,000**
	03	**Y20**	**105**	**2**	**U-Shape**	**10200**	**2,142,000**
	04	**Y12**	**27**	**2**	———	**16000**	**864,000**

Total Length of Y20 = 2,142,000 + 2,142,000= 4,284,000

Total Length of Y12 = 864,000 + 864,000 = 1,728,000

Conversion

Y20

1 Length = 11,500mm

4,284,000mm

$$= \frac{4,284,000}{11,500} = 372 \text{ Length}$$

Y12

1 Length = 11,500mm

1,728,000mm

$$= \frac{1,728,000}{11,500} = 151 \text{ Length}$$

APPENDIX B

INTERNAL STRESSES

Table B1 Summary of Internal Stresses for Structural Members of Single Cell Box Culverts.

ELEMENTS	MOMENT (KNm)	SHEAR FORCE (KN)
TOP SLAB	**48.67**	**53.96**
WALLS	**58.61**	**128.69**
BOTTOM SLAB	**58.61**	**63.77**

Table B2 Summary of Internal Stresses for Structural Members of Triple Cell Box Culvert.

ELEMENTS	MOMENT (KNm)	SHEAR FORCE (KN)
TOP SLAB	**154.83**	**63.05**
WALLS	**178.75**	**529.3**
BOTTOM SLAB	**190.49**	**73.85**

APPENDIX C

Manual Calculation

Design Proper

Top Slab

Standard HB loading width adopted is 1800mm and the standard depth is 1000mm

Slab own load = thickness of culverts x density of concrete x factor of safety = 0.3mx25kN/m^2 x 1.35 = 10.13kN/m^2

Wheel load on slab = calculated wheel load x height of fill x factor of safety = 14.35kN/m^{2}x 1.4m x 1.5 = 30.14kN/m^2

Earth load on slab = Density of active earth pressure x height of earth fill x factor of safety = 18kN/m^3 x 1.4m x 1.5 = 37.8kN/m^2

Total load on top slab = 10.13kN/m + 30.14kN/m + 37.8kN/m = 78.07kN/m

Fixed End Moment on Top Slab = wl^2/12

= 78.07x2.8^2/12 = 51.01kN/m

Vertical Walls

The wall is divided into two sections, the part of the earth fill referred to as $P_{1.4}$ and the part that span from the earth fill soffit to bottom of slab referred to as $P_{4.7}$ is gotten from (1400mm + 2700mm + 300mm + 300mm).

Wall own load = culvert thickness x density of concrete x factor of safety = 0.3 x 25kN/m^2 x 1.35 = 10.13kN/m

Load for earth fill, $P_{1.4}$ = density of earth pressure x factor of earth pressure (ka) x height of fill x factor of safety = 18kN/m^3 x 0.33x 1.4mx 1.5 = 12.47kN/m^2

Other wall load, $P_{4.7}$ = 18kN/m^3 x 0.33 x 4.7m x 1.5 = 41.88kN/m^2

Total wall load = 10.13 + 12.47+ 41.88 = 64.48kN/m

The wall takes a triangular profile, decomposing the structure we have triangle and rectangle

Triangle value is obtained as follows: 41.88-12.47= 29.41

Rectangular value is obtained as follows: 12.47+ 10.13 = 22.6

Fixed end moment at the two corners of the wall labeled A and D is given as:

$$M_A = \frac{29.41\ x\ 2.35}{2}\ x\ \frac{2.35}{15}\ x\ \frac{22.6\ \ x 2.35\ x\ 2.35}{12} = 15.81\text{kNm}$$

$\mathbf{M_D} = \frac{29.41\,x\,2.35}{2}\ x\ \frac{2.35}{10}\ x\ \frac{22.6\ x2.35\,x\,2.35}{12}$ **= 18.52kNm**

Bottom Slab

The bottom slab is calculated from surcharge from the top slab and two vertical side walls.

Top slab load = load from top slab x width of bottom = 78.07kN/m^2 x 2.8m = 218.60kN/m

Vertical walls = 2 (29.41x 2.35x 0.5+ 22.6x 2.35) = 2 (34.56 + 53.11) = 175.34kN/m

Total bottom slab load = 218.60 + 175.34 = 393.94kN/m

Load per meter (m) = $\frac{393.94}{2.8}$ **= 140.69kN/m^2**

Fixed end moment for bottom slab is given as:

M = $\frac{140.69\,x\,2.8x\ \ 2.8}{12}$ **= 91.92kNm**

Applying Hardy cross method of moment distribution

Since both corners are fixed – fixed, the stiffness for depth and width of culvert would be shared between 2.8m and 3m = 0.36 + 0.33 = 0.69

Stiffness for wall = $\frac{0.33}{0.69}$ **= 0.48**

Stiffness for bottom slab = $\frac{0.36}{0.69}$ **= 0.52**

AD	**AB**	**BA**	**BC**
0.48	**0.52**	**0.52**	**0.48**
-15.81	**51.01**	**-51.01**	**15.81**
-16.90	**-18.30**	**18.30**	**16.90**
17.62	**9.15**	**-9.15**	**-17.62**
-12.85	**-13.92**	**13.92**	**12.85**
6.61	**6.96**	**-6.96**	**-6.61**
-6.51	**-7.06**	**-7.06**	**6.51**
-27.84	**27.84**	**-27.84**	**27.84**

DA	DC	CD	CB
0.48	0.52	0.52	0.48
18.52	-91.92	91.92	-18.52
35.23	38.17	-38.17	-35.23
-8.45	-19.09	19.09	8.45
13.22	14.32	-14.32	-13.22
-6.43	-7.16	7.16	6.43
6.52	7.07	-7.07	-6.52
58.61	-58.61	58.61	-58.61

Top Slab

M= 0.125x 78.07 x 2.8^2= 76.51kNm

Vertical walls

Rectangular = $\frac{22.6 \ x \ 3x3}{8}$ = 25.43kNm

Triangular wall = $\frac{2 \ x \ 1.7 \ x \ 29.41 \ x \ 1.7}{2 \ x \ 9x \ \sqrt{3}}$ = 30.51kNm

Bottom Slab = $\frac{91.92 \ x \ 2.8 \ x \ 2.8}{8}$ = 90.08kNm

Superimposing the mid span moment we have:

$M_{A\text{-}B}$ = 76.51kNm – $\frac{(27.84+27.84)}{2}$ = 48.67kNm

$M_{B\text{-}C}$ = 30.51kNm – $\frac{(27.84+58.61)}{2}$ = 12.72kNm

$M_{C\text{-}D}$ = 90.08kNm – $\frac{(58.61+58.61)}{2}$ = 31.47kNm

Case Two

Assuming culvert is full of water and flooded to a maximum depth of 1.5m

Top Slab

Water load = height of water x water pressure x factor of safety = 1.5m x 10kN/m^2x 1.5 = 22.5kN/m

Slab own load = 0.3m x 25kN/m^3x 1.35 = 10.13kNm

N.B: water pressure less than slab load will be acting on the slab, therefore slab load is considered negative.

Total slab load = 22.5kN/m – 10.13kN/m = 12.37kN/m

Wall Load

At top of slab = 1.5mx 10kN/m x 1.5 = 22.5kN/m

At bottom of bottom slab = 4.7x 10x 1.5 = 70.5kN/m

Total load = 22.5kN/m + 70.5kN/m = 93kN/m

Bottom Slab

Due to top slab and wall

Top slab = -12.37x3.1 = -38.35kN/m

Water on walls = 2(22.5+ 70.5) x 0.5x 3.3 = 306.9kN/m

Wall own load = 2x10.13x 3 = 60.78kN/m

Total load = -38.35 + 306.9 + 60.78 = 329.33kN/m

Unit Load = $\frac{329.33kN/m}{3.3m}$ **= 99.8kN/m**^{2}

These loads are less than that obtained for bottom slab load for case 1, therefore, the case 1 load when the culvert is empty will be adopted for design purpose.

Shear Force Calculation

Top Slab

$V_{AB} = \frac{78.07x2.8}{2}$ **= 109.298kN =** V_{BA}

Walls

$V_{DA} = V_{CB} = \frac{22.6x3}{2} + \frac{2}{2}$ **x29.41 +** $\frac{(58.61-27.84)}{3}$ **= 63.77kN**

$V_{AD} = V_{BC} = \frac{22.6x3}{2} + \frac{1}{3}$ **x29.41 +** $\frac{(58.61-27.84)}{3}$ **= 53.96kN**

Bottom Slab

$V_{CD} = V_{DC} = \frac{91.92x2.8}{2}$ **= 128.69kN**

The values obtained for the internal stresses are shown in Table C1 below:

Table C1 Summary of Internal Stresses for Structural Members of Single Cell Box Culverts.

ELEMENTS	MOMENT (KNm)	SHEAR FORCE (KN)

TOP SLAB	**48.67**	**53.96**
WALLS	**58.61**	**128.69**
BOTTOM SLAB	**58.61**	**63.77**

Reinforcement Design

Top Slab

N/bh = $\frac{53.96\ x\ 10x10x10}{1000x30}$ = **0.18**

M/bh^2 = $\frac{48.67\ x\ 1000000}{1000x300x300}$ = **0.541**

NB: breadth of slab was taken as 1000mm

As = 0.4%bh

As = $\frac{0.4x1000x300}{100}$ = **1200mm**^{2}

Provide Y16@150mmc/c each face (1340mm^2**)**

Vertical walls

N/bh = $\frac{128.69\ x\ 10x10x10}{1000x30}$ = **0.43**

M/bh^2 = $\frac{58.61\ x\ 1000000}{1000x300x300}$ = **0.65**

As = 0.4%bh

As = $\frac{0.4x1000x300}{100}$ = **1200mm**^{2}

Provide Y16@150mmc/c each face (1340mm^2**)**

Bottom Slab

N/bh = $\frac{63.77\ x\ 10x10x10}{1000x30}$ = **0.21**

M/bh^2 = $\frac{58.61\ x\ 1000000}{1000x300x300}$ = **0.65**

As = 0.4%bh

As = $\frac{0.4x1000x300}{100}$ = **1200mm**^{2}

Provide Y16@150mmc/c each face (1340mm^2**)**

Same procedure was employed for design of Triple Cell Box Culvert.

EFFECT OF COCONUT SHELL ASH AS A PARTIAL REPLACEMENT FOR PORTLAND CEMENT IN COMPRESSIVE STRENGTH AND WORKABILITY OF CONCRETE

BY

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NNAMDI AZIKIWE UNIVERSITY, AWKA

ANAMBRA STATE.

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHEALOR OF ENGINEERING (B.ENG) IN CIVIL ENGINEERING

FEBURARY, 2022

CERTIFICATION

This is to certify that this project topic titled “Investigation on the Effects of Coconut of shell ash as a Partial Replacement of Ordinary Portland Cement in Compressive Strength and workability of Concrete” was carried out by UDOCHUKWU KELECHI DABERECHI with registration number (NAU/2016224011) in the Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

Udochukwu Kelechi Daberechi Date

(Student)

APPROVAL

This is to certify that all the information given in this project “Investigation on the Effects of Coconut shell ash as a Partial Replacement of Ordinary Portland Cement in Compressive Strength and workability of Concrete” has been assessed and approved by the department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra state.

____________________ _______________

Engr.Dr. Adinna, Boniface Okafor Date
(Project Supervisor)

____________________ ________________

Engr. Dr. C.A Ezeagu Date
(Head of Department)

____________________ _______________

Engr. Prof. D.O. Onwukwa Date

(EXTERNAL EXAMINER)

DEDICATION

This work is dedicated to God Almighty, the giver of all wisdom and knowledge for his guidance and protection, and to my beloved parents for all their support and advice.

ACKNOWLEDGEMENT

My deepest gratitude to God, in whom I have put my faith and trust during the entire course of this study.

My utmost regards goes to my parents Mr and Mrs K.U Nwaopara for their prayers, encouragement and moral support throughout the duration of my study

In a very special way, I say a very big thank you to my project supervisor Engr. Dr. Adinna, whose contribution and constructive criticisms has pushed me towards greater heights of research. Thanks sir, for your patience.

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I will also like to extend my heartfelt appreciation to all the staff (academic and non-academic) of the Department of Civil Engineering starting from Engr. C. A. Chidolue, Engr. Prof. Ekenta, Engr. Prof. Nwaiwu, Engr. A.I. Nwajuaku, Engr. C.M. Nwakaire, Engr. B. Njotea, Engr. Prof. Aginam, Engr. Ezewamma and the non-academic teams comprising of Engr. Ngozi, Engr. Nnonso, Engr. Samson and Engr. John for their invaluable tutorship and professional guidance.

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To the whole Nnamdi Azikiwe University, Awka, Faculty of Engineering, Class of 2021, I acknowledge you all as well for all your support.

ABSTRACT

The cost of cement used in concrete works is on the increase and unaffordable, yet the need for housing and other constructions requiring this material keeps growing with increasing population. The environmental impact of Portland cement is significant because its production emits large amounts of CO_2. Utilization of industrial waste or secondary materials has been encouraged in construction field for the production of cement and concrete because it contributes for reducing the consumption of natural raw materials as resources. The volume of wastes generated in the world has increased over the years due to increase in population, socioeconomic activities and social development. One of the most attractive options of managing such waste is to look into the possibility of waste minimization and re-use. Agricultural waste material, in this case, coconut shells, which is an environmental pollutant, are collected and burnt in the open air (uncontrolled combustion), which in turn was used as pozzolana in partial replacement levels of 0, 5, 10, and 15 % of Ordinary Portland Cement with coconut shell ash. A total of 32 cubes were produced and cured by immersing them in water for 7, 14, 21 and 28 days respectively. Properties such as compressive strength and workability were determined. From the tests conducted and the tests results recorded, the data analysis showed improvement in both compressive strength and workability of concrete with addition of coconut shell ash after 28 days. Addition of ash contributes to strength increase but only up to a certain amount of ash content.

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CHAPTER ONE

INTRODUCTION

1.0 BACKGROUND

The growing need of construction trade and issue of environmental problem created from agricultural wastes has initiated research towards producing a new green concrete material. Researches all over the world today are focused on ways of utilizing, either industrial or agricultural wastes as a source of raw materials for the industry. These wastes utilization would not only be economical, but also result to foreign exchange earnings and environmental pollution control. Coconut shell is an agricultural waste and is available in very large quantities throughout the tropical countries of the world. Moreover, coconut is becoming an important agricultural product for tropical countries around the world. Moreover, coconut is becoming an important agricultural product for tropical countries around the world as a new source of energy- biofuel. Previously, coconut shell was burnt as a means of solid waste disposal which contributed significantly to CO_2 and methane emissions. However as the cost of fuel oil, natural gas and electricity supply has increased and become erratic, coconut shell has come to be regarded as source of fuel rather than refuse. Presently, the Nigerian coconut shell is used as a source of fuel for the boilers, and residual coconut shell is disposed off as gravel for plantation roads maintenance. Black smiths also buy the coconut shell as fuel material in their casting and forging operations. Bamgboye and Jekayinfan regretted that 90% of coconut (empty fruit bunches, fibers, fronds, trunks, shell) was discarded as waste and either burnt in open air or left to settle in waste ponds. This way the coconut processing industries waste according to him contributed significantly to CO_2 and methane emissions. (Madakson et. Al, 2021).

Based on economic as well as environmental related issues, efforts should be directed worldwide towards coconut management issues i.e. of utilization, storage, storage and disposal. Different avenues of coconut shell utilization are more or less known but none of them have so far proved to be economically viable or commercially feasible. Hence, the objective of this present work is to characterize coconut shell in order to explore its use in concrete as a partial replacement for Portland cement. Leaving this agro waste material to biodegrade by itself would take longer time and the pollution created by this waste material to biodegrade by itself would take longer time and the pollution created by this waste while rotting can pose negative impact to the healthy lifestyle of community surrounding. Therefore, placing the issue of environmental preservation for the future generation being utmost importance has lead towards the efforts of integrating this agro waste as a mixing ingredient in concrete production. The potential of this material to play the role as partial replacement for Portland cement in concrete formation is what this research is all about. It is anticipated that formulation of concrete integrating crushed coconut shell ash to substitute the use of Portland cement partially would offer alternative to the concrete manufacturer to use this waste material in the production rather than heavily relying on Portland cement. Application of this material as one of the mixing ingredient or component in concrete production would expand the functionality of this waste thus reducing the amount of coconut shell ending up at landfill. In this recent research study, the effect of replacing various percentages of Portland cement with crushed coconut shell ash (CCSA) towards the concrete properties were investigated through experimental work conducted in n the laboratory of civil engineering, Nnamdi Azikiwe University Awka. The present study discusses the performance of various concrete mixes in terms of density, compressive and flexural strengths. Many of the non-decaying waste materials will remain in the environment for hundreds, perhaps thousands of years. The non-decaying waste materials cause disposal crisis, thereby contributing to the environmental problems. However, the environmental impact can be reduced by making more sustainable use of this waste. This is known as the Waste Hierarchy. Its aim is to reduce, reuse, or recycle waste, the latter being the preferred option of waste disposal (Zhang et. Al,1996).

Concrete is the most widely used construction material in the world. It is used in many different structures such as dam, pavement, building frame or bridge. Also, it is the most widely used material in the world, far exceeding other materials.

According to Berg, (1993), concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space between the aggregate particles and glues them together. We can also consider concrete as a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregates.

According to the type of binder used, there are many different kinds of concrete.

For instance, Portland cement concrete, asphalt concrete, and epoxy concrete. In Nigeria’s concrete construction, the Portland cement concrete is utilized the most. Thus, in our course, the term concrete usually refers to Portland cement concrete. For this kind of concrete, the composition can be presented as follows;

(Cement + fine aggregate)= (Resulting mixture + coarse aggregate + water) = (Concrete)

However, to produce a good concrete for construction, many factors must be considered since the materials are available in a wide range. It is not all the materials that are used for concrete production. Concrete produced must be workable and should develop necessary strength to carry the structural loading imposed on it (Hannant, 0.1., 2001). For concrete to be workable means it can be mixed, placed, moulded and cast into any shape desired with ease. Furthermore, concrete should not be over workable since there is every tendency that increasing workability beyond the level required affects the strength development with age.

There were many experimental work conducted to improve the properties of the concrete by putting new materials, whether it is natural materials or recycle materials or synthetic materials in the concrete mix. Concrete is an artificial material similar in appearance and properties to some natural lime stone rock. It is a man made composite, the major constituent being natural aggregate such as gravel, or crushed rock, sand and fine particles of cement powder all mixed with water. The concrete as time goes on through a process of hydration of the cement paste, producing a required strength to withstand the load. The use of coconut shell in concrete has never been a usual practice among the average citizens, particularly in areas where light weight concrete is required for non-load bearing walls, non-structural floors, and strip footings.

1.1 STATEMENT OF PROBLEM

The high demand for traditional construction material such as concrete, bricks, hollow blocks, solid blocks, pavement blocks and tiles in construction industry has led towards a rapid decrease in natural sources such as gravel, granite and river sand, thus causing ecological imbalance. The high cost of construction materials like cement and reinforcement bars has led to increased cost of construction. This coupled with the pollution associated with cement production, has necessitated a search for an alternative binder which can be used sorely or in partial replacement of cement in concrete production. More, so disposal of agricultural waste materials such as rice husk, groundnut husk, corn cob and coconut shell have constituted an environmental challenge, hence the need to convert them into useful materials to minimize their negative effect on the environment. Research indicates that most materials that are in rich amorphous silica can be used in partial replacement of cement. It has also been established that amorphous silica found in some pozzolanic materials react with lime more readily than those of crystalline form. Use of such pozzolans can lead to increased compressive and flexural strengths. The American Society of testing materials (ASTM) defines pozzolans as siliceous or aluminous materials which possess little or no cementitous properties but will, in presence of moisture, react with lime [$Ca(OH)_2$] at ordinary temperature to form a compound with pozzolanic properties. In Nigeria, coconut demand have continued to increase due to the high demand of human needs such as coconut oil, coconut as a source of food, its fluid being used in preparation of delicacies in many restaurants. This shell has been dumped and stockpiled at landfill, thus causes storage problem in the vicinity of the factories that uses it in their coconut oil production, that uses the coconut fluid in preparation of coconut rice and fruit sellers thus the wastes are produced daily. Hence, theses wastes are harmful to the ecosystem. In addition, with the global economic recession coupled with the market inflationary trends, the constituent material used for these structures has led to a very high cost of construction. Using coconut shell waste in the production, concrete material would not only reduce the environmental problem but also the cost of green concrete.

1.2 OBJECTIVES OF STUDY

The general aim of this study can be summarized as follows:

1. To determine the effect of finely crushed coconut shell ash as partial replacement of ordinary Portland cement on compressive strength of concrete.
2. To determine the effect of finely crushed coconut shell ash as partial replacement of ordinary Portland cement on workability of concrete.

1.3 SCOPE OF STUDY

The tests to be carried out for this study are compressive strength and workability test, which would be performed at the Concrete Laboratory of Civil Engineering, Nnamdi Azikiwe University Awka. The mix ratio for this practical is 1:2:4 and the density of the concrete used is 2400kg/m³ with the concrete strength of 25N/mm². Compressive strength tests were conducted on the hardened concrete mixes at the stages of 7, 14, 21 and 28 days in order to determine the compressive strength of concrete cube of size 150mm x 150mm x 150mm.

The total specimens to use for this practical are 48 cubes. With the cement being replaced with coconut shell ash at 0%, 5%, 10% and 15%.

In order to study the effect of workability, slump has been con ducted on all mixes. The workability tests is conducted to determine the ease and homogeneity of fresh concrete which it can be mixed, placed, consolidated and finished.

1.4 SIGNIFICANCE OF STUDY

The high cost of construction materials like cement and reinforcement bars, has led to increased cost of construction. This, coupled with the pollution associated with cement production, has necessitated the search for an alternative binder which can be used solely nor in partial replacement of cement in concrete production, Utilization of coconut shell ash as partial replacement in concrete would be able to reduce the amount of coconut shells thrown at landfill. Also successful production of concrete containing coconut shell ash would provide an alternative green concrete material to the local contractor.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter discusses the effect of coconut shell ash in concrete in terms of engineering properties of concrete such as; workability and compressive strength.

2.1 CONCRETE

Concrete is a combination of cement, fine and coarse aggregates and water which are mixed in a particular proportion to get a particular strength. A good knowledge of the properties of cement, aggregates and water is required in understanding the behavior of concrete (Olufemi et al, 2002). Because of its convenient use, it is not only used in building construction but also in other civil engineering areas such as roads, harbors, bridges and many more. Concrete is comparatively economical, easy to make, offers continuity solidity and indeed it lays the role of developing and improving our modern society. Nowadays, concrete is most widely used man-made construction material in mostly every type of engineering and architectural structure all round the world.

According to Simmons H.L, (2007), the usage of concrete can trace back as early as third century B.C. where the Romans were using concrete made with lime, broken stones and sand to built temples and other buildings. First, the surface of the concrete was left rough and finished with a form of stucco. Later on, they began to produce a decorative finish by embedding small stones in the concrete surface. Finally, they incorporated broken terra cotta roof tiles by embedding it at the outer surface of the concrete and this led to the manufacture of the clay bricks. After the collapse of the Roman Empire, the concrete technology fell into disuse and has remained unknown until the time of Renaissance. Around 15th century, ***'De architectura'***, the book series written by Roman architect and engineer Marcus Vitruvius Pollio became a famous object to be studied. But it was until the end of 18th century that the research in the concrete technology was resumed and by the year of 1824, that essential ingredient in the modern concreted was just discovered.

2.3 CLASSIFICATION OF CONCRETE

2.3.1 Based on unit weight;

• Ultra light concrete	<1,200k g/m^3
• Light weight concrete	1200- 1,800kg/m^3
• Normal-weight concrete	2,400 kg/m^3
• Heavyweight concrete	> 3,200 kg/m^3

2.3.2 Based on strength;

• Low-strength concrete	<20 MPa compressive strength
• Moderate-strength concrete	20-50 MPa compressive strength
• High-strength concrete	50-200 MPa compressive strength
• Ultra high-strength concrete	>200 MPa compressive strength

2.3.3 Based on addictives;

- Normal concrete
- Fiber reinforced concrete
- Shrinkage-compensating concrete
- Polymer concrete

2.4 PROPERTIES OF CONCRETE

To obtain a good quality concrete, its properties in both plastic as well as hardened stages play important rules.

The properties in plastic stages include;

I. Workability
II. Segregation
III. Bleeding
IV. Hardness

The properties in hardness stage include;

I. Strength
II. Durability
III. Impermeability
IV. Dimensional change

2.5 STRENGTH OF CONCRETE

According to the book by T.W.Love and U.S. Department of Army (1999), the strength of the concrete is the concrete’s ability to resist the load in the compression, flexural or shear. The strength of concrete is mainly determined by the water-cement ratio (w/cm), the design constituents and the mixing, placement and curing methods employed. Concrete with lower water-cement ratio makes a stronger concrete than that with a higher ratio (RAJU, 1988). By allowing additional water into the mixing process means to thin the paste and to allow it to coat more particles. But, if the water was too much, then it would affect the concrete's strength by reducing it due to the dilution of the paste.

2.5.1 COMPRESSIVE STRENGTH

The compressive strength of concrete is the maximum compressive load it can carry per unit area (Bolen, 1963). Concrete mixtures can be designed to provide a wide range of mechanical and durability properties to meet the design requirements of a structure. The compressive strength of concrete is the most common performance measure used by the engineer in designing buildings and other structures. The compressive strength is measured by crushing concrete cube specimens in a compression-testing machine. The compressive strength is calculated from the failure load divided by the cross-sectional area resisting the load and reported in units of pound-force per square inch (psi) in US Customary units or Megapascals (MPa) in SI units. Concrete compressive strength requirements can vary from 2500psi (17 MPa) for residential structures to 4000 Psi (28 MPa) and higher in commercial structures. Higher strengths up to and exceeding 10,000 psi (70 MPa) are specified for certain applications.

Compressive strength test results are primarily used to determine whether the concrete mixture as delivered meets the requirements of the specified strength, in the job specification. Strength test results from cast cubes may be used for quality control, acceptance of concrete, or for estimating the concrete strength in a structure for the purpose of scheduling construction operations such as for removal or for evaluating the adequacy of curing and protection afforded to the structure. Cubes tested for acceptance and quality control are made and cured in accordance with procedures described for standard-cured specimens in ASTM C 31 Standard Practice for Making and Curing Concrete Test Specimens in the Field. For estimating the in-place concrete strength, ASTM C 31 provides procedures for field-cured specimens. Cube specimens are tested in accordance with ASTM C 39, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. A test result is the average of at least two standard-cured strength specimens made from the same concrete sample and tested at the same age. In most cases strength requirements for concrete are at an age of 28 days.

2.5.2 FACTORS AFFECTING STRENGTH OF CONCRETE

The strength of concrete is usually affected by many factors. In this project work, such factors are discussed with particular reference to the compressive strength. The factors include:

- Quality of raw materials
- Water / cement ratio
- Coarse / fine aggregate ratio
- Aggregate / cement ratio
- Age of concrete
- Compaction of concrete
- Curing of concrete

QUALITY OF RAW MATERIALS:

- **Cement**: Provided that the cement conforms to the appropriate standard and it has been stored correctly (i.e. in dry conditions), it should be suitable for use in concrete. The influence of cement on the strength of concrete for a given mix proportion is determined by its fineness and chemical composition through the process of hydration. Generally, cement can be described as binder material with adhesive and cohesive properties which makes it capable of holding mineral fragments into a compact whole. Cement used in construction works can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to be used in the presence of water. Thus, cement can harden underwater or when constantly exposed to wet weather. The chemical reaction results in hydrates that are not very water-soluble and so are quite durable in water and are free from chemical attack. Non-hydraulic cements and plasters do not harden in wet conditions. The role of the chemical composition of cement in the development of concrete strength can always be appreciated. It is apparent that cement which contains high percentage of tricalcium silicate (CA_3S)gain much more strength rapidly than those rich in dicalcium silicate(Ca_2S).The sulphate resistance of concrete can be improved by the use of sulpahte-resisting cement which has low tricalcium alumunate (Ca_3A) content (Seeley, 1995). The most important uses of cement are as an ingredient in the production of mortar in masonry, and of concrete, a combination of cement and aggregate to form a strong building material. The most common cement used for construction works is ordinary Portland cement (OPC), which is a low heat cement. The specification for Portland cement is the BS 1221991 of the British standards institution.

- **Aggregate**: The quality of aggregate, its size, shape, texture, strength, etc determines the strength of concrete. The presence of salts (chlorides and sulpahtes), silt and clay also reduces the strength of concrete. Aggregate is an important ingredient in concrete, which is generally regarded as an inert material distributed in a cement paste to form a rigid mass that could be moulded or cast into various shapes. It is also regarded as the skeleton of the concrete. When a concrete mass is stressed, failure may originate within the aggregate, the matrix or at the aggregate-matrix or any combination of these may occur. The aggregate-matrix interface is an important factor determining concrete strength. Band strength is influential by the shape of the aggregate, its surface texture and cleanliness. Surface texture is generally only considered in relation to concrete flexural strength, which is found to reduce with increasing particle smoothness (Feldman, 1969). However, inadequate surface texture can similarly adversely\ affect compressive strength in high strength concrete (< 50N/mm²) when the bond with the cement matrix may not be sufficiently strong enough to enable the maximum strength of the concrete to be realized.

According to the weight of aggregate, there are three main types of aggregates, namely;

- **Light weight aggregate:** These include clinker and foamed slag and expanded clay and sintered pulverized fuel ash. Their porosity is high and their absorption is faster than normal aggregate.
- **Medium weight aggregate:** They include sand, gravel, broken bricks, crushed stones and blast furnace slay. They are commonly used in the manufacture of quality concrete. The fine aggregate often called sand is not larger than 5mm.
- **Heavy weight aggregate:** These include steel punches, magnetite and scrap iron. They are used for high density concrete construction to shut off or screen against x-rays and neutrons (Taylor, 1983).

Good concrete can be made by using different types of aggregates like rounded and irregular gravel and crushed rock which is mostly angular in shape. The grading of aggregate is a major factor influencing the workability of a concrete mix. The grading should be such as to ensure that voids between the lager aggregates are filled with smaller fractions and mortar so as to achieve maximum density and strength. The coarse and finer fractions of aggregates available at site can be suitably combined to obtain the desired standard grading (Neville, 1981).

For the same w/c ratio, mixes with larger aggregates give lower strength. This is due to the presence of a weak zone at the aggregate/paste interface, where cracking will first occur. With larger aggregates, larger cracks can form at the interface, and they can interact easier with paste cracks as well as other interfacial cracks. With the same mix proportion, rougher and more angular aggregates give higher strength than smooth and round aggregates. However, with smooth aggregates, a lower w/c ratio can be employed to achieve the same workability. Therefore, it is possible to achieve similar strength with smooth and rough aggregates, by adopting slightly different w/c ratios. For a fixed w/c ratio, the strength increases slightly with the aggregate/cement ratio. This is because aggregates are often denser than the cement paste. With less paste in the concrete, the overall density is increased. For normal strength concrete, the aggregate strength is seldom a concern. However, in the development of high strength concrete, it is important to select aggregates with strength higher than that of the hardened paste.

- **Water:** Water plays a critical role in the strength of concrete, particularly the amount used. The strength of concrete increases when less water is used to make concrete. Frequently the quality of the water is covered by a clause stating "...the water should be ht for drinking..." This criterion though is not absolute and reference should be made to respective codes for testing of water for construction purposes. A concrete mix containing the minimum amount of water required complete hydration of its cement, if it could be fully compacted would develop the maximum attainable strength at any given age. The hydration itself consumes a specific amount of water. A water-cement ratio of approximately 0.5 (by weight) is required for full hydration of the cement but with this water content normal concrete mix would be extremely dry and virtually impossible to compact. Concrete is actually mixed with more water than is needed for the hydration reaction. This extra water is added to give concrete sufficient workability. ln practice, if the ratio of water to cement increases, the strength of the concrete decreases. BSEN1008:2002 specifies mixing specification for water in concreting.

WATER / CEMENT RATIO

W/C ratio is one of the most important parameters governing the strength of concrete. The density of hardened cement (in terms of a gel/space ratio) is governed by the water/cement ratio. With higher w/c ratio, the paste is more porous and hence the strength is lower. The strength continues to increase with decreasing w/c ratio only if the concrete can be fully compacted. For concrete with very low w/c ratio, if no water-reducing agent is employed, the workability can be so poor that a lot of air voids are entrapped in the hardened material. The strength can then be lower than that for concrete with higher w/c ratio. For a given set of materials and environment conditions, the strength of ant concrete age depends only on the water-cement ratio, providing full compaction can be achieved. The standard water/cement ratio is 0.5.

COARSE / FINE AGGREGATE RATIO

The following points should be noted for coarse/fine aggregate ratio;

- If the proportion of the fine aggregate is increased in relation to the coarse aggregate, the overall aggregate surface area will increase.
- If the surface area of the aggregate has increased, the water demand will also increase.
- Assuming the water demand has increased the water-cement ratio will increase.
- Since the water-cement ratio has increased the compressive strength will decrease.

AGGREGATE / CEMENT RATIO

The following points should be noted for aggregate-cement ratio;

- If the volume remains the same and the proportion of cement in relation to that of sand is increased, the surface area of the solid will increase.
- If the surface area of the solid has increased, the water demand will stay the same for the constant workability.
- Assuming an increase in cement content for no increase in water demand, the water-cement ratio will decrease.
- If the water-cement ratio reduces, the strength of the concrete will increase.

AGE OF CONCRETE

The degree of hydration is synonymous with the age of concrete provided that the concrete has not been allowed to dry out or the temperature is too low. In theory, provided that the concrete is not allowed to dry out, then it will always be increasing albeit at an ever reducing rate. For convenience and for most practical applications, it is generally accepted that the majority of the strength has been achieved by 28 days. The 7th day strength can range from 60 - 80% of the 28th day strength, with a higher percentage for a lower w/c ratio. After 28 days, the strength can continue to go up. Experimental data indicates that the strength after one year can be over 20% higher than the 28 day strength. The reliance on such strength increase in structural design needs to be done with caution, as the progress of cement hydration under real world conditions may vary greatly from site to site.

COMPACTION OF CONCRETE

Once the concrete has been placed, it is ready to be compacted. The purpose of compaction is to get rid of the air voids that are trapped in loose concrete. Air voids reduce the strength of the concrete. For every 1% of entrapped air, the strength falls by somewhere between 5% and 7% (Gambhir ML, 1999). This means that concrete containing a mere 5% air voids due to incomplete compaction can lose as much as one third of its strength. Air voids also increase concrete's permeability. That in turn reduces its durability. If the concrete is not dense and impermeable, it will not be watertight. It will be less able to withstand aggressive liquids and its exposed surfaces will weather badly. The difference between air voids and entrapped air bubbles should be noted at this stage. The air bubbles that are entrained are relatively small and spherical in shape, increase frost resistance. Entrapped air on the other hand tends to be irregular in shape and is detrimental to the strength of the mix. In order to remove both, the concrete must be properly compacted.

CURING OF CONCRETE

It should be clear from what has been said above, that the detrimental effects of storage of concrete in a dry environment can be reduced if the concrete is adequately cured to prevent excessive moisture loss. Curing is the process of protecting the freshly poured concrete from evaporation and temperature extremes which might adversely affect cement hydration. Curing ensures the continuation of hydration of cement and the strength gain of concrete. Concrete surfaces are cured by sprinkling with water. Most of the strength gain and hydration take place within the first month of concrete's life cycle but hydration continues at slower rate for many years. Concrete continues to get stronger as it gets older.

2.6 WORKABILITY OF CONCRETE

Workability is often referred to as the ease with which a concrete can be transported, placed and consolidated without excessive bleeding or segregation. It can also be defined as the internal work done required to overcome the frictional forces between concrete ingredients for full compaction. It is obvious that no single test can evaluate all these factors. In fact, most of these cannot be easily assessed even though some standards tests have been established to evaluate them under specific conditions. In the case, consistence is sometimes taken to mean the degree of wetness; within limits, wet concretes are more workable than dry concrete, but concrete of same consistence may vary in workability. Because the strength of concrete is adversely and significantly affected by the presence of voids in the compacted mass, it is vital to achieve a maximum possible density. This requires sufficient workability for virtually full compaction to be possible using a reasonable amount under the given conditions. Presence of voids in concrete reduces the density and greatly reduces the strength: 5% of voids can lower the strength by as much as 30%. Slump test can be used to find out the workability of concrete.

2.6.1 SLUMP TEST (BS 1881: 102, ASTM C143)

There are four different possible slump; true slump, zero slump, shear slump, collapse slump. Conventionally, when shear or collapse slump occur, the test is considered invalid. However, due to recent development of self-compact concrete, the term of collapse slump has to be used with caution.

Factors affecting concrete workability:

i. Water-cement ratio
ii. Amount and type of aggregate
iii. Amount and type of cement
iv. Weather conditions
v. Admixtures.
vi. Sand to aggregate ratio

WATER-CEMENT RATIO

The more the water cement ratio, the more the workability of concrete. Since by simply adding water the inter particle lubrication is increased. High water content results in a higher fluidity and greater workability but reduces the strength of concrete. Because with increasing w/c ratio the strength decreases as more water will result in higher concrete porosity. So, the lower the w/c, the lower is the void volume/solid volume, and the stronger the hardened cement paste. Increased water content also results in bleeding, hence, increased water content can also mean that cement slurry will escape through the joints of the formwork (Shuttering).

AMOUNT AND TYPE OF AGGREGATE

Since larger aggregate sizes have relatively smaller surface areas (for the cement paste to coat) and since less water means less cement, it is often said that one should use the largest practicable aggregate size and the stiffness practical mix. Most building elements are constructed with a maximum aggregate size of ¾” to 1”, larger sizes being prohibited by the closeness of the reinforcing bars.

Because concrete is continuously shrinking for years after it is initially placed, it is generally accepted that under thermal loading it will never expand to its originally-placed volume. The more the amount of aggregate, the less the workability. Using smooth and round aggregate increases the workability. Workability reduces if angular and rough aggregate is used. Greater size of aggregate, less water is required to lubricate it; the extra water is available for workability.

Angular aggregate increases flakiness or elongation, thus reducing workability. Round smooth aggregates require less water and less lubrication and greater workability in a given w/c ratio. Porous aggregates require more water compared to non-absorbent aggregates for achieving same degree of workability.

AMOUNT AND TYPE OF CEMENT

Aggregate cement ratio; more ratios will result in less workability. Since less cement means less water, so the paste is stiff.

WEATHER CONDITIONS

i. Temperature: If temperature is high, evaporation increasers, thus workability decreases.
ii. Wind: If wind is moving with greater velocity, the rate of evaporation also increases thus reduces the amount of water and ultimately reducing workability.

ADMIXTURES

Chemical admixture can be used to increase workability. Use of air entraining agent produces air bubbles which act as a sort of ball bearing between particles and increasing mobility, workability and decreases bleeding, segregation. The use of fine pozzolanic materials also has better lubricating effect and more workability.

SAND TO AGGREGATE RATIO

If the amount of sand is more, the workability will reduce because sand has more surface area and more contact area causing more resistance. The ingredients of concrete can be proportioned by weight or volume. The goal is to provide the desired strength and workability at minimum expense. A low water-cement ratio is used to achieve a stronger concrete. It would seem therefore that by keeping the cement content high one could use enough for good workability and still have a low w/c ratio.

2.7 ADVANTAGES AND LIMITATIONS OF CONCRETE

2.7.1 Advantages:

- **Economical:** Concrete is the most inexpensive and the most readily available material. The cost of production of concrete is low compared with other engineered construction materials. There are three major components of concrete which are: water, aggregate and cement. Comparing with steel, plastic and polymer, they are the most inexpensive material and readily available in every corner of the world. This enables concrete to be locally produced anywhere in the world, thus avoiding th transportation costs necessary for the most other materials.

- **High temperature resistance:** Concrete conducts low heat slowly and is able to store considerable quantities of heat from the environment (can stand 6-8 hours in fire) and thus can be used as protective coating for steel structure.
- **Excellent resistance to water:** Unlike wood and steel, concrete can harden in water and can withstand the action of water without serious deterioration. This makes concrete an ideal material for building structures to control, store and transport water. Examples include pipeline (such as the central Arizona project which provides water from Colorado River to central Arizona. The system contains 1560 pipe sections, each 6.7m long and 7.5m in outside diameter), dams and submarine structures. Contrary to popular belief, pure water is not deleterious to concrete, such as chlorides, sulphates and carbon dioxide, which causes deterioration of concrete structures.
- **Ability to cast:** It can be formed into different desired shapes and sizes right at the construction site.
- **Ambient temperature hardened material:** Because cement is a low temperature bonded inorganic material and its reaction occurs at room temperature, concrete can gain its strength at ambient temperature.
- **Ability to consume waste:** Many industrial wastes can be recycled as substitutes for cement or aggregate. Examples are fly ash, ground tyre and slag.

- **Less maintenance required:** No coating or painting is needed as for steel structures.

2.7.2 Limitations:

- Concrete possess low tensile strength. Therefore concrete is required to be reinforced to avoid cracks.
- In long structures, expansion joints are required to be provided if there is large temperature variance in the area.
- Due to drying shrinkage and moisture expansion concrete may crack. Therefore construction joints are provided to avoid these types of cracks.
- If soluble salt is present in concrete then it may lead to efflorescence when it comes in contact with moisture.
- Concrete made with ordinary Portland cement gets integrated in the presence of alkalis, sulphates.
- Sustained loads develop creep in structures.

2.8 FRESH CONCRETE

Fresh concrete is that stage of concrete in which concrete can be moulded and it is in plastic state. This is also called “Green Concrete”. Another term used to describe the state of fresh concrete is consistence, which is the case with which concrete will flow.

2.8.1 PROPERTIES OF FRESH CONCRETE

The following are important properties of fresh concrete;

- Setting
- Workability

- Bleeding
- Segregation
- Hydration
- Air entrainment

SETTING OF CONCRETE: The hardening of concrete before its hydration is known as setting of concrete or the hardening of concrete before it gains strength or the transition process of changing of concrete from plastic state to hardened state. Setting of concrete is based or related to the setting of cement paste. Thus cement properties greatly affect the setting time. Factors affecting setting are water cement ratio, suitable temperature, cement content, type of cement, fineness of cement, relative humidity, admixtures, type and amount of aggregate.

CONCRETE BLEEDING: Bleeding in concrete is sometimes referred to as water gain. It is a particular form of segregation, in which some of the water from the concrete comes out to the surface of the concrete, being of the lowest specific gravity among all the ingredients of concrete. Bleeding is predominantly observed in a highly wet mix, badly proportioned and insufficiently mixed concrete. In thin members like roof slab or road slabs and when concrete is placed in sunny weather show excessive bleeding. Due to bleeding, water comes up and accumulates at the surface. Sometimes, along with this water, certain quantity of cement also comes to the surface. When the surface is worked up with the trowel, the aggregate goes down and the cement and water comes up to the top surface. This formation of cement paste at the surface is known as “Laitance”. In such a case, the top surface of slabs and pavements will not have good wearing quality. This laitance formed on roads produces dust in summer and mud in rain y seasons.

Water while traversing from bottom to top, makes continuous channels. If the water cement ratio used is more than 0.7, the bleeding channels will remain continuous and unsegmented. These continuous bleeding channels are often responsible for causing permeability of the concrete structures. While the mixing water is in the process of coming up, it may be intercepted by aggregates. The bleeding water is likely to accumulate below the aggregate. This accumulation of water creates water voids and reduces the bond between the aggregates and the paste. Bleeding rate increases with time up to about pone hour or so and thereafter the rate decreases but continues more or less till the final setting time of cement.

➢ PREVENTION OF BLEEDING IN CONCRETE

Bleeding can be reduced by proper proportioning and uniform and complex mixing.

- Use of finely divided pozzolanic materials reduces bleeding by creating a longer path for water to transverse.
- Air-entraining agent is very effective in reducing the bleeding.
- Bleeding can be reduced by the use of finer cement or cement with low alkali content. Rich mixes are less susceptible to bleeding than less mixes.

The bleeding is not completely harmful if the rate of evaporation of water from the surface is equal to the rate of bleeding. Removal of water, after it had played its role in providing workability, from the body of concrete by way of bleeding will do good to the concrete. Early bleeding when the concrete mass is fully plastic, may not cause much harm, this is because concrete being in a fully plastic condition at that stage, will get subsided and compacted. It is the delayed bleeding, when the concrete has lost its plasticity, which causes undue harm to the concrete. Controlled revibration may be adopted to overcome the bad effect of bleeding.

SEGREGATION IN CONCRETE: Segregation can be defined as the separation of the constituent materials of concrete. A good concrete is one in which all the ingredients are properly distributed to make a homogenous mixture. There are considered differences in the sizes and specific gravities of the constituent ingredients of concrete. Therefore, it is natural that the materials show a tendency to fall apart. A well-made concrete, taking into consideration various parameters such as grading, size, shape and surface texture of aggregate with optimum quantity of waters makes a cohesive mix. Such concrete will not exhibit any tendency for segregation. The cohesive and fatty characteristics of matrix do not allow the aggregate to fall apart, at the same time; the matrix itself is sufficiently contained by the aggregate. Similarly, water also does not find it easy to move pout freely from the rest of the ingredients.

HYDRATION IN CONCRETE: Concrete derives its strength by the hydration of cement particles. The hydration of cement is not a momentary action but a process continuing for long time. Of course, the rate of hydration is fast to start with, but continues over a long time at a decreasing rate. In the field and in actual work, even a higher water/cement ratio is used, since the concrete is open to atmosphere, the water used in the concrete evaporates and the water available in the concrete will no0t be sufficient for effective hydration to take place particularly in the top layer. If the hydration is to continue, extra water must be added to refill the loss of water on account of absorption and evaporation. Therefore, the curing can be considered as creation of a favorable environment during the early period for uninterrupted hydration. The desirable conditions are suitable temperature and ample moisture. Concrete while hydrating, releases high heat of hydration. This heat is harmful from the point of view of volume stability. Heat of hydration of concrete may also cause shrinkage in concrete, thus producing cracks. If the heat generated is removed by some means, the adverse effect due to the generation of heat can be reduced. This can be done by a thorough water curing.

AIR ENTRAINMENT: Air entrainment reduces the density of concrete and consequently reduces the strength. Air entrainment is used to produce a number of effects in both the plastic and the hardened concrete.

2.9 HARDENED CONCRETE

Strength is defined as the ability of a material to resist stress without failure. The failure of concrete is due to cracking. Under direct tension, concrete failure is due to the propagation of a large number of cracks, leading to a mode of disintegration commonly referred to as ‘crushing’. Performance of concrete is evaluated from mechanical properties which include shrinkage and creep, compressive strength of concrete is the most important characteristic and it is generally assumed that an improvement in concrete compressive strength will improve its mechanical properties; however, in case of concrete in which cement is partially replaced by mineral admixtures, all mechanical properties are not directly associated with compressive strength and the effects of the same amount of different mineral admixtures on the mechanical properties of hardened concrete are not the same. This difference of the effects of different minerals on the mechanical properties is as follows. The strength is the property generally specified in construction design and quality control, for the following reasons;

i. It is relatively easy to measure.

ii. Other properties are related to the strength and can be deduced from strength data.

The 28 day compressive strength of concrete determined by a standard uniaxial compression test is accepted universally as a general index of concrete strength.

2.10 ADMIXTURES IN CONCRETE

Admixtures are those ingredients in concrete other than Portland cement, water, and aggregates that are added to the mixture immediately before or during mixing. Admixtures are equally known as additives. So often, instead of using special cement, it is possible to change some of the properties of the more commonly used cements by incorporating a suitable additive or admixtures (Chen, 2004). These days, concrete is being used for so many purposes in different conditions. In these conditions ordinary concrete may fail to exhibit the required quality or durability. In such cases admixtures are used to modify the properties of ordinary concrete so as to make it more suitable for any situation (Liu, 2004). Despite these considerations, it should be borne in mind that no admixture of any type or amount can be considered a substitute for good concreting practice. The effectiveness of an admixture depends upon factors such as type, brand, and amount of cementing materials; water content; aggregate shape, gradation, and proportions; mixing time; slump; and temperature of the concrete. Admixtures being considered for use in concrete should meet applicable specifications such as; Trial mixtures should be made with the admixture and the job materials at temperatures and humidities anticipated on the job. In this way the compatibility of the admixture with other admixtures and job materials, as well as the effects of the admixture on the properties of the fresh and hardened concrete, can be observed. The amount of admixture recommended by the manufacture or the optimum amount determined by laboratory tests should be used.

2.10.1 The major reasons for using admixtures:

- To reduce the cost of concrete construction

- . To achieve certain properties in concrete more effectively than by other means
- To maintain the quality of concrete during the stages of mixing, transporting, placing, and curing in adverse weather conditions
- To overcome certain emergencies during concreting operations.

Admixtures are classified by the 855075: part 1: 1982 in various types according to the requirements of characteristics strength and function of concrete. They range from Retarders, plasticizers, water reducers, air-entraining admixtures, bonding admixtures, accelerators, colouring agents, water proofing, miscellaneous agents etc. But commonly used admixtures are: accelerators, retarders, plasticizers/super plasticizers, air entraining colouring agents, and are usually available at any local concrete supply retailer.

2.10.2 Beneficial effects of admixtures on concrete properties

Table 2.1: BENEFICIAL EFFECTS OF ADMIXTURES ON CONCRETE PROPERTIES

Concrete property	Admixture Type	Category of Admixtures
Workability	Water reducer Air-entraining agents Inert mineral powder Pozzolans Polymer latexes	Chemical Air-entraining Mineral Mineral Miscellaneous
Set control	Set accelerators Set reducers	Chemical Chemical

Strength	Water reducers Pozzolans Polymer latexes Set retarders	Chemical Mineral Miscellaneous Chemical
Durability	Air-entraining agents Pozzolans Water reducers Corrosion inhibitors Water-repelent admixtures	Air-entraining Mineral Chemical Miscellaneous Miscellaneous
Special Concrete	Polymer latexes Slags Expansive admixtures Color pigments Gas-forming admixtures	Miscellaneous Mineral Miscellaneous Miscellaneous Miscellaneous

Whiting and Dziedzic, (1992)

2.10.3 Air-entraining admixtures:

They are admixtures used to purposely introduce and stabilize microscopic air bubbles in concrete. Air-entrainment will dramatically improve the durability of concrete exposed to cycles of freezing and thawing Entrained air greatly improves concrete’s resistance to surface scaling caused by chemical deicers. Furthermore, the workability of fresh concrete is improved significantly, and segregation and bleeding are reduced or eliminated. Air-entrained concrete contains minute air bubbles that are distributed uniformly throughout the cement paste. Entrained air can be produced in concrete by use of air-entraining cement, by introduction of an air-entraining admixture, or by a combination of both methods. Air entraining cement is a Portland cement with air-entraining addition interground with the clinker during manufacture. An air-entraining admixture, on the other hand, is added directly to the concrete materials either before or during mixing. Specifications and methods of testing air-entraining admixtures are given in ASTM C 260 and C 233 (AASHTO M 154 and T 157). Air-entraining additions for use in the manufacture of air-entraining cements must meet requirements of ASTM C 226. Applicable requirements for air-entraining cements are given in ASTM C 150 and AASHTO M 85.

2.10.4 Water-reducing admixtures:

They are admixtures used to reduce the quantity of mixing water required to produce concrete of a certain slump, reduce water-cement ratio, reduce cement content, or increase slump. Typical water reducers reduce the water content by approximately 5% to 10%. Adding a water-reducing admixture to concrete without reducing the water content can produce a mixture with a higher slump. The rate of slump loss, however, is not reduced and in most cases is increased. Rapid slump loss results in reduced workability and less time to place concrete. An increase in strength is generally obtained with water-reducing admixtures as the water-cement ratio is reduced. For concretes of equal cement content, air content, and slump, the 28-day strength of a water-reduced concrete containing water reducer can be 10% to 25% greater than concrete without the admixture. Despite reduction in water content, water-reducing admixtures may cause increases in drying shrinkage. Usually the effect of the water reducer on drying shrinkage is small compared to other more significant factors that cause shrinkage cracks in concrete. Using a water reducer to reduce the cement and water content of a concrete mixture while maintaining a constant water-cement ratio can result in equal or reduced compressive strength, and can increase slump loss by a factor of two or more (Whiting and Dziedzic 1992).Water reducers decrease increase, or have no effect on bleeding, depending on the chemical composition of the admixture. A reduction of bleeding can result in finishing difficulties on flat surfaces when rapid drying conditions are present. Water reducers can be modified to give varying degrees of retardation while others do not significantly affect the setting time. The effectiveness of water reducers on concrete is a function of their chemical composition, concrete temperature, cement composition and fineness, cement content, and the presence of other admixtures.

2.10.5 Retarding admixtures:

They are those admixtures used to reduce the rate of setting of concrete. High temperatures of fresh concrete (30°C [86°F]) are often the cause of an increased rate of hardening that makes placing and finishing difficult. One of the most practical methods of counteracting this effect is to reduce the temperature of the concrete by cooling the mixing water and/or the aggregates. Retarders do not decrease the initial temperature of concrete. The bleeding rate and bleeding capacity of concrete is increased with retarders. Retarding admixtures are useful in extending the setting time of concrete, but they are often also used in attempts to decrease slump loss and extend workability, especially prior to placement at elevated temperatures. Retarders are sometimes used to; offset the accelerating effect of hot weather on the setting of concrete, delay the initial set of concrete or grout when difficult or unusual conditions of placement occur, such as placing concrete in large piers and foundations, cementing oil wells, or pumping grout or concrete over considerable distances and delay the set for special finishing techniques, such as an exposed aggregate surface. In general, some reduction in strength at early ages (one to three days) accompanies the use of retarders. The effects of these materials on the other properties of concrete, such as shrinkage, may not be predictable. Therefore, acceptance tests of retarders should be made with actual job materials under anticipated job conditions.

2.10.6 Accelerating Admixtures:

They are those admixtures used to accelerate the rate of hydration (setting) and strength development of concrete at an early age. Calcium chloride ($CaCl_2$)is the chemical most commonly used in accelerating admixtures, especially for non-reinforced concrete. It should conform to the requirements of ASTM D 98 (AASHTOM 144) and should be sampled and tested in accordance with ASTMD
345. The widespread use of calcium chloride as an accelerating admixtures has provided much data and experience on the effect of this chemical on the properties of concrete. Besides accelerating strength gain, calcium chloride causes an increase in drying shrinkage, potential reinforcement corrosion, discoloration (a darkening of concrete), and an increase in the potential for scaling. Calcium chloride is not an antifreeze agent. When used in allowable amounts, it will not reduce the freezing point of concrete by more than a few degrees. Attempts to protect concrete from freezing by this method are foolhardy. Instead, proven reliable precautions should be taken during cold weather. When used, calcium chloride should be added to the concrete mixture in solution form as part of the mixing water. If added to the concrete in dry flake form, all of the dry particles may not be completely dissolved during mixing. Undissolved lumps in the mix can cause pop outs or dark spots in hardened concrete. The amount of calcium chloride added to concrete should be no more than is necessary to produce the desired results and in no case exceed 2% by mass of cementing material. An overdose can result in placement problems and can be detrimental to concrete. It may cause rapid stiffening, a large increase in drying

shrinkage, corrosion of reinforcement, and loss of strength at later ages (Abrams1924 and Lackey1992).

2.10.7 Coloring Admixtures (pigments):

Natural and synthetic materials are used to color concrete for aesthetic and safety reasons. Red concrete is used around buried electrical or gas lines as a warning to anyone near these facilities. Yellow concrete safety curbs are used in paving applications. Generally, the amount of pigments used in concrete should not exceed 10% by weight of the cement. Pigments used in amounts less than 6% generally do not affect concrete properties. Unmodified carbon black substantially reduces air content. Most carbon black for coloring concrete contains an admixture to offset this effect on air. Before a coloring admixture is used on a project, it should be tested for color fastness in sunlight and autoclaving, chemical stability in cement, and effects on concrete properties. Calcium chloride should not be used with pigments to avoid color distortions. Pigments should conform to ASTM C 979.

2.10.8 Miscellaneous admixtures:

Include all those materials that do not come under the above mentioned categories such as latexes, corrosion inhibitors, and expansive admixtures.

2.11 MODIFIED CONCRETE USING WASTE

Continuous reduction of natural resources and environmental problem in many countries has caused the research on the effective utilization of various types of solid waste such as agricultural, industrial, mining and domestic waste to gain greater attention in the past several decades. These waste materials have potential to be utilized as construction materials to replace conventional Portland cement, sand and aggregate in the formation of concrete. The integration of these wastes as replacement material in concrete at suitable proportion, results in concrete material possessing enhanced strength and durability.

2.11.1 Waste as Partial Cement Replacement Material

There are many types of wastes that have been added as mixing ingredient production of normal concrete. The high cost of cement, used as binder, in the production of mortar, sandcrete blocks, lancrete bricks and concrete has led to a search for alternative. In addition to cost, high energy demand and emission of CO_2, which is responsible for global warming, the depletion of lime stone deposits are disadvantages associated with cement production. Research on alternative to cement, has so far centered on the partial replacement of cement with different materials. In advanced countries, partial replacement of cement with pozzolans is well documented and recommended. Pozzolans are siliceous material, which by itself possesses no cementitous properties but in processed form and finely divided form, react in the presence of water with lime, to form compounds of low solubility having cementitious properties. They are grouped into natural and artificial sources; clay and shale calcined to become active, volcanic tuff and pumicite are naturally occurring pozzolanas, whereas good blast furnace slag and fly ash are the artificial varieties. In advanced countries, the use of fly ash, a residue obtained from the combustion of pulverized coal in partial replacement of cement is recommended within the range of 10-30% by weight of cement. Mixture of Portland cement and pozzolanic material is referred to as pozzolanic cements, such cement have the following advantages good resistance to chemical attack, low evolution of heat of hydration, economy, improvement of workability, reduction of bleeding and greater impermeability. Its disadvantages being, slower rate of strength development and increased shrinkage. In the third world countries, the most common and readily available material that can be used to partially replace cement without economic implications are agro based wastes, notable ones are Acha husk ash (AHA), Bambara groundnut shell ash (BGSA), Bone powder ash (BPA), Groundnut husk ash (GHA), Rice husk ash (RHA) and Wood Ash (WA) gave a list of additional agro waste material as Ashes from the burning of dried banana leaves, coconut shell ash (CSA), bamboo leaves, some timber species, sawdust and periwinkle shell ash (PSA). (Oyedepo et,al, 2015)

2.12 COCONUT SHELL FROM VARIOUS PARTS OF NIGERIA

2.12.1 Coconut shell

Cocos Nucifera trees, otherwise known as coconut palm trees, grow abundantly along the coast line of countries within 150 of the equator. They prosper in sandy, saline soil and in tropical climates. A healthy coconut tree will produce approximately 120 watermelon-sized husks and shells per year, each with a coconut imbedded inside. There are three constituents of the ***Cocos Nucifera*** that can be used for fuel: the husk, the coconut shell, and the coconut oil that is in the white coconut “meat” or copra as it is usually called. Thus, the coconut tree is a very abundant, renewable resource of energy. When coconuts are harvested, the husks are removed, thereby leaving the shell and the copra. These husks are considered as waste materials and are usually dumped into refuse bin. When consumers buy the coconut, they buy it with the shell and when it is to be consumed it is broken and the shell is removed. Large quantities of the shells can be obtained in places where coconut meat is used in food processing. The husk and shell are both regarded as waste materials. The shells are then burnt into ashes in a furnace at a very high temperature to produce the coconut shell ash. (Walter et.al, 2006).

2.12.2 Use of CSA in concrete production

The availability of CSA in large amount has lead towards the studies on utilization of this material as partial cement replacement in normal concrete production, likewise lightweight concrete and high strength concrete.

2.13 REVIEW OF PAST WORKS

Industrialization in developing countries has resulted in an increase in agricultural outputs and consequent accumulation of unmanageable agro-wastes. Coconut shell is an agricultural/industrial waste in the coconut palm industry and causes nuisance to both health and environment when not properly disposed. These create large amount of waste by-products which must be transported away and disposed in landfills. The pollution arising from such a waste is a cause of serious concern for many countries like Nigeria **(Mahmood *et al.*, 2002).** Recycling of such waste materials into new construction materials might be a viable solution to the problem of high cost of construction materials in the developing nations **(Abdulfatai *et al.*, 2013)**. Amongst these construction materials are Ordinary Portland Cement and mineral admixtures. Admixtures may be defined as the materials other than the basic ingredients of concrete (i.e. cement, aggregates and water) added to the concrete mix immediately before or during the mixing process to modify one or more specific properties of concrete in fresh or hardened state **(Gupta, 2004)**. Admixtures depending on the type may be imported or sourced locally. The ones imported from abroad are often too expensive. The cost of conventional admixtures is often high, which makes the cost of obtaining durable concrete too high for the common man **(Aboshio *et al.*, 2009)**. In developing countries like Nigeria, and most African countries, the demand for construction is never ending. Consequently, the demand for building materials like Ordinary Portland Cement and admixtures are also high to meet the infrastructure needs of the citizens. The production of these products requires capital intensive plants and expertise. As a means of addressing these problems, researches have been carried out and many more still on going to explore the possibilities of using locally available waste materials as a replacement of the more expensive conventional admixtures in concrete. To reduce the cost of material and construction to affordable rate, several research works have been directed towards utilization of cheap and readily available local materials such as agricultural and industrial by-products as a substitute to Ordinary Portland Cement and aggregate in infrastructural construction **(Elinwa *et al,* 2005; Wazumtu and Ogork, 2015)**. In view of this, several studies already carried out on the use of wastes as innovative materials have been very encouraging. A recent study reported by **Utsev and Taku (2012)** on the use of coconut shell ash (CSA) as a supplementary cementing material in cement and concrete work has shown that inclusion of coconut shell ash in concrete production not only lowers the cost of concrete but also offers a large potential for the utilization of coconut shell ash in concrete as a cost-effective alternative to current disposal method of the wastes. They suggested that up to 10-15% replacement of OPC with CSA could be used for both heavy weight and light weight concrete production. **Nagarajan *et al.* (2014)** also opined that CSA can be used up to 10% to replace cement for concrete production despite its 7.1% lesser strength than the control. Many other researchers have also been conducted on coconut shell and coconut shell ash. For instance **Olugbenga *et al.* (2011)** explained that the plastic index of paste samples produced with coconut shell and husk ash (CSHA) reduces with addition of various replacement of CSHA, indicating a reduction in swelling potential and hence an increase in strength properties; **Oluremi *et al.* (2012)** also stated that coconut husk ash can be used to improve the California bearing ratio of soils with low CBR values; **Popoola *et al.* (2019)** also encouraged the use of coconut waste ash in the construction industry to reduce the cost of lime since its use improves the maximum dry density (MDD), unconfined compressive strength (UCS), optimum moisture content (OMC) and CBR values of stabilized soil; **Amarnath and Ramachandrudu (2012)** in their research on properties of concrete with coconut shells as aggregate replacement found that, coarse aggregate replacement with equivalent weight of fly ash had no influence when compared with properties of corresponding coconut shell replaced concrete. In spite of the many efforts made by researchers in using coconut shell ash, coconut shell, coconut husk ash as replacement materials for cement, coarse aggregate and cement/lime respectively, properties of its concrete or mortar produced though good are still below those of normal concrete. This research therefore sets out to investigate the effect of coconut shell ash as admixture in order to improve the properties of concrete made with conventional materials in normal environment.

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CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter discusses the structured process for conducting this research. All the necessary calculation details are also explained in this chapter. Detailed descriptions about the material used, specimens tested are also explained in this chapter. The structured experiments and testing were conducted in the Concrete Laboratory at NNAMDI ZIKIWE UNIVERSITY, AWKA.

3.2 EXPERIMENTAL PROGRAM

The purpose of this experiment is to investigate the effect of coconut shell ash (CSA) inclusion as a partial replacement of or Portland cement on the compressive strength of concrete. The cube size 150 X 150 X 150mm is used during the study in mixing, curing,, and other processes. The coarse aggregate integrated in the mix consist of single sized 20mm granite and fine sand was local river sand.

The mixture proportions were prepared using water cement ratio of 0.5 keeping aggregates (both coarse and fine) content constant in all mixes except for the variation of the percentage of ordinary Portland cement used. A mix ratio of 1:2:4 was used and with different volume of concrete shell ash (0%, 5%, 10% and 15%).The first mix is the reference concrete mix (control mix) consisting 100% ordinary Portland cement. Then the remaining mixes are prepared by integrating coconut shell ash (CSA) by volume.

Metal moulds were used for casting test samples. The inner parts of the moulds were coated with engine oil to ensure easy de-moulding and smooth surface finish. Immediately after mixing, portion of the mix was tested for workability (slump test) the fresh mixtures were cast into the moulds of 150 X 150 X 150mm cube using hand trowel. They were filled in three layers and compacted using the compaction rod (25mm diameter steel rod). Each layer was compared manually by uniformly distributing 25 blows of the steel rod across the cross-section of the mould. The top of each mould was smoothened and leveled and the outside surfaces cleaned. The mould and their contents were kept in the curing room at temperature 21℃ and relative humidity not less than 70%. After 24 hours, the specimens were de-moulded and subjected to water curing until the testing date. Compressive strength test was determined for 7, 14, 21 and 28 days according to British Standard Institution.

A total of 32 cube specimens were prepared with a water to cement ratio of 0.5 maintained throughout the experiment. The strength and other results on fresh concrete were also compared to specimen that did not contain CSA as the control specimen.

3.3 INSTRUMENTATION AND LABORATORY WORK

3.3.1 MATERIALS

The materials listed and discussed below were used in the preparation of the specimen in this study in order to achieve design objectives;

- Cement
- Fine aggregate
- Coarse aggregate
- Water
- Coconut shells

3.3.1.1 CEMENT

The cement used in this research work was the locally produced BUA brand of the Ordinary Portland cement and it conformed to the requirement (BS 12, 1996).

Presently the company produces CEM II type of cement in accordance with the Nigerian Industrial Standards. BUA Cement is ideal for all construction purposes in Nigeria. Its unique quality makes it the cement of choice for block-making, plastering and concrete works. Its high early strength, rapid setting and low heat of hydration are all distinct features that characterize our high quality production process.

Figure 3.1: BUA Portland Cement bag

3.3.1.2 FINE AGGREGATE

Fine aggregate normally consists of natural, crushed, or manufacture sand. Locally available Natural sand conforming to BS 882: 1992 and compiling with coarse, medium and fine grading requirement of MS: 30 Part 8, 1995 was used for this research. The maximum grain size and size distribution of the fine aggregate depends on the type of product being made. I ensured that the sand was free from clayey materials and other particles so as not to cause expansion and contraction when the water dries up in the mortar. I also ensured that the fine aggregate was air dried to obtain saturated surface dry condition to ensure the water cement ratio is not affected. The sand (fine aggregate) was sourced from a local dealer at Ring Road in Awka.

Figure 3.2: Fine aggregate

3.3.1.3 COARSE AGGREGATE

The coarse aggregate component of a concrete mix occupies 60-70% of the volume of concrete. Coarse aggregate is often referred to as gravel, stone or granite. The coarse aggregate used in this research is crushed granite and it’s of normal weight, irregular shape of 20mm diameter and conforming to BS 882: 1992 [7]. I ensured that the coarse aggregate air-dried to obtain saturated surface dry condition to ensure that water-cement ratio was not affected. The granite (coarse aggregate) was sourced from a local dealer at Ring Road in Awka.

Figure 3.3: Coarse aggregate

3.3.1.4 WATER

Water is a major component in the mixing of concrete. Too little or too much water will significantly affect the mix and the overall strength of the concrete. Using the optimum weight or volume of water during the mix is very important. The water used was cleaned and free from any visible impurities. It conformed to BS 3148 (1980) requirements.

Water added to a concrete mix must fill the spaces among the particles. Additional water “lubricates” the particles by separating them with a water film. Increasing the amount of water will increase the fluidity and make concrete to be easily compacted. Indeed, the total water content reduces cohesiveness, leading to segregation and bleeding. With increasing water content, concrete strength is also reduced. Therefore, a water cement ratio of 0.5 was maintained throughout the work. Portable water from the tank at the concrete tech lab was used for the concrete mix.

3.3.1.5 COCONUT SHELL ASH

Coconut shell was sourced from Onitsha. The fibrous outer parts of the coconut shell were thoroughly removed. After collection, the shells were sundried and later burnt. Then they were grinded into powdered form and air dried.

Figure 3.4: Coconut shell

3.4 MIX DESIGN

Considering the concrete mould of 0.15m x 0.15m x 0.15m

The density of concrete is 2400kg/m^3

Density= Mass of concrete/Volume of concrete

Volume of one cube = 0.15m x 0.15m x 0.15m= 3.375 x 10^{-3}m^3

Therefore; Mass of one cube = Density x Volume = 2400 x 3.375 x 10^{-3} = 8.1kg

Since the intended mix ratio is 1:2:4 and a water/cement ratio is 0.5, the weight of the corresponding materials was calculated as shown below:

Mass of cement

1/7 x 8.1kg = 1.16kg

Mass of fine aggregate (sand)

2/7 x 8.1kg = 2.31kg

Mass of coarse aggregate (granite)

4/7 x 8.1kg = 4.36kg

Mass of water with water/cement ratio of 0.5

Mass of cement x 0.5 = 1.16kg x 0.5 = 0.58kg

Convert from kg to ml = 0.58kg = 580ml.

The percentages of coconut shell ash used were 0, 5, 10 and 15 % by weight of Portland cement.

0% CSA replacement:

Cement content = 1.16kg CSA content= 0kg

5% CSA replacement = 5/100 x 1.16kg = 0.058kg

1.16-0.058 (kg) = 1.102kg

Cement content = 1.102kg CSA content= 0.058kg

10% CSA replacement = 10/100 x 1.16kg = 0.116kg

1.16-0.116 (kg) = 1.044kg

Cement content = 1.044kg CSA content= 0.116kg

15% CSA replacement = 15/100 x 1.16kg = 0.174kg

1.16-0.174 (kg) = 0.986kg

Cement content = 0.986kg CSA content= 0.174kg

Table 3.1: WEIGHT OF INGREDIENTS OF ONE CONCRETE CUBE

Cement	Fine aggregate (Sand)	Coarse aggregate (Granite)	Water
1.16kg	2.31kg	4.36kg	580ml

CONTENT	CEMENT (kg)	COCONUT SHELL ASH (kg)
0%	1.16	0
5%	1.102	0.058
10%	1.044	0.116
15%	0.986	0.174

The weight of one cube is now multiplied by the number of specimens to be produced on a particular day

Due to the method of mixing (hand mixing) adopted in this research, there was risk of wastage. Therefore 5% of the individual components of the concrete was added as a factor of safety.

3.5 PREPARATION OF TEST SPECIMENS

Cube mould measuring 150 x 150 x 150mm was used for the compressive test. The mould for the slump test was a frustum of a cone, 305mm high. The base of 203mm diameter was placed on a smooth surface with smaller opening of 102mm diameter. It is very essential that the test specimens be kept ready before the actual mixing of concrete.

Total of 32 specimens were used for this research. Sufficient metallic moulds in accordance with BS1881 were available to enable simultaneous casting of almost all specimens. I ensured that the two sections of the mould were bolted firmly together and the moulds held down firmly on the base plate in order to prevent the concrete slurry from leaking from mould when vibration takes place. Then I cleaned and applied a release agent (condemn oil) to all the internal surfaces of the metallic mould to ensure that the concrete is not damaged during the loosing of the mould, after which I positioned the moulds properly under shed at a place free from vibration.

Figure 3.5: Metallic mould for concrete casting

3.5.1 MIXING PROCESS

Mixing was carried out by the traditional hand mixing method. Weighing of components was done by a weighing balance. The components were weighed accordingly to achieve the work in the mix design. The main challenge in the mixing was to produce sufficiently volume of crushed coconut shell ash added to partially replace Portland cement in the concrete. Since hand mixing was adopted the coconut shell ash was added immediately after the fine aggregate and the cement has been thoroughly mixed together, before the coarse aggregate is then added and water is added lastly, and they are all mixed together.

Figure 3.6: Mixing of concrete

3.6 TESTS ON CONCRETE

- **Test on fresh concrete**
- **Test on hardened concrete**

3.6.1 TEST ON FRESH CONCRETE

Fresh concrete is concrete at the state when its components are fully mixed but its strength has not yet developed. This period corresponds to the cement hydration stages. The properties of fresh concrete directly influence the handling, placing and consolidation, as well as the properties of hardened concrete. ASTM makes provision for sampling of concrete. It spells out the procedure for sampling various production systems like the **Slump test**. The specimen must be tested within 10 minutes and must be protected from weather during testing.

3.6.1.1 SLUMP TEST

The concrete slump test is on empirical test that measures the workability of fresh concrete. More specifically, it measures the consistency of the concrete in that specific batch. This test is performed to check the consistency of freshly made concrete and this test was carried out in accordance with ASTM C143-05a. This test is popular due to the simplicity of apparatus used and simple procedure.

3.6.1.2 APPARATUS

- The metal mould for the slump test was a frustum of a cone, 305mm high, open at both ends. The base of 203mm diameter was placed on a smooth surface with smaller opening of 102mm diameter at the top.
- A 610mm long bullet nosed metal rod, 16mm in diameter.
- Spirit level
- Trowel

3.6.1.3 PROCEDURE AND HEIGHT MEASUREMENT

- The slump cone is filled with concrete in three layers using the trowel. Each layer was tamped 25 times with a standard steel rod and the top surface is struck off by means of screeding and rolling motion of the tamping rod. I made sure that the mould was firmly held against its base during the entire operation; this is facilitated by handles or foot-rests brazed to the mould.
- Immediately after filling, the cone is slowly lifted and the unsupported concrete slumped - hence the name of the test. The decrease in the height of the centre of the slumped concrete is called slump and measured with the spirit level to the nearest 5mm. If the slump is <100mm and measured to the nearest 10mm if the slump is >100mm.

3.6.1.4 INTERPRETATION OF RESULTS

The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as true slump, zero, shear slump or collapse slump. If a shear, zero or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump is an indication of ton wet a mix. Only a true slump is of any use in the test. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which slump test is not appropriate. Very dry mixes; having slump 0-25mm are used in road making, low workability mixes; having slump 10-40mm are used for foundations with light reinforcement, medium workability mixes; 50-90 for normal reinforced concrete placed with vibration, high workability concrete, > 100mm.

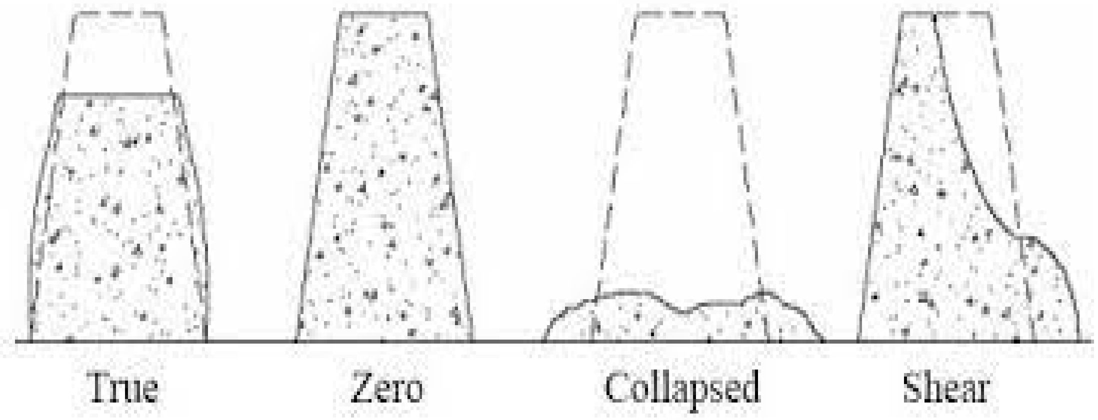

Figure 3.7: Different slump test results

3.6.2 TEST ON HARDENED CONCRETE

The type of test that was done on concrete cubes was the compressive strength test and the cubes were tested for 7, 14, 21 and 28 days.

3.6.2.1 COMPRESSIVE STRENGTH TEST

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one can judge whether concreting has been done properly or not. The compression test was conducted by using compressive test machine at the Concrete Laboratory of Civil Engineering of Nnamdi Azikiwe University, Awka.

3.6.2.2 APPARATUS

- Compressive testing machine
- Metallic moulds of size 150mm x 150mm x 150mm
- Shovel and trowel for mixing
- Tamping rod for compaction

3.6.2.3 MIXING

- Measure the required amount of raw materials needed.
- Mix the cement and fine aggregate on a water tight none-absorbent platform until the mixture is thoroughly blended and is of uniform color.
- Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.
- Add water and mix it until the concrete appears to be homogenous and of the desired consistency.

3.6.2.4 SAMPLING

- Clean the moulds and apply oil.
- Fill the concrete in the mould in layers about 5cm thick.
- Compact/tamp each layer 25 times using the tamping rod.
- Level the top surface and smoothen it with a trowel.

Figure 3.8: Concrete moulds filled with fresh concrete

Figure 3.9: Casted concrete specimens

3.6.2.5 CURING

- The test specimens are stored in moist air for 24 hours and after this period the specimens are marked and removed from the molds and kept submerged in clear fresh water until taken out prior to test.
- The water for curing should be tested and changed every 7 days and the temperature of water must be at 27±2°C.

Figure 3.10: Concrete cubes in a concrete water tank

3.6.2.6 PROCEDURE FOR COMPRESSION TESTING

- Remove the specimen from water after the specified curing time and keep to dry.
- Measure the weight and dimension of the specimen to the nearest 0.2m.
- Clean the bearing surface of the testing machine.
- Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cubes cast.
- Align the specimen centrally on the base plate of the machine.
- Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
- Apply the load gradually without shock and continuously at the rate of 140kg/cm²/minute till the specimen fails.
- Record the maximum load and note any unusual features in the type of failure.

Figure 3.11: Crushing of concrete beam specimen using the compression testing machine

NOTE

- Average of their specimens gives the crushing strength of concrete.
- The maximum compressive load at the failure divided by the area of the specimen gives the compressive strength of concrete.

3.6.2.7 CALCULATIONS

Size of cube = 150mm x 150mm x 150mm

Area of specimen = 150mm x 150mm = 3,375,000mm^3 = 0.003375m^3

Compressive strength = P/A

Where:

P = Maximum load applied to the specimen (KN)

A = Surface area in contact with the plate (mm^2)

3.7 SIEVE ANALYSIS OF FINE AGGREGATE

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (part I) – 1963. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

3.7.1 APPARATUS USED

1. A set of IS sieves of sizes – 4.75mm, 2.00mm, 1.18mm, 850µm, 600µm, 425µm, 300µm, 100µm and 75µm.
2. Sensitive weighing balance
3. Mechanical shaker device
4. Wire brush and other miscellaneous apparatus

3.7.2 PROCEDURE TO DETERMINE PARTICLE SIZE DISTRIBUTION OF AGGREGATE

1. The test sample is dried to a constant weight temperature of 110 + 5°C and weighed.
2. The sample is sieved using a set of IS sieves agitated by the mechanical shaker.
3. On completion of sieving, the material on each sieve is weighed.
4. Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.

5. Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100.

3.7.3 REPORTING OF RESULTS

The results should be calculated and reported as

1. The cumulative percentage by weight of the total sample.
2. The percentage by weight of the total sample passing through one sieve and retained on the next smaller sieve, to the nearest 0.1%. The results of the sieve analysis can be recoded graphically on a semi-log graph with particle size as abscissa (log scale) and the percentage smaller than the specified diameter as ordinate. The values gotten from % on sieve are been added up to get 100, then you subtract 100 from the entire percentage on sieve to get % passing sieve.

3.8 PRECAUTIONARY MEASURES

The precautionary measures that are carried out in this research were as follows;

- Wear adequate safety equipments such as waterproof gloves, a sturdy jacket, waterproof trousers and long boots.
- Ensure that all the internal surfaces of the metallic mold are cleaned by applying a release agent (condemn oil) so that the concrete is not damaged during the losing of the moulds.
- During casting, ensure that the concrete was properly compacted to avoid voids.
- Avoid error due to parallax during the slump test, when measuring the difference in height between the cone height band the slumped concrete with a measuring tape.

- Ensure that during the slump test that the frustum was firmly connected to its base to avoid any form of movement during tamping.
- Ensure that the concrete cubes and beams were fully submerged inside the water to facilitate good curing.
- Occasionally change the curing water when it got contaminated to terminate any chances of concrete being attacked by any form of impurity.
- The water in the curing tank was highly alkaline so ensure to use waterproof gloves when handling cubes in the tank.
- During the crushing test, ensured that the pointer in the machine deflected from a zero point to the maximum strength of the concrete specimen.
- Ensured that the concrete cubes were placed with the surfaces in contact with the platens of the crushing machine.
- Above all, ensure that all measurements are carefully carried out.

CHAPTER FOUR

RESULT AND DISCUSSION

4.0 INTRODUCTION

In this chapter, various test conducted on the specimen and results will be discussed in this chapter. The present study aims to investigate the workability and compressive strength of coconut shell ash (CSA) as a partial ordinary Portland cement replacement in concrete.

The 32 specimens were cured and results were collected for 7, 14, 21 and 28 days with 2 specimens crushed for each day and the average of the two values taken. The mix ratio of the concrete is 1:2:4 and the size of aggregate is 20mm with water cement ratio of 0.5 maintained throughout the experiment. All the test methods were done as described in chapter three of this report.

4.1 DRY SIEVE ANALYSIS RESULTS OF FINE AGGREGATE USED

Table 4.1: Sieve analysis results

SIEVE SIZE (mm)	WEIGHT OF SAMPLE RETAINED (g)	% OF WEIGHT RETAINED (%)	CUMMULATIVE (%) RETAINED	% PASSING
4.750	4.700	0.940	0.940	99.060
2.000	8.840	1.768	2.708	97.292
1.800	16.260	3.252	5.960	94.040

0.850	20.430	4.086	10.046	89.954
0.600	49.570	9.914	19.960	80.040
0.425	92.570	18.412	38.372	61.628
0.300	154.13	30.826	69.198	30.802
0.100	143.01	28.602	97.800	2.200
0.075	8.050	1.610	99.410	0.590
PLATE	1.300	0.260	99.670	0.330
TOTAL	499.98	99.670		0

Initial weight of sample used = 500g

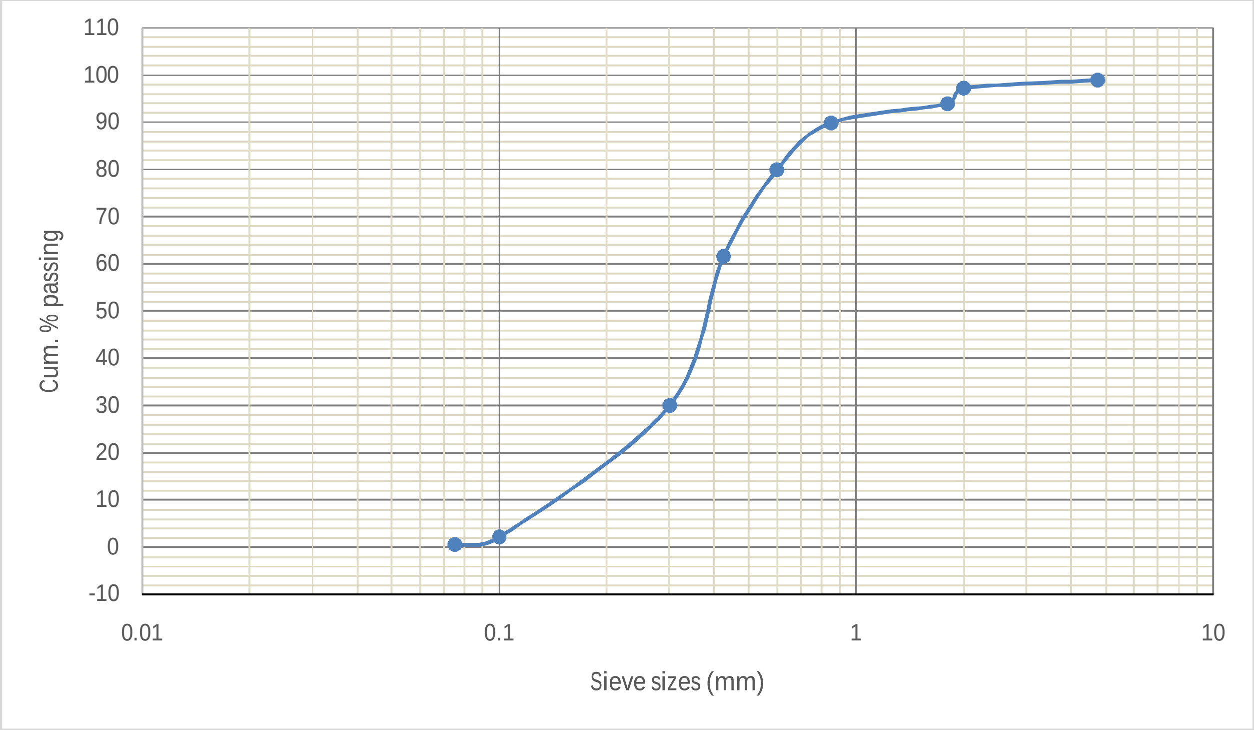

Figure 4.1: Particle size distribution analysis of fine aggregate

From the particle size distribution graph of fine aggregate (sand);

D_{10} = 0.25 D_{30} = 0.35 D_{60} = 0.40

Cc = Coefficient of curvature = $D_{30}^2/D_{10} \times D_{60}$ = $0.35^2/(0.25 \times 0.40)$ = 1.225mm

Cu = Uniformity coefficient = D_{60}/D_{10} = 0.40/0.25 = 1.6mm

For a well graded sand and gravel, Cc should lie between 1 and 3. But if its value is less than 1, it will be poorly graded. The value of Cc was **1.225mm** and this means the sand is well graded.

Also if;

Cu <5 = very uniform

Cu = 5 = medium uniform

And Cu was gotten to be **1.6mm**, so the sand is very uniform.

4.2 WORKABILITY TEST RESULTS

The results of the slump tests indicating the workability of the concrete for different percentage replacement of Portland cement with coconut shell ash is shown in Table 4. Tests were done according to BS EN 12350-2 (16).

REPLACEMENT OF CSA (%)	SLUMP (mm)
0	65
5	52
10	45
15	25

Table 4.2: Slump test result

From the table above, reduction in workability is evident with the increase in CSA. The concrete slump decreases as the percentage of the CSA increased in the mixes. The table shows loss from 65mm to 25mm (40mm loss) when the CSA is included for 15%. This indicates that the moisture content of the mixture has decreased. When adding 5%-10% CSA, the slump loss is not so significant.

Hence, the more the CSA content, the more stiffened the mixture becomes. Super plasticizer may be used as water reducing agent in order to obtain high workability from coconut shell according to earlier researchers.

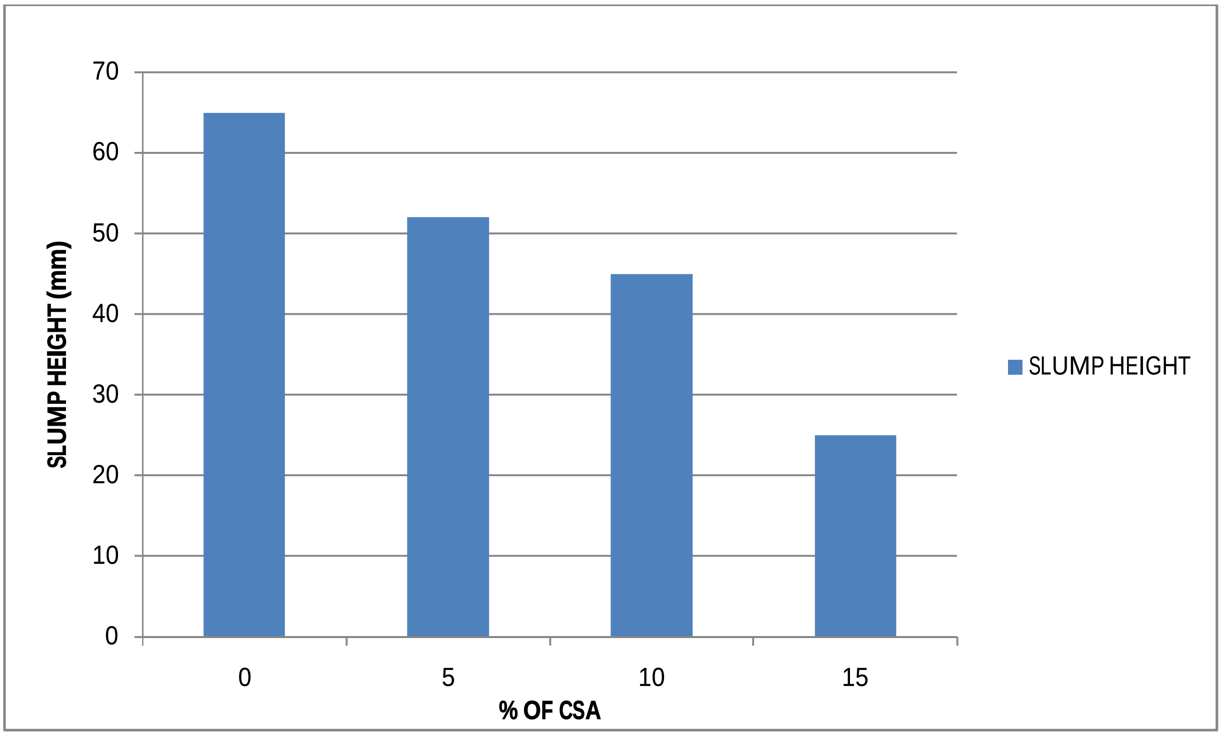

Figure 4.2: Slump height Vs % of CSA

4.3 COMPRESSIVE TEST RESULT

Table 4.3: Compression strength of cubes

SPECIMEN		**COMPRESSION STRENGTH (N/mm²)**		**CROSS SECTIONAL AREA (mm²)**	**AVERAGE WEIGHT (kg)**	**AVERAGE COMPRESSION STRENGTH (N/mm²)**
0% OF CSA	TIME	C1	C2	(150X150)	-	-
	7 days	15.56	17.42	22500	8.20	16.49
	14 days	16.00	18.74	22500	8.25	17.37
	21 days	21.48	18.60	22500	8.29	20.04
	28 days	25.11	21.09	22500	8.37	**23.10**
5% OF CSA	7 days	14.39	19.27	22500	8.11	16.83
	14 days	19.21	24.23	22500	8.30	21.72
	21 days	24.00	22.80	22500	8.32	23.40
	28 days	26.80	25.00	22500	8.41	**25.90**
10% OF CSA	7 days	18.00	19.60	22500	8.12	18.80
	14 days	24.50	22.10	22500	8.18	23.30
	21 days	29.55	27.25	22500	8.14	28.40
	28 days	30.95	34.45	22500	8.24	**32.70**
15% OF CSA	7 days	11.70	12.50	22500	8.18	12.10
	14 days	13.98	15.50	22500	8.24	14.74
	21 days	18.58	16.02	22500	8.32	17.30
	28 days	20.11	19.29	22500	8.45	**19.70**

The results for 28 day-test compressive strength for all specimens tested and the average of the reading is shown in the table above. From the above results, it clearly shows that the addition of CSA into cement composite does increase the compressive strength but the strength only increases up to certain CSA content.

Specimen with 10% CSA gave the highest compressive strength of 32.70 N/mm² and this optimum strength dropped when the CSA content is further increased from 10-15%. Specimen with 15% CSA gave the lowest compressive strength of 19.70 N/mm².

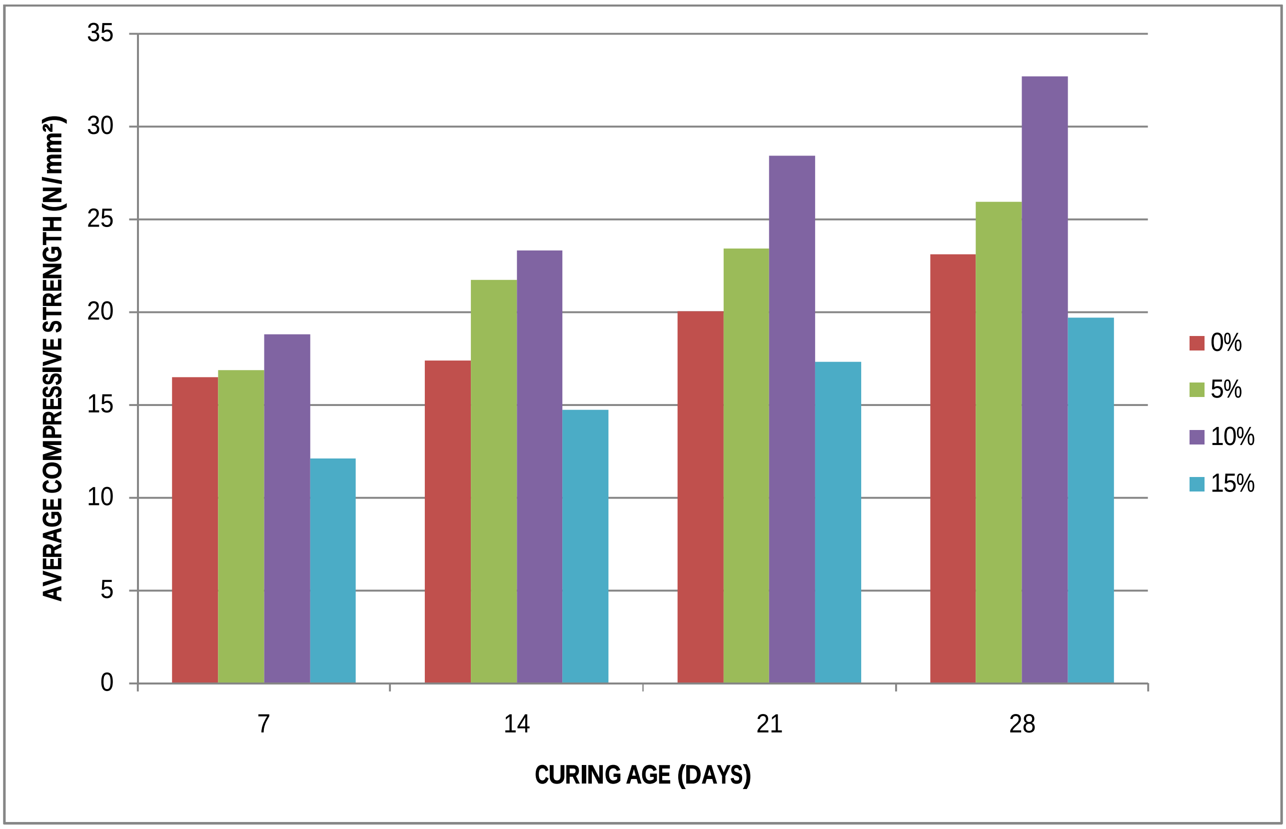

Figure 4.3: Average compressive strength Vs curing age (days)

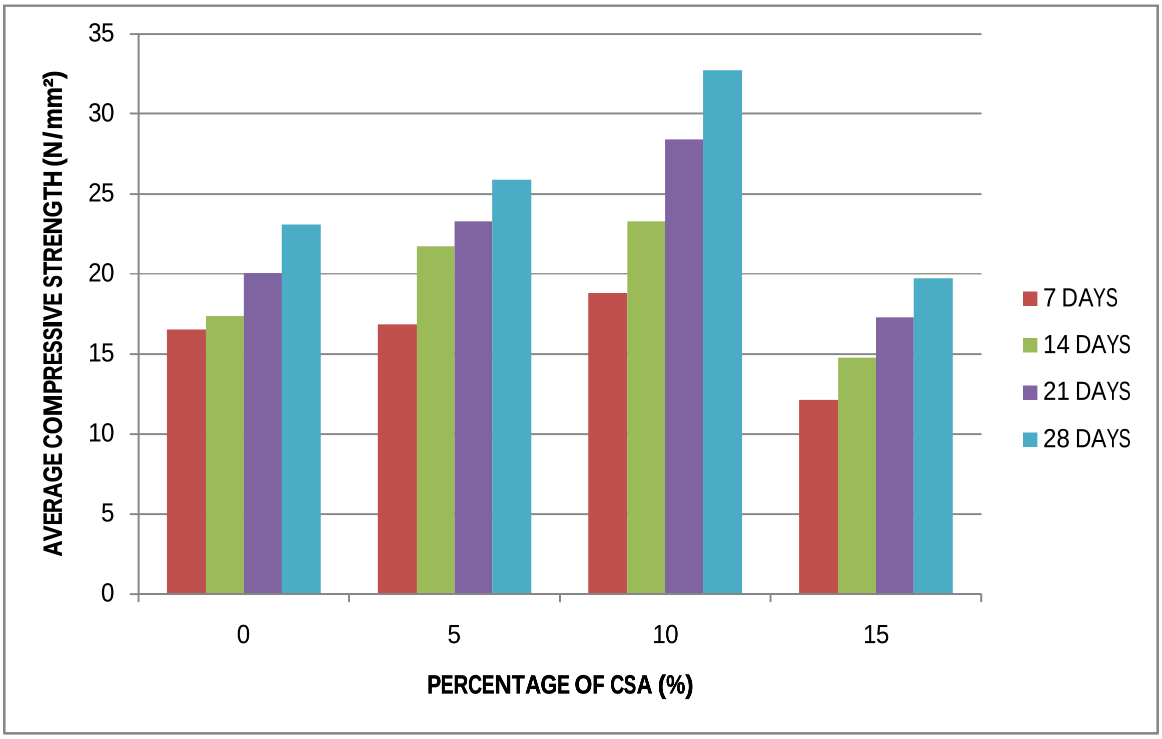

Figure 4.4: Average compressive strength Vs percentage of CSA

4.4 SUMMARY

Replacement up to 10% produces hardened concrete which can still be considered as normal weight concrete. Discussing factors affecting the mixes strength performance, the lower strength exhibited by mixture with higher percentage of CSA when compared with the one consisting smaller percentage is due to increment in the quantity of cementitious material used as adhesive materials. From the results obtained, CSA/OPC mix showed some promise for use in reinforce concrete as well as mass concrete structures in building construction. The compressive strength of the cubes at 28 days curing indicates that 10% replacement level meet the requirement of BS EN 206-1: 2000 for class C25/30 and C20/25 respectively for heavy weight concreting and LC25/28 and LC20/22 respectively for light weight concreting. In conclusion, the study reveals that 10% partial replacement of OPC with CSA using

W/C ratio of 0.5 are suitable for production of both heavy weight and light concrete. (Utsev and Taku, 2012).

Conclusively, the proportion and characteristics of coconut shell ash used as partial replacement for ordinary Portland cement influences the strength and workability of concrete.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0 CONCLUSION

The effectiveness of coconut shell ash (CSA) in enhancing the performance of concrete was compared with normal concrete. All the normal/plain and ash concrete were designed with a fixed proportion (1:2:4) and also with the same type and size of materials. The only variable parameter is in the CSA content which was done by the replacement of 5-15% by weight of ordinary Portland cement to the concrete mix. Results obtained in the test were the effect of partial Portland cement replacement with CSA on compression test and workability (slump test).

5.0.1 WORKABILITY

The workability of coconut shell ash-concrete decreases with the increase in ash content of the concrete mix. This is due to the water absorption characteristics of CSA during the mixing process and thus gave low slump during the slump test. The tests also show that with high ash content, the mixture got stiffer, causing a reduction in the consistency of the mixture. Consistency is a function of workability.

5.0.2 COMPRESSIVE STRENGTH

The study on CSA-Portland cement replaced concrete cubes under compression test shows that, replacing 10% of Portland cement by CSA to the concrete mix increases the strength of the composite. The result shows that the composite had low early strength and high final strength at 10% CSA when compared to the control. And also the strength from 10%-15% is found to decrease. This may be due to segregation and voids that exist in the composite due to excess addition of coconut shell ash (CSA).

5.1 RECOMMENDATIONS

This study has its own limitations and the following recommendations are made for further studies to improve the current work on coconut shell ash (CSA) replacing Portland cement.

1. The study was conducted using 5-15% of CSA to partially replace Portland cement. It is recommended to use different percentages I other to get the optimum percentage of finely crushed CSA that replaces fine aggregate.
2. It is recommend that future studies should be done for a longer period of time asides the 28 days used in this project in order to observe the maximum effects of CSA because when used for construction, it is essential that the material used are long lasting.
3. It is recommended that more tests be done to find out the effects of CSA concrete on other properties of concrete.
4. This study was also done using a fixed proportion of mix. I recommend that different mix ratios should be used in further investigations in order to maximize the optimum CSA.
5. It is recommend that future studies should be done to determine the characteristics of CSA during hydration process as the hydration process plays the most important role in strength development.

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