

**EFFECT OF PARTIAL REPLACEMENT OF SHARP SAND WITH LATERITE IN
INTERLOCKING PAVEMENT**

BY

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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**

MAY, 2023

CERTIFICATION

This is to certify that this project topic titled “Partial Replacement of Sharp Sand with Laterite in Concrete Pavement Production” was done by Nwosu Chukwuebuka Christian with registration number (NAU/2016224006) in the Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

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APPROVAL PAGE

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DEDICATION

This work is dedicated to God Almighty.

ACKNOWLEDGEMENTS

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.

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 good lord enlarge your coast and also protect your family.

Special thanks go to the Head of Department of Civil Engineering in the person of Engr. Prof. C. A. Ezeagu. 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.

Also I will like to express my profound gratitude to my mum for her moral support, constant prayers throughout my stay in school, special thanks goes also to my siblings for their encouragement during trying times of my academic pursuit.

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

The need to reduce the high cost of concrete production resulting from increasing cost of fine aggregate formed the basis for the study. The study was undertaken to effect of partial replacement of sand with laterite on strength properties of concrete. Laterite sample was added to sand in an increasing order of 5%, 10%, 15%, 20% and 25% by weight of sand. Experimental testing was conducted so as to evaluate the effect of partial replacement of sand with laterite on strength properties of concrete. These tests are: sieve analysis test, specific gravity test, bulk density test, slump test and compressive strength test. Results obtained from sieve analysis test revealed that granite, sand and laterite were classified as A-1-b, A-2-4 and A-2-6 according to AASHTO Soil Classification System, GC, SM and SC according to Unified Soil Classification System, the specific gravity of granite, sand and laterite were 2.61, 2.55 and 2.66 respectively, the liquid limit, plastic limit and plasticity index of the laterite sample was 42.4%, 25.9% and 16.5%. The slump of the concrete increased from 0% addition of laterite to 15% addition of laterite to sand, the hardened density and compressive strength of the concrete increased from 0% addition of laterite to sand to 5% addition of laterite to sand beyond 5% laterite content, the hardened density and compressive strength was found to decrease. This study therefore discourage the use of laterite as partial substitute for sand in concrete beyond 5% addition of laterite to sand as the compressive strength of the concrete were found to decrease.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

As the world population increases, with a continuous and rapid increase in urbanization, so does the demand for housing and other infrastructures and hence the demand for concrete and its constituents. Basically, concrete is a series of aggregates bonded together by a binder which is usually hardened cement paste formed by hydration of Portland cement. In Nigeria and most other countries, river sand is traditionally used as fine aggregate in concrete production. The continuous mining of sand from our rivers has led to environmental degradation and unchecked depletion in its natural reserve. Hence, many sand mining sites have been closed because of the damage they cause to the environment and these have led to scarcity of the product. Moreover, because of scarcity of the product, it is often transported from relatively distance places at high cost. The need for an economic alternative fine aggregate material is therefore obvious.

To solve this problem, several attempts have been made to either partially or completely replace river sand with other materials in concrete production. Aggregate can be classified as fine or coarse aggregate. Fine aggregate is generally natural sand and is graded from particles size of 5 mm down to the finest particles size but excluding dust. Coarse aggregate is natural gravel or crushed stone usually larger than 5mm and usually less than 16 mm size in ordinary structure. In this research, the emphasis will be on fine aggregate. Such materials have included laterite and quarry dust, formed as a result of weathering of basalt under humid, tropic condition; laterite is a mixture of clayey iron and aluminum oxides and hydroxides and it is abundantly available in tropical regions including Nigeria. Concrete containing laterites are termed laterized concrete. The availability of laterite aggregate has initiated research to investigate the possibility of using this material as partial coarse aggregate replacement in concrete production.

Research on properties of laterized concrete has yielded positive results. Udoeyo et al, investigated properties of concrete with partial and complete replacement of sand with laterite and observed that the workability of the resulting concrete was directly proportional to the percentage of laterite while compressive strength, split tensile strength, flexural strength and water absorption were inversely proportional to the level of sand replacement with laterite. It was however concluded that laterized concrete with 0 to 40% laterite content produces compressive strength of up to 20MPa. Ettu et al studied the suitability of using laterite as the sole fine aggregate in concrete production using several

mix proportions. It was reported that a reasonable number of mix compositions produced laterized concrete that met the minimum compressive strength of 25MPa for reinforced concrete as specified by BS 8110: 1997.

In most developed and developing countries concrete have been major construction/building and civil engineering materials alongside steel and wood. The use of concrete in the building industries cannot be overemphasized. Therefore, ways of improving or modifying some of its properties such as strength, setting characteristics and durability; in order to effectively maximize its use and most likely reduce the cost of construction; are constantly been developed. The use of admixtures in concrete works are some of the ways of improving the qualities of concrete (Mamlouk and Zaniewski, 2006). Jayaraman et al investigated the compressive and tensile strength of concrete with varying combinations of lateritic sand and limestone filler as fine aggregate. The result showed that concrete with 0 to 50% of laterite content possessed improved or similar compressive and tensile strengths compared to conventional concrete. The optimum combination was 25% laterite. Lateritic aggregate has progressively replaced most other competing construction materials due to its versatility, accessibility and availability. Some Architects and structural engineers prefer it since it is a long-lasting material that does not require any maintenance or protection.

Concrete as a construction material encompasses hydraulic cement, aggregate and water, each with its individual or unique properties but all acting together to form a composite structure. However, the use of laterite and quarry dust as fine aggregate in concrete production has still not been generally accepted in design and construction despite the potential economic and sustainability benefits. This is obviously because of the lack of standard specifications for these materials as constructions materials. This study aims at generating additional data on the workability and compressive strength of laterized quarry dust concrete with concentration on 0 to 50% laterite content. This is to support the specification of laterite and quarry dust as concreting materials.

Therefore, it is important to note that by improving or modifying some of the properties of the individual constituents of the concrete; it could provide a means of producing a new composite material with enhanced characteristics that complies with the demands of Engineers and Architects.

1.2 Statement of Research Problem.

A major challenge faced by concrete users is its limited performance in unpredictable circumstances, such as changing climatic and jobsite conditions for instance, hot or cold weather concreting, underwater concreting, concreting in corrosive environments (acidic or alkaline), delays in placing fresh concrete etc. Most of the conventional materials used in construction are too expensive and usually not readily available. Therefore, the use of locally available and renewable materials with unique properties, is investigated to determine its suitability as concrete admixtures.

1.3 Aim and Objectives.

The aim of this study is to know the effects of partial replacement of sharp sand with laterite as fine aggregate in concrete production as interlocking pavement, and a suitable percentage that can replace it.

The objectives of this research work are:

1. To determine the characteristics of the laterite, sharp sand and coarse aggregate.
2. To verify if lateritic soils can be used as a partial replacement for construction in the bid to reduce cost of concrete production.
3. To study the effect of partially replaced lateritic soil inclusion on various characteristics of hardened concrete.
4. To study the changes in the test parameters with variation of lateritic soil and determine optimum inclusion amount that will give a desired results.

1.4 Scope and Limitation of Research.

The scope of this study will cover the determination of the strength of laterite replaced concrete pavement. The investigation will be done for 5%, 10%, 15%, 20% and 25% replacement of sand with laterite available in the location of the study.

The soil sample will be collected in the location of the study area. At a depth ranging from 1 meter to 2 meter of the soil profile. However, the lateritic soil firstly be characterized. The

application of the result of this study will however, be limited to the location of sample collection. Nonetheless, it can serve as guide in the evaluation of laterite from other location as replacement for fine aggregates in concrete.

1.5 Justification of research.

This research work will be carried out in order to replace conventional fine aggregate used in concrete production with lateritic soils in order to reduce the cost of production. This will be made possible due to the availability of laterite everywhere.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

A good quality concrete is desirable for any construction. A good quality concrete is strong, durable and ensures economy as well. Factors effecting concrete quality are the use of admixtures, availability of moisture for curing, mix proportions, curing temperatures (Tattersall, 2007) and quality of raw materials (Kurdowski, 2014). A number of ways are ventured to attain good quality concrete. Among them using supplementary material is quite a popular one. Problems arise regarding the quality of concrete and subsequently of concrete structure due to poor quality of materials, incorrect specifications, faults in design, poor workmanship during construction, exposure to extreme environmental conditions etc. (Shash, 2005).concrete is a composite material consisting of binding medium or glue (cement and water) in which particles of a relatively inert filter material (sand, and gravel aggregate) and embedded. Sometimes an additional materials, known as an admixture is added to modify some of its properties (Bye, 1999). The most commonly used binding medium is the product formed by chemical reaction between cement and water. Other binding mediums are used on a much smaller scale for special concretes in which the cement and water of normal concrete are replaced either wholly or in part by epoxide or polyester resins. These polymer known as resin-based or resin-additive concrete respectively are costly and generally not suitable for use where fire-resistant properties are required but they are useful for repair work and special applications.

Concrete begins as a plastics mixtures and gradually hardens into a stone-like mass.in its hardened state concrete is a rock-like material with a high compressive strength. By virtue of the ease with which fresh concrete in its plastics state, it may be moulded into virtually any shape and be used to advantage architecturally or solely for decorative purpose, special surface finishes etc. the aggregate occupy roughly three-quarter of the available space within a given mass of concrete. Particle less than 5mm in diameter are designated as fine aggregate, which is represented by sand in normal concrete. The space not occupied by the

aggregate roughly one-quarter of the entire volume of a given mass of concrete is filled up with cement paste and air voids. In a freshly made and well compacted concrete of suitable proportions, the volume of unavoidable entrapped air is not more than one or two percent of the entire volume. The impact strength, as well as the tensile strength, of normal concretes is low and this can be improved by the introduction of randomly fibers into the concrete mix steel, polypropylene, asbestos and glass fibers all have been used with some success in products for example, pipes, building panels and piles. Concrete structures are of great deal more than sand, gravel, cement and water stirred up and left to harden into usefully shaped lumps. Considerable care and knowledge are required to produce quality concrete before it is even placed.

2.2 Constituents of Interlocking Concrete Block Pavement (ICBP)

The constituents materials that make up this concrete block pavement are cement, fine aggregate, coarse aggregate (gravel or granite) and water. Sometimes admixtures are added. The properties, characteristics and requirements of these constituents' materials are discussed below:

2.2.1 Cement

Cement is one of the most important constituents of concrete. The amount or volume of cement content greatly affects the strength of the concrete. Cement is a conglomeration of compounds which includes lime, silica, and alumina. The different cement used for making concrete are finely grounded powders and all have the important property that when mixed with water a chemical reaction (hydration) takes place, which produces a very hard and strong binding medium for the aggregate particle. In the early stages of hydration, while in its plastic stage, cement mortar gives to the fresh concrete its cohesive properties (Jackson, 1984).The different types of cement and the related British standards, in which certain physical and chemical requirement are specified, Portland cement is the most widely used, the others used where concrete with special properties are required.

Portland cement was developed in 1824 and derives its name from Portland limestone in Dorset because of its close resemblance to the rock after hydration has taken place .the

basic raw-material used in the manufacture of Portland cement are calcium carbonate, found in calcareous rocks such as limestone or chalk, and silica, alumina and iron oxide found in argillaceous rocks such as clay or shale, (Bye, 1999).

2.2.2 Types of Portland cement.

There are five of Portland cement currently in use in the United States. Type I is the most commonly used cement and is available from all mills. Type II often provides greater resistance to disintegration by aggregate chemicals, notably the sulphates, found in some soil or water. However, this type of cement may gain strength more slowly and have a lower heat of hydration than Type I. The high-early strength cement, Type III gains strength more rapidly than the others and is used in cold weather concreting where high early strength are needed, as well as in most pre-stressed and some precast structural members. Type III is generally readily available. Type V cement has much greater resistance to the action of sulphates in soils or water than the other cement because of their special nature, Types IV and V are not usually carried in stock and must be made on special order (Bye 1999).

2.2.3 Aggregates.

Aggregates for concrete are mainly fine aggregate and coarse aggregate. In most work the aggregate should compose the greatest possible volume of the mix. A typical concrete mix consists of 75% aggregate and 25% paste. Proper aggregate selection according to size assures maximum aggregate content in concrete. It is essential to know something about aggregate in order to select those that will give concrete the desired properties at the desired price.

The aggregate used for concrete and mortar can be conveniently divided into heavy and lightweight aggregate. The former class includes all the aggregates normally used in mass and reinforced concrete, such as sand, gravel, crushed rock, and slag. The light-weight class includes pumice, clinker, foamed slags, expanded clay, shale and slate, exfoliated vermiculate and expanded volcanic glasses such as perlite. It is important that fine aggregate have an adequate proportion of very small particles called fines. Concrete made

with this type of fine aggregate is easier to finish than concrete made with coarse sand. The latter requires more paste to produce an equally acceptable surface finish.

Aggregate should be clear and free of dust or salt deposits. For durability, washing of both coarse aggregate and sand is very desirable. Beach sand in particular should be washed with fresh or brackish water to remove the salt.

2.2.4 Water

The water used in concrete should generally be of drinking water quality and free of excessive turbidity and or organic matter. For best durability, particularly in tropical exposures, strict limitations should be placed on the percentage of chlorides.

Water is the activating agent for hydration, it is essential since the precursor binder material are anhydrous or nearly so, while the set product consist principally of a gel like calcium silicate hydrate, of which water is an essential component. It initiates the chemical reaction that produces the binding qualities of Portland cement. Without it cement is merely so much as an unusable powder, and concrete is impossible to make. Just as there are standards for acceptable cement, so too are there standards for acceptable water.

2.3 Properties of Concrete.

The properties of concrete in its fresh and hardened state can show large variation depending on the type, quality and the proportion of the constituent's materials. The properties are discussed under two headings: namely, the plastic (fresh) state and the hardened state.

2.3.1 The Plastic State.

The properties of concrete in its plastic state or the stage during which it is to be handled, placed and compacted in its final form, should be sufficiently workable for the required properties in its hardened state to be achieved with the facilities available on site. This means that:

- a) The concrete should be sufficiently fluid for it to be to flow into and fill all parts of the formwork or mould, into which it is placed.
- b) It should do so without any segregation, or separation, of the constituent materials while being handled from mixer or during placing
- c) It must be possible to fully compact the concrete when placed in the position; and
- d) It must be possible to obtain the required surface finish.

At this juncture it is imperative to discuss what workability means, its measures and factors affecting it. They are:

A. Workability

Workability can be defined as the ease with which concrete can be mixed transported placed and finished without loss of homogeneity. The three main characteristics of the property of workability 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 formwork. Compatibility is the ease with which a given mix can be fully compacted, all the trapped air being removed. Workability also depends on:

- I. The method employed for conveyance and compaction.
- II. The size, shape and surface and roughness of framework or moulds.
- III. The quantity and spacing of reinforcement.

B. Measurement of workability

The test commonly used for measuring workability does not measure the individual characteristics (consistency, mobility, and compatibility) of workability. However, they do provide useful and practical guidance on the workability of mix. Three tests widely used for measuring workability are the slump, compacting factors and V-B Consistometer test.

C. Factors affecting workability

. The change in workability for a given change in water-cement ratio is greater when the water content is changed than when only the cement content is changed. For a given mix,

the workability of concrete decreases as the fineness of the cement increased specific surface, this effect being more marked in rich mixture.

The principal admixtures affecting improvement in the workability of concrete are water-reducing and air-entraining agent (Feldman et al., 1984). This extent of the increase in workability is dependent on the type of and amount of admixture used and the general characteristics of the fresh concrete. Other factors are aggregate content, ambient conditions, time that elapse between mixing of the concrete, and the final compaction (depends on the general condition of work such as the distance between the mixer and point of placing), stability, segregation, bleeding.

2.3.2 The Hardened State

In the hardened state, the concrete should have adequate durability, the required strength and also the desired surface finish. The behaviour of concrete is also affected by some properties namely, thermal properties, the mix proportion and hardness of the concrete, permeability and shrinkage .The meanings of some of the terms are discussed below.

A. Durability

Durability of concrete refers to its ability to endure weathering action, attack by various chemicals substance, and many other conditions to which it may be exposed over the years. Many of the conditions that cause concrete to lack durability are not immediately apparent. Some of them are harmful materials in the aggregate that causes large deflection and cracking, use of highly absorptive aggregate that expands when moist , and exerts sufficient force to disrupt concrete when frozen , and impure mixing water(pomeroy,1989). In order to produce a durable concrete, care should be taken to select suitable constituent materials. It is also important that the mix contained adequate quantities of material in proportion suitable for producing a homogenous and fully compacted concrete mass.

Adequate durability of exposed concrete can be obtained by ensuring that suitable material are used ,also the use of good mix proportioning, careful batching ,mixing, handling and placing ,adequate consolidation and sufficient curing. The choice of aggregate is also

important particularly for concrete wearing surfaces and where improved fire resistance is required.

B. Thermal properties of Concrete

The thermal expansion of concrete varies only a little with the proportion of aggregate present, increasing slightly with the richness of the mix, but it varies much with the type of aggregate. Dry and wet specimen's shows about the same value at an intermediate condition of dryness the value is some 20% higher. The temperature at which concrete is used has an important bearing on the development of its Strength. Concrete made with Portland cement increased temperature at early ages, although at later ages, the concrete made and cured at lower temperature shows high strength.

C. Shrinkage

Shrinkage of concrete is caused by the settlement of solids and loss of free water from the plastic concrete (Plastic shrinkage), by the chemical combination of cement with water (autogenous Shrinkage) and by drying of concrete (drying shrinkage). Where movement of the concrete is restrained, shrinkage will produce tensile stresses within the concrete which may cause cracking. Most concrete structures experience a gradual drying out and the effect of drying shrinkage should be minimized by the provision of movement joints and careful attention to detail at the design stage. A good quality concrete should have the good quality of reducing or minimizing shrinkage of any sort to its minimum. Several factors influence the overall drying shrinkage of concrete. These include the type, content and proportion of the constituent materials of concrete, the size and shape of the Concrete structure, the amount and environment (Jackson, 2012).

2.4 Strength of Concrete

The strength of concrete is defined as the maximum load (Stress) it can carry. The Potential strength of Concrete is determined by the properties and proportions of its constituent material. The compressive strength of concrete is commonly used the construction industry for the purpose of specifications and quality control.

A primary function of practically all structures is to carry load or resist applied forces of whatever nature, other functions such as retention of fluids, or the exclusion of weathering or

other destructive agents may be involved too. So in order to maintain continuity of structures without failure or cracking tensile Stress strength is affected by water/cement ratio, importance although its actual magnitude is relatively low, usually steel reinforcement is provided to resist tensile forces.

Strength is affected by water/cement ratio, the age of the concrete, and the quality of curing as well as the size and shape of the specimen tested. A specimen tested a compressive strength will have a higher indicated strength if the specimen is dry before testing, whereas flexural strength will be lower in a dry specimen Strength must be carefully planned, designed and controlled.

2.4.1 Compressive Strength

The compressive strength of concrete is taken as the maximum compressive load it can carry per unit area. The compressive strength of concrete is important and has useful properties and most easily determined. Concrete strengths of up to 80N/mm can be achieved by selective use of the type of cement, mix proportions, method of compaction and curing conditions. The compressive strength is frequently used as measure of these properties. Similarly, the compressive strength is used as a measure of the overall quality of the concrete and thus as an indication of other properties relating to deformation or durability.

2.4.2 Tensile Strength

The tensile strength is of importance in the design of concrete roads and runway. For example, its flexural strength or modulus of rupture (tensile strength in bending) is utilized for distributing the concentrated loads over a wide area or road pavement. Concrete members are also required to withdraw tensile stresses resulting from any restraint to contraction due to drying or temperature variation. Unlike metals, it is difficult to measure concrete strength in direct tension and indirect methods have been developed for assessing this property. Of these the split cylinder test is the simplest and most widely used. The tensile strength of concrete is usually taken to be above one-tenth of its compressive strength of may vary, however depending on the method used for measuring tensile strength and type of concrete.

2.4.3 Factors Affecting Strength of Concrete

In this section the influence of these factors are discussed with particular reference to compressive strength.

A. Influence of the Constituent Materials.

I. Cement:

The influence of cement on concrete strength, for given mix proportions, is determined by its fineness and chemical composition through the processes of hydration (Jackson, 1984).

Fineness and finish-grinding temperature of cement affect concrete strength. Finer grinding increases cement Strength development, especially an early age. Probably the most important factor determining the ultimate strength of concrete is the water-cement ratio. A low ratio of water to cement will produce stronger concrete. High early Strength cement (Type III) produces concrete with greater strength at, 7, 14, 21, and 28 days.

II. Water:

A Concrete mix containing the minimum amount of water required for complete hydration of cement, if it could be fully compacted, would develop the maximum attainable Strength at any given age. Stagnant pools or swamps should not be considered sources for concrete mixing water, especially if they contain moss or algae. Strength deficiency can be caused by as little as 0.2% organic material in mix water. Sugar extremely detrimental to setting, and salt can corrode reinforcing steel. In general, if the water is considered drinkable, it can be used in concrete.

III. Aggregate:

The potential strength of concrete is determined by properties of the aggregate as well as the amounts used. Aggregate is usually stronger than the cement paste that surrounds it. Therefore, the actual effect of normal weight aggregate is not of great importance to strength unless very high strength is specified. However, some characteristics of Aggregate-particle shape, texture, maximum size, soundness, grading, and freedom from harmful materials affect bonding and

strength (Bye, 1999). The effect of admixtures on concrete strength depends on the properties of the admixtures and the characteristics of the concrete mix.

B. Influence of Methods of Production.

When concrete materials are not adequately mixed into a consistent and homogenous mass, some poor quality concrete is inevitably the result. Variations in concrete strength are also caused by the method of batching procedures employed. Inaccuracies in measuring materials may be due to volumetric batching, inaccurate scales, careless weighing procedures, materials sticking to the weigh hopper, and uncompensated variations in aggregate moisture content. Also, variations in the sequence in which materials are charge into mixer cause changes in strength. Proper mixing procedures and length of mixing time are important. Mixing must be long enough to produce a homogenous mix, but no longer than necessary. Over-mixing reduces slump and causes an increase in fines from the grinding action of the materials. Delays in transportation and placing also cause slump loss.

C. Influence of Curing

A proper curing is essential to quality concrete otherwise excellent concrete can be ruined if improperly cured Concrete will continue to gain strength as long as moisture available and temperature is satisfactory, loss of moisture or excessively low temperatures will stop strength gain. Generally, the longer the period during which concrete is kept in water, the greater its final strength, it is apparent that concrete left in air achieves the lowest strength values at all ages owing to the evaporation of the water from mixing water from the concrete. The gain in strength depends on a number of factors such as relative humidity, wind velocity and the size of structural member of test specimens.

D. Influence of Test Conditions.

The conditions under tests to determine concrete strength are carried out can have a considerable influence on the strength obtained and it is important that these effects are understood it test results are to be correctly interpreted. Test conditions that can influence the strength of concrete are the specimen shapes and sizes, specimen moisture content and temperature, the method of heading employed, the specimen's bearing surface condition

2.5 Production of Concrete: Proportioning and Mixing.

The purpose of proportioning is to make economical concrete that is satisfactorily workable and has all of the specified quantities after hardening in mixing most compounds, the proportions of the various ingredients can be varied without seriously affecting the product. In concrete, the amounts of the various constituents in the mix have a critical effect on the qualities and usefulness of the final product. As a result, before product is desired and what performance is expected. The strength required of the concrete must be known, as well anticipated exposure conditions, availability and costs of component materials, amount of reinforcing steel or pre-stress cables to be used, and special requirement for transporting, placing and finishing. All these requirements and imitation must be considered before the proportions of material can be calculated, regardless of planned mix design method. Since most of the desired properties of hardened concrete are dependent on the quality of the cement pastes and water-cement ratio. Once it has been established, gradation and maximum Size of the aggregate and consistency of the concrete can be varied without strength or other desirable of qualities being affected. If however, the water-cement ratio is altered by adding water, the resulting concrete can no longer adequately serve its end purpose. For this reason an appropriate water-cement ratio must be selected and maintained through an entire job, or that portion of it having the same requirement.

In determining the water-cement ratio, four factors must be considered:

- a) The type of structure in which the concrete will be used.
- b) The exposure conditions
- c) The contact, if any with sulfates in soil and ground water and;
- d) The strength required of the structure once these are known, the water-cement ratio can be estimated through the use of time-tested tables. When the water-cement ratio has been established, these are still a number of factors that must be considered before final mix proportions are selected. One of these is slump range, an indication of the consistency of the concrete. A good aggregate for concrete is evenly graded, from the smallest particle of sand to the largest of coarse aggregate, the larger this maximum size, the more economical the resulting

concrete will be. There is a practical limit, however, to maximum aggregate Size. Generally, it should not exceed one-fifth of the minimum dimension of the concrete member nor three-fourth of the clear space between reinforcing bars or between reinforcements and forms.

2.5.1 Methods of Proportioning.

Although there are numerous methods of proportioning the two most widely used are the

A. Unit-Weight (Trial mix) method.

B. Absolute Volume method.

A. Unit-Weight Method (Trial Mix)

The unit weight method of proportioning is a good way to determine a mix design when very little is known about the materials to be used. It involves very few calculations and makes use of saturated, surface-dry aggregates making it unnecessary to determine aggregate moisture content, specific gravity, and fineness modulus. This is a condition, which is difficult to achieve though it could be approximated to by using dry aggregates and adding an extra amount of water equivalent to that which the aggregate is known to absorb. But to ensure that absorption of the aggregate does not affect strength or workability, wet aggregate should be used in the trial mix.

A trial mix consists of mixing together the designed proportions of cement, aggregate, water and admixture, if any, and of measuring the workability and the strength of concrete cast from the mix. The amounts of materials are accurately weighted, and mixed, the mixing water being added gradually during the mixing and the appearance of the mix continuously observed. After mixing. The slump measured, the measurement should be made about 10 minutes after mixing or such other time as is appropriate. When the trail mix has been carried out, it may be obvious that the workability is not as great as was anticipation anticipated by increasing the richness, i.e. adding amounts of cement and water, keeping the water/cement ratio consistent. If the mix is unworkable due to harshness then improved by adding water, cement and sand in such proportion of the coarse materials. The mix has the appearance of over sanding denoted by excessive stiffness, then water, cement and coarse aggregates are added, again keeping the water/cement, aggregate/cement ratios constant but decreasing the ratio of fine to coarse material. If the mix is excessively workable but appears to contain the right amount of fine to

coarse material, the mix is made leaner by adding fine and coarse aggregate in the same proportions as previously used. This reduces the richness but maintains the water/cement ratio constant that confirmation can be obtained that the calculated effective water/cement ratio will result to a compressive strength of the right order (Akroyd, 2000).

B. Absolute Volume Method.

When the strength of the concrete is important or its quality must be controlled, then proper batching is usually describe but first-class work can be produced if a mechanical volume batcher, Such as is incorporated in a continuous mixer, is used and when the man responsible for the plant operation is fully competent and has sufficient experience. Large errors can occur in other methods of volume batching. The type of batching plant to be used its simplicity or complexity depends upon the total quantity and the throughput of materials to be achieved.

2.5.2 Mixing of Concrete.

The purpose of mixing concrete is to ensure that the various materials are thoroughly worked into a consistent and uniform mass in which all the ingredients are equally distributed. There are three main types of concrete mixer in general use: the batch mixer, the continuous mixer and the paving mixer. The batch mixer is the most important, and of this there are three types: the tilting drum, the non-tilting drum and the open pan mixer. The tilting drum was used for small portable mixers on small sites, the non-tilting drum for most other mixers from the largest to the smallest job, and the open pan mixer for rich dry concrete. Most mixers will mix a wet mix satisfactorily with some degree of efficiency, but great difficulty used to be experienced with rich dry mixes for pre-stressed concrete or harsh dry mixes such as are used For pavement constructions. Probably more concrete has been made with non-tilting drum mixers than with any other mixer. At the same time many are inefficient, they discharge a fatty mix at the beginning and a lean mix at the end of their discharge they take too long to mix and too long to discharge. The mixer is essentially a short cylindrical drum, which rotates about a horizontal axis. The drum is fitted with fixed blades set at angles. Their blades pick up the materials, carry them to the top of drum as it rotates, and allow them to fall freely and so mix together. The actual size and shape of the blades, their angle of set in relation to the drum and their peripheral speed are important matters which affect the efficiency of any individual machine. The material is charged into the mixer through a chute or hopper. After mixing the concrete is usually discharge by inserting a

retractable chute into the mixer drum, which catches the concrete as it falls and discharges it. This method helps to produce lack of uniformity of the discharged mix. The tilting drum mixer in the shape of an open-ended round-based cone was one of the first mixers made. The mixer is headed and is discharged through the same end. During charging and mixing the end points upward at an angle. With the small portable machines the charging is usually manual, but with the large mixers a cone hopper or chute is used to charge in the materials from the weight batcher hoppers. The blade in the mixer lifts up the materials, part of which falls in the inclined surface and then slides back down into the body of the mixer whilst the rest falls freely, by this means an efficient action can be obtained, but the angle at which the drum operates is critical and should be between 20 and 30. If the angle is too steep the fine material tends to remain near the base and segregation may be caused. The paddle or open-pan mixer consists of a circular pan, which rotates about a central axis. Inside the pan, mounted off center, is a rotating paddle. The rotating pan carries the materials round with it, while the rotating paddles mix and stir them. The materials are charged into the open pan from a hopper and mixed by the action of the paddle. After mixing the concrete is discharged through a trap door in the bottom of the pan. Discharge is affected by blades, which guide the material to the discharge opening.

2.6 Interlocking Concrete Block Pavement (ICBP)

Interlocking Concrete Block Pavement (ICBP) has replaced the conventional concreting technique that required the use of traditional bricks and asphalt on the surface of the road. The traditional method was cumbersome as it required skill and accuracy to maintain the thickness of the road in addition to constant supervision by the site engineer. The roads had to be closed for hours as time was consumed in laying and mixing works. This problem was noticed by the higher authorities and the implementation of concrete blocks was recommended for ease of work.

The shape of such blocks varies as well as in size aspects because the design of these blocks constantly evolved during the years. The interlocking between the blocks was not good initially but as time went on, the design was modified so as to provide perfect interlocking. Interlocking is required to be perfect while laying as sand or other impurities might penetrate the gaps leaving the blocks isolated from the nearby blocks. This would result in breaking of the pattern and

eventually the blocks would come out of the place. Hence, the works need to be precise on the field and is to be well monitored by the site engineers.



Plate 2.1: Laying of paver blocks

Advantages of Interlocking Concrete Block Pavement (ICBP)

Such blocks provide more advantages compared to disadvantages. Some of which are listed below:

- These blocks are produced in factories in large quantities, so the dimensions can be made accurate as well as the production time is saved in the process.
- The better the quality of such blocks, the longer will be the life of the road. So, durability plays an important role in this aspect.
- Such blocks can sustain thermal expansion and contraction which is a big thumbs-up since the weather conditions like extreme cold or extreme hot have adverse effects on the pavements.
- Large deflections under structural load are much avoided in such blocks and so structural failure is not observed here, which is the opposite in the case of asphalt roads.

- Laying of such blocks does not require any skill. The importance is emphasized solely on the interlocking portion and maintaining the accuracy on laying.
- Time is saved here unlike in the case of asphalt roads where traffics had to be diverted since long hours were consumed in the process. Here, blocks are laid in no time which enables the traffic to pass within a few hours.
- Such blocks can be repaired very easily without any skills. If any blocks get detached from the surface then it can be repaired to the gap of the old block can be replaced by a new block without any hassle. It is very much more efficient than asphalt pavement in this aspect.
- Such blocks do not require much maintenance effort and is not affected by any type of fluid spilled on the road from passing vehicles like oil tankers or water tankers.
- Instead of using the paint on road for clear markings, colored bricks can manufacture in the laboratory. This will reduce the cost of paint and other painting equipment that is required in asphalt roads.
- When heavy vehicles pass on these roads, the shear force, lateral force and punching force are generated on such pavements, which can cause breaking of the pavements. In such cases, concrete blocks are effective as they can take the impact and other such forces that can lead to disintegration of road sections.

Disadvantages of Interlocking Concrete Block Pavement (ICBP)

Apart from having so much benefit, it also has some disadvantages that discourage the use of such bricks to some extent. These are:

- Different works require different specifications and so such blocks cannot be used in this aspect as the property of such blocks cannot be changed much.
- If base course gets disturbed, then the whole laying process gets disturbed. This will lead to the shifting of the course of pavement which can prove fatal leading to road accidents.

- High quality sand and fillings are needed to fill the gaps as much as possible. Thus, the quality of such materials must not be neglected or compromised for maintaining the economy.
- Such blocks are not suitable for high-speed vehicles as such blocks also act as a speed breaker because of bumps in gaps. Thus, asphalt roads prove to be better here.
- If a granulated base course is laid below these concrete blocks, then there is a possibility of low drainage which can deteriorate the condition of the road.

2.6.1 Shape and types of Interlocking Concrete Block Pavement (ICBP)

There are four types of concrete blocks that are used in pavements. They are:

- **Type A:** In this type, the blocks are with plain vertical faces. Here, the key is not required to be inserted between adjacent blocks when laying in any pattern.
- **Type B:** In this type, the blocks are with plain and corrugated vertical faces that are placed in alternate positions. Here, key is required to be inserted along the corrugated faces when laying in any pattern.
- **Type C:** In this type, the blocks are having all faces corrugated. Here, key is required to be inserted along all vertical faces when laying in any pattern.
- **Type D:** In this type, the blocks have 'L' and 'X' shaped which have all faces corrugated. Here is the key required to be inserted along all vertical faces when laying in any pattern.

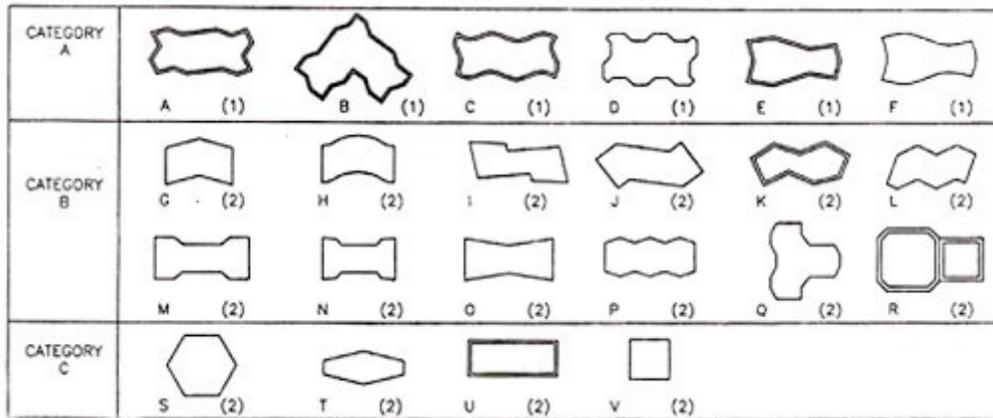


Fig 2.1: Different shapes and dimensions of paver blocks
 Courtesy: Pavers India

2.7 Lateritic Soil.

Lateritic soil is abundant in nature, low cost and renewable. It is said to be one of the most abundant materials in nature. Lateritic soils, being locally available, have been one of the major building materials in Nigeria and in most tropical countries in general.

2.7.1 Source.

Laterite is a weathered material composed principally of 90-100% of iron oxide, aluminum, titanium and manganese, typically reddish to yellow and derived from wide range of rocks weathering under strongly oxidizing and leaching conditions and is classified as a soft porous earthy soil; often found 15 cm below the top soil.

2.7.2 Laterized Concrete

Laterized concrete is defined as concrete in which stable laterite fine replaces fine aggregate (Sand) Salau, (2008). Adepegba was identified as the first to study the effect of using laterite as fine aggregate in concrete (Olugbenga, 2017). This was supported by Salau, (2008) when he asserted that “Adepegba (1975) recommended up to 40% laterite in clay for laterized concrete. In a further research by Adepegba, (1977) compared resistance to high temperature, modulus of elasticity and compressive and tensile strength of laterized concrete mixes (1:2:4; 1:1.5:3 and 1:1:2 by weight) with that of normal concrete. It was deduced that for high strength and

workability, only 25% of sand in concrete should be substituted with lateritic fine, while the mix ratio should be 1:1.5:3 (cement: sand/laterite: granite) with a water/cement ratio of 0.65.

According to Osunade, (2002a), laterized concrete is concrete in which the fine aggregates are lateritic soils. Laterite is a mixture of clayey iron and aluminum oxides and hydroxides formed as a result of the weathering of basalt under humid, tropical conditions. It is readily available in all parts of Nigeria.

Working on shrinkage deformations of laterized concrete, Salau and Balogun, (1998) recommended that laterized concrete with up to 25% laterite content of the aggregate could be used in load-bearing structural elements. It was also found out in another work by Balogun and Adepegba, (1982) that the most suitable mix for structural application of laterized concrete was 1:1.5:3 with about 0.65 water/cement ratio provided that the percentage of laterite content was kept below 50%. They asserted also that compressive strength of not less than 25N/mm² was obtained at 28days for the mix with laterite content of about 25-50%. A combination of crushed granite, sharp sand and fine laterite was used in their experiment.

The quest of having concrete which is cheaper has prompted many researchers to work on laterized concrete. Different properties of laterized concrete have been considered at different stages with far reaching recommendations in favour of laterite as suitable for use in the construction industry. This study will therefore investigate the recommendation of laterite as an effective stabilizer for partial replacement of fine aggregate in concrete.

CHAPTER THREE

METHOD AND MATERIALS

3.1 General

The research demands a series of Civil Engineering laboratory test that would aid in understanding the effect of lateritic soil as a partial replacement on the compressive strength and setting time of concrete.

- Sieve Analysis: This was determined as described in accordance with BS 812-103.1 [1985]. 500g sample of the fine aggregate was weighed and poured gently into the 600 μ m BS sieve. The sieving operation was carried out by shaking the 600 μ m BS sieve. The weight retained on the pan was recorded and the percentage passing was determined.
- Slump Test: For most concrete works, slump test is a practical means of measuring the workability of such concretes. The test is very popular due to its simplicity in the procedure of carrying it out as well as the apparatuses used. The slump test is used to ensure consistency or uniformity for different batches of similar concrete under field conditions. Details of the procedure and mode of investigations to be carried out in this project presented here Highlights on materials source to be used, Equipment's and apparatus to be used, with the set standards of operations are discussed as well.

3.2 Selection of Materials

Various materials to be used in this project include the following

- A. Laterite
- B. Portland Cement
- C. Granite
- D. Fine Aggregate (sand)
- E. Water

These materials were obtained from different sources.

3.2.1 Collection of the Laterite.

The soil sample was collected in the location of the study area. At a depth ranging from 1 meter to 2 meter of the soil profile. However, the lateritic soil was initially characterized. The tests that were conducted in the laboratory were Atterberg Limits Tests, Grain Size Analysis, Specific Gravity Test, Compressive strength Test and the Determination of Moisture Content.

3.2.2 Portland Cement.

The Choice of Portland cement for this experiment is hoped to conform to the requirements. This should give satisfactory results for concrete works .the cement will tested visually to make sure it is free of Lumps or balls

3.2.3 Granite: This was used as the coarse aggregate and sizes between 5mm to 20mm equivalent to half inch in other to allow for easy compaction, available in the market for the particular size range for the purpose of this research, the selection of granite size to purchase is to be carefully carried out so as to avoid shortage.



Plate 3.1: coarse aggregate.

3.2.4 Fine Aggregate (Sand)

The sand used was natural river sand found to be suitable for the purpose of these experiments. Batches by weight was obtained from the stock pile. Sufficient quantity was also obtained and were spread out few days before use, to dry, removing dampness and moisture content in order to

maintain consistent weights when batching. Cobbles pebbles and other odd objects were hand-picked from the pile during shoveling and spreading/drying.

3.2.5 Water

Water is necessary for the mixing of concrete for workability and ease of compaction. The water used for casting was gotten from the tap at the laboratory of the Department Civil Engineering concrete laboratory Nnamdi Azikiwe University Awka, Anambra state. The water also used for curing was gotten from the same source. The water was colorless, odourless and generally satisfactory for the work to be carried out.

3.3 Test Equipment and Apparatus

The following equipment's in the structures and concrete laboratory is to be used in the course of this study for the experiments.

3.3.1 Electrical Weighing balance

3.3.2 B.S Sieves

3.3.3 Moulds

3.3.4 Rammer / Tamping Rod

3.3.5 Universal testing machine (compressive strength test)

3.3.6 Slump cone (for workability)

3.3.7 Other Instruments Used.

3.3.1 Electrical Weighing balance

This has a range of 0-50kg and was used in weighing the required proportion of constituent materials for the concrete, as batching is by weight. It is also used for weighing the cubes after curing.

3.3.2 BS Sieves

These were used in the sieve analysis of aggregates and are also used in getting the required Sizes of granite for the purpose of the experiment. They are circular vessel with a bottom of woven wire to separate different sizes of aggregate and manufactured to BS 410 (1969) specification.

3.3.3 Moulds

An open Cast-iron or steel square comprising of four sides and a base plate to which the mould is clamped. They are of size 150mm by 150mm by 150mm but also available in sizes 100mm by 100mm by 100mm.

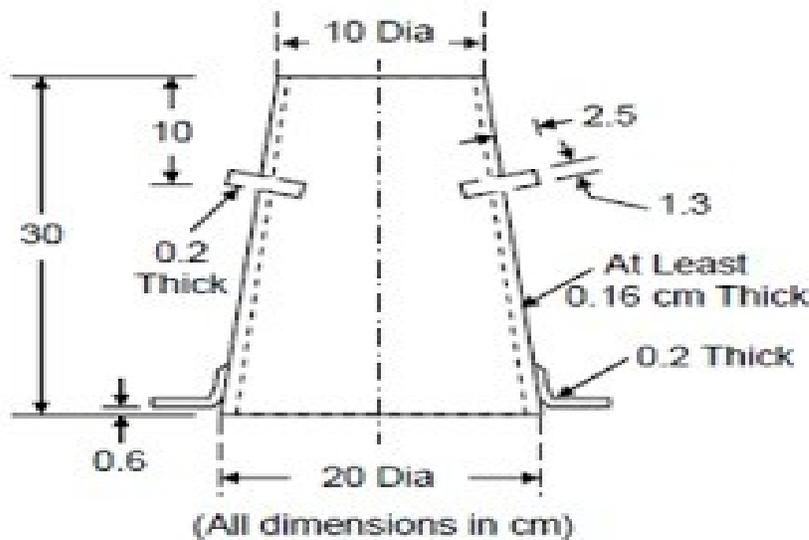


Figure 3.1: slump cone

3.3.4 Rammer/ Tamping Rod

This is a steel bar about 38mm long 18kg mass and a bottom ramming face 15mm, which is used to tap 25 times for each of the three (3) layer of the concrete mix during casting to achieve good compaction.

3.3.5 Universal Testing Machine (Compressive Strength Test)

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. An earlier name for a tensile testing machine is a tensometer. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures (in other words, that it is versatile).



Plate 3.2: universal testing machine (UTM)

3.3.6 Slump cone (for workability)

The Slump Cone apparatus along with Tamper (16 mm in diameter and 600 mm length. The tamping end of rod shall be rounded to a hemispherical tip), Ruler, etc. Conforming to IS 7320:1974 Specifications for Concrete Slump Test Apparatus. The cones are constructed of rust-resistant spun steel or high-density plastic. The cones meet inch (4x8x12) or metric (100x200x300) dimensional requirements for holding the compacted concrete layers.

The slump cone test can be carried out in the lab or field. Slump base plates are available and can be used interchangeably with steel or plastic cones.

- [Steel Slump Cones](#) : There are available in inch or metric units. The slump cones meet ASTM criteria for top diameter, bottom diameter, and height indicated within the standards.
- [Plastic Slump Cones](#) : There are made from lightweight, easy to clean, durable high-density plastic. They meet ASTM inch or metric dimensional requirements.

3.3.7 Other Instruments Used.

This includes the trowel, shovels, scrappers, head pans, wheelbarrows etc.

3.4 Preliminary Tests

For general works involving the materials highlighted above, the knowledge of some properties of these materials is paramount. These properties are examined in ratio to their effect on the case of mixing and strength of the concrete.

The tests to be carried out include:

- I. the determination of the moisture content of the aggregates (Fine and coarse).
- ii. The determination of the fines content in fine aggregates.
- iii. The mechanical grading (Sieve analysis).

The preliminary tests will be performed in laboratory of the Department Civil Engineering concrete laboratory Nnamdi Azikiwe University Awka Anambra state.

3.4.1 Sieve Analysis Gradation

This test will be carried out to obtain the range of particle size of an aggregate to obtain the normal Size or the particles and its suitability as aggregate and also the sawdust ash to be free from impurities like solid particles.

APPARATUS

1. Set of sieves (4.75mm,2.00mm,1.00mm,0.600mm,0.300mm,0.150mm,0.075mm)



Plate 3.3: 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 0.1% 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.

PROCEDURE

- The test sample was dried to a constant weight at a temperature of $(110 \pm 5^\circ\text{C})$.
- 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 was calculated as a percentage of the total sample weight.

3.4.2 Moisture Content

Weighed quantities of specimens of sand, and granite were placed in the oven for 24 hours and re-weighed. A decrease in weight corresponds to loss of moisture content.

3.4.3 Slump Test

The freshly mixed concrete was loaded into the slump test mould in (3) three layers each layer will be compacted with 25 blows of the tamping rod. This was done for each mix proportion before casting or moulding of the cubes and sections.

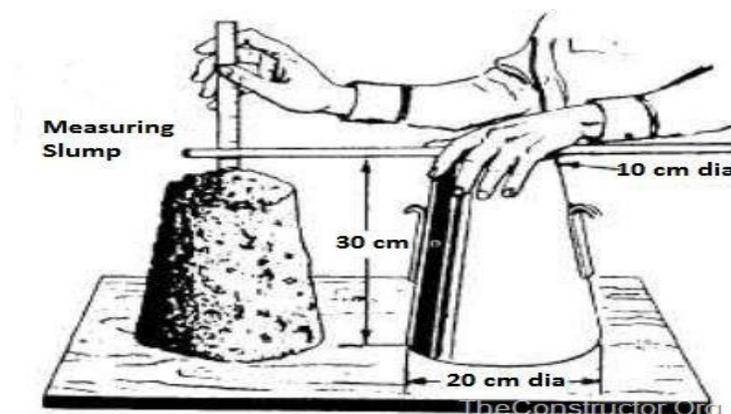


Plate 3.8: showing results of slump test

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 was prepared of M20 grade with mix ratio of 1:2:4 where the selected coarse aggregate size used was 19mm as this project topic recommends.

PROCEDURES

1. The internal surface of the mould was carefully cleaned and oil applied.
2. The mould was placed on a clean, smooth, horizontal and non-porous base plate.
3. The mould was filled with freshly prepared concrete in three layers, where each of the layers was tamped 25times using the tamping rod.
4. Excess concrete were removed and the surface levelled with a trowel.
5. The mould was gently removed in vertical direction to allow the unsupported concrete slump.
6. The slump was measured (i.e the difference between height of the cone and that of highest point of the specimen being tested).

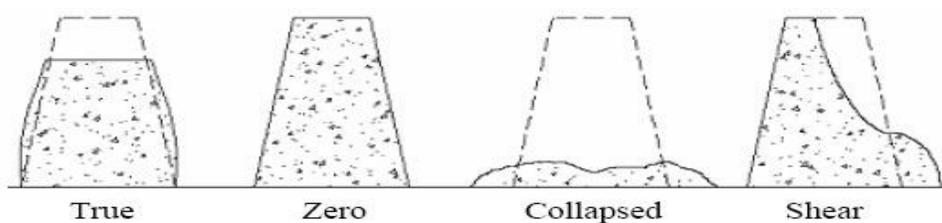


Figure 3.2: Types of Concrete Slump Test Results

- True Slump – True slump is the only slump that can be measured in the test. The measurement is taken between the top of the cone and the top of the concrete after the cone has been removed as shown in figure 3.2.
- Zero Slump – Zero slump is the indication of very low water-cement ratio, which results in dry mixes. These type of concrete is generally used for road construction.
- Collapsed Slump – This is an indication that 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.
- Shear Slump – The shear slump indicates that the result is incomplete, and concrete to be retested.

3.4.4 Atterberg Limit Test.

The atterberg limit is a limit characterized by visible transition of soil (especially fine grained soils) from liquid-plastic-semi-solid-solid state consequent upon the variation of moisture content. This test was developed by Albert Atterberg a Swedish agricultural scientist in 1911. This test is divided into three limits namely:

1. Liquid Limit (LL)
2. Plastic Limit (PL)
3. Shrinkage Limit (SL)

3.4.4.1 Liquid Limit

It is the water content at which the soil has a small shear strength that it flows to close a groove of standard width when jarred in a specified manner. It is the minimum water content at which the soil tends to flow like a liquid. When a soil is mixed with an excessive amount of water, it will be in a liquid state and flow like a viscous liquid. When the viscous liquid dries gradually due to loss of moisture it will pass into a plastic state. With further loss of moisture, the soil will pass into a semi-solid state. With even further reduction of moisture, the soil will pass into a solid state. The moisture content (%) at which a cohesive soil will pass from liquid state to plastic state is referred to as the liquid limit of the soil.

The apparatus used for liquid limit determination is outlined below:

1. Liquid limit device (Cassagrande type)

2. Grooving tool
3. Moisture content tins
4. Porcelain evaporating dish
5. Spatula or pellet knife
6. Thermostatically controlled oven
7. Weighing balance sensitive to 0.01g
8. Plastic wash bottle containing distilled water
9. Paper towels
10. Masking tape for identification of tin.
11. Exercise book and pen for recording of data
12. 425um Sieve
13. Airtight container

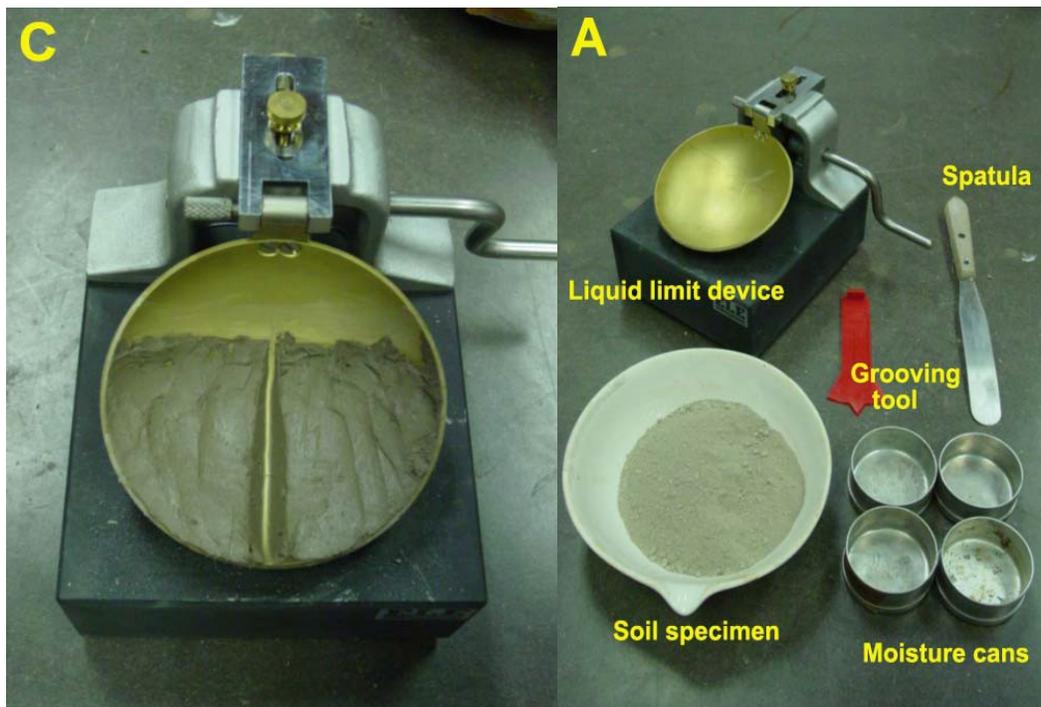


Plate 3.9: Apparatus for Liquid and Plastic Limit Test

Test Procedure

1. The laterite sample was prepared by weighing about 150g of soil passing through 425um sieve, and mixed with distilled water in a glass plate using a pellet knife to form a thick homogenous paste. The mixed soil was placed in an airtight container and allowed to mature for 24hrs.
2. The mass of five moisture content tins was measured and recorded.
3. The matured sample was placed on an evaporating dish and mixed properly with little water added using the plastic squeeze bottle to ensure uniform distribution of moisture.
4. A portion of the paste (mixed soil) was placed on the liquid limit device and levelled so as to obtain a maximum depth of 1cm.
5. A grooving tool was used to cut a groove along the symmetrical axis of the cup, holding the tool perpendicular to the cup.
6. The handle of the liquid limit device was rotated at the rate of 2 revolution per second and the number of blows required to close the groove at a distance of 13mm was recorded.
7. About 10g of soil in the closed groove was put in the moisture content tins for moisture content determination.
8. The rest of the soil in the cup was removed and the cassagrande cup was cleaned using paper towel.
9. The moisture content of the soil was increased and the process repeated to get the number of blows in the range of 12-49 blows that will close the groove.
10. A graph of moisture content against the log of no of blows was plotted and the moisture content corresponding to 25 blows on the abscissa gave the value of the liquid limit.

The Procedure employed for the Computation of the Result obtained is as Follows:

$$\text{Moisture content} = \frac{\text{Weight of water}}{\text{weight of dry soil}} \times 100 = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Where W_1 = Weight of empty tin.

W_2 = Weight of tin + wet soil.

W_3 = Weight of tin + oven-dried

3.4.4.2 Plastic Limit Test

The plastic limit of a soil is the moisture content expressed as a percentage of the weight of oven-dried soil at the boundary between the plastic and the semi-solid state of consistency. It is the moisture content at which a soil will just begin to crumble when rolled into a uniform 3mm diameter thread using a glass plate or other recommended surface for rolling. Soil used for Atterberg limit test can be classified based on the plasticity index of the soil. The plasticity index is the amount of water required to change a soil from its plastic limit to liquid limit, in other word it is the numerical difference between the liquid limit and the plastic limit of soil. Table 3.2 is used to classify soil based on the ranges of it plasticity index.

Table: 3.1 Plasticity Ratings for Fine grained Soil (Braja, M.Das, 2002).

Plasticity Index	Plasticity
0	Non-Plasticity
<7	Low Plasticity
7-17	Medium Plasticity
17-35	High Plasticity
>35	Very High Plasticity

1. The apparatus used for this experiment includes:
2. A smooth glass plate about 300mm square and 10mm thick.
3. A palette knife or spatula
4. A short length of 3mm metal rod
5. Moisture content tins
6. Plastic squeeze bottle
7. Weighing balance with 0.01g sensitivity
8. Veneer caliper
9. Masking tape for tin identification
10. Exercise book and pen for recording of result.

Test Procedure

1. The sample was prepared by the method described in the liquid limit using the sample passing 425um sieve.
2. The empty moisture content tins were identified, weighed and recorded.
3. About 20g of the prepared soil paste was placed on a porcelain evaporating dish, water from the plastic squeeze bottle was added and mixed thoroughly until the paste is plastic enough to be rolled into a ball.
4. A portion of the ball was rolled on a glass plate with the palm of the hand into a thread of uniform diameter throughout its length by rolling forward and backward.
5. Rolling and remoulding continued until the thread just start to crack at a distance of 3mm.
6. The small crumbed pieces were collected, placed in a moisture content tin, weighed and recorded.
7. The tin was placed in the oven at a constant temperature of 80-110°C for a period of 16-24hrs.
8. After 24hrs, the tin was removed from the oven and the weight of the dry soil plus the tin was measured and recorded.
9. The test was repeated for two more trials and the average plastic limit value for all the trials was obtained.

The Computation for Plastic Limit is as follows:

$$\text{Plastic limit} = \frac{\text{Weight of water}}{\text{Weight of oven-dried soil}} \times 100 = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Where W_1 = Weight of empty tins.

W_2 = Weight of tin plus wet soil

W_3 = Weight of tin plus oven-dried soil

3.5 Concrete Mix Ratio

Concrete material was batched in weight. The ratio of the mix was 1:2:4. The water cement ratio is 0.6. The variation of laterite to sharp sand is indicated in Table 3.2.

Table 3.2: Variation of the ratio of sharp sand and laterite.

Test	% Sharp Sand	% Laterite
1	100	0
2	95	5
3	90	10
4	85	15
5	80	20

3.5.1 Mixing

The batching of the materials was done by weight and the mixing was carried out by hand on a dry, clean hard surface using shovels. The appropriate size of granite was then be measured and added to the cement and the sharp sand. The mix was then be spread out and a hole made in the center where water was added bit by bit (until the 0.6 water cement ratio was achieved). Further mixing was then done without allowing the water to seep away, until a uniform colour and acceptable workability was achieved.

3.6 Casting and Curing

Before the commencement of casting, the 150mm by 150mm by 150mm steel cube moulds was cleaned and internal surface oiled. This oiling is to facilitate easy and smooth de-moulding of the concrete after hardening. The wet homogeneous mix is then poured into the moulds in 3 layers. Proper tamping of the concrete mix was done when putting the mix in the mould to ensure that air bubbles are driven out and that the concrete and 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 levelled and allowed to set slightly before some identification marks were

written on them. This is done in order to ensure that the correct cubes are cured and tested over a specified period of time by practice. The concrete grade used is grade 20 and mix ratio of 1:2:4



Plate 3.10: showing a concrete curing pond.

3.7 Compressive Strength Test

The concrete cubes were tested for their compressive strengths at the 7, 14 and 21 days curing ages respectively. The cubes was then removed from the tanks and placed on the Avery weighting machine, then allowed to dry under room temperature for a few hours. Each cube was placed centrally on the Avery testing machine in a position such that the load is applied to the face adjacent to the marked and exposed face during casting. The cubes was then loaded uniformly until the maximum failure was achieved.

APPARATUS

1. A cubical mould of size 150 mm×150 mm ×150 mm



Plate 3.11: A set of metallic mould

2. Tray
3. Tamping rod
4. Curing tank
5. Trowel
6. 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.

PROCEDURE

1. A given quantity of cement and fine aggregate were place on a tray and mixed thoroughly.
2. Another given quantity of coarse aggregate after being sieved was added to the already mixed fine aggregate and cement and then mixed thoroughly until the coarse aggregate was uniformly distributed throughout the batch.
3. The required water-cement ratio was added and then mixed until the concrete appears to be homogeneous and of the desired consistency.
4. The concrete cubes mould was cleaned and the internal surface and base was greased uniformly.
5. 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.

6. 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.
7. After tamping was done, the top surface of the concrete was leveled and smoothed by using the trowel or knife edge.
8. The concrete was left to set for a duration of 24hours.
9. After 24 hours setting, the concrete cubes were removed from the mould and placed into the curing tank and cured for 7, 14, 21 days respectively.
10. After 7 days, three cubes each from the three different samples were removed from the curing tank and dried with sunlight.
11. After drying, the cubes were weighed with the weighing balance, then crushed with the crushing machine and the reading was obtained and recorded.
12. The same procedure for the crushing will be repeated for the remaining curing days.



Plate 3.12: The Compression testing machine and crushed concrete cubes after compression.

3.8 Grading Curve

A graphical representation of the proportions sizes in a material. There are many ways of recording a sieving test, the most common being cumulative percentages of material passing through (or the sieves against apertures size. Particle size is usually a horizontal logarithmic scale and percentages on arithmetic vertical scale.

3.9 Proportioning of the Constituent Material

The constituent materials used for the concrete were proportioned by weight. The analysis and calculation of the proportioning are shown below:

Density of concrete = 2400 kg/m

Volume of cube sample = $0.15 \times 0.15 \times 0.15 = 0.003375\text{m}$

Mass = Density x Volume = $2400 \text{ kg/m} \times 0.003375\text{m} = 8.1\text{kg}$

Ratio = 1:2:4: $1+2+4 = 7$

Mass of constituent of cube:

Cement = $\frac{1}{7} \times 8.1 = 1.16\text{kg}$

Sand = $\frac{2}{7} \times 8.1 = 2.31\text{g}$

Granite = $\frac{4}{7} \times 8.1 = 4.63\text{kg}$

Water = $1.16 \times 0.6 = 0.696\text{kg}$

Total mass of constituent for 9 cubes of each mix:

Cement = $1.16 \times 9 = 10.44\text{kg}$

Sand = $2.31 \times 9 = 20.79\text{kg}$

Granite = $4.63 \times 9 = 41.67\text{kg}$

Water = $0.696 \times 9 = 6.264\text{kg}$

CHAPTER FOUR

RESULTS AND DISUSSION

During the course of the experimental study, certain results were obtained which was valuable in evaluating the strength properties of concrete containing laterite as partial replacement of fine aggregate. These results are presented in Table 4.1.

4.1 Results

Table 4.1: Physical Properties of Concrete Components Employed in the Research

PROPERTIES	GT	SD	LAT
Specific Gravity	2.61	2.55	2.50
Compacted Density (kg/m³)	-----	1523.33	1487
Loosed Density (kg/m³)		1133.33	1366.67
Liquid Limit (%)	-----	-----	41.86
Plastic Limit (%)	-----	-----	20.87
Plasticity Index (%)	-----	-----	20.99
Percentage Passing Sieve Size 0.075mm	----- --	22.36	38.36
Percentage Passing Sieve Size 4.75mm	1.63	-----	-----
AASHTO Classification System	A-1-b	A-2-4	A-7-6
Unified Soil Classification System	GC	SM	CL

4.1.1 Particle Size Distribution

Figure 4.1 is a semi logarithmic plot of the particle size distribution of sand and laterite samples respectively. Results obtained shows that the percentage passing through sieve size 0.075mm for sand and laterite were 22.36 and 38.36 they are classified as A-2-4 and A-7-6 according to AASHTO Classification System, SM (sand mixed with silt) and SC (sand mixed with clay) according to unified soil Classification System. Since more than 35% of the samples passes through sieve No 200 (0.075mm), the laterite does not satisfy the requirement of a good sub-grade material for road construction. According to AASHTO classification of soil samples for highway, A-1 and A-2 soils are excellent and good soils for highway, while A-3 to A-7 soils are fair to poor soils.

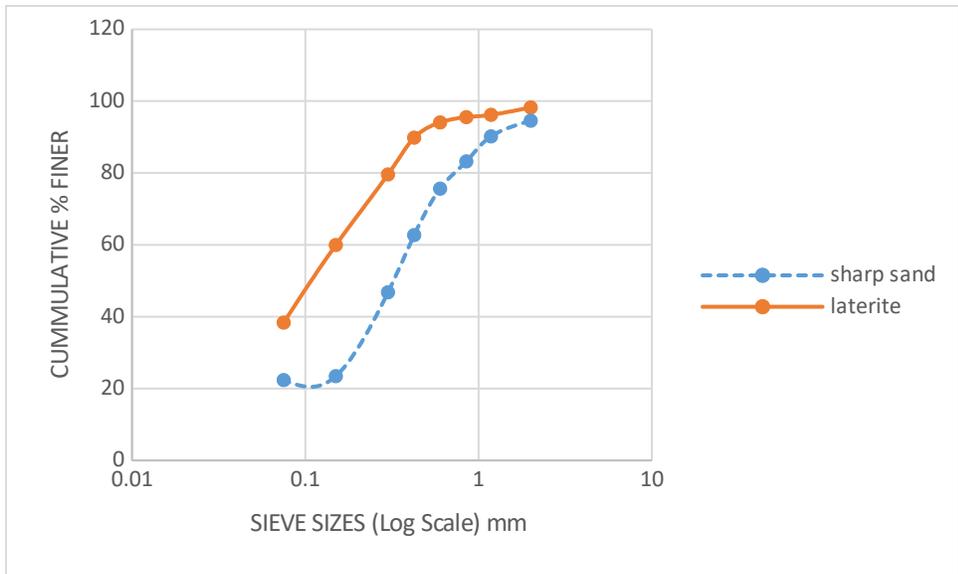


Figure 4.1: Particle Size Distribution Curve

Table 4.2: Sieve Analysis Result for Granite

Sieve Sizes (mm)	Mass Retained (g)	% Mass Retained	Cum Retained	% Cum Finer
31.25	0.14	0.01	0.01	99.99
25	88.5	8.63	8.64	91.36
20	362.11	35.33	35.34	64.66
12.5	504	49.17	49.18	50.82
9.5	14.61	1.43	1.44	98.56
6.3	29.02	2.83	2.84	97.16
4.75	14.83	1.45	1.46	98.54
Tray	12.44	1.21	1.22	98.78

4.1.2 Atterberg Limit Test

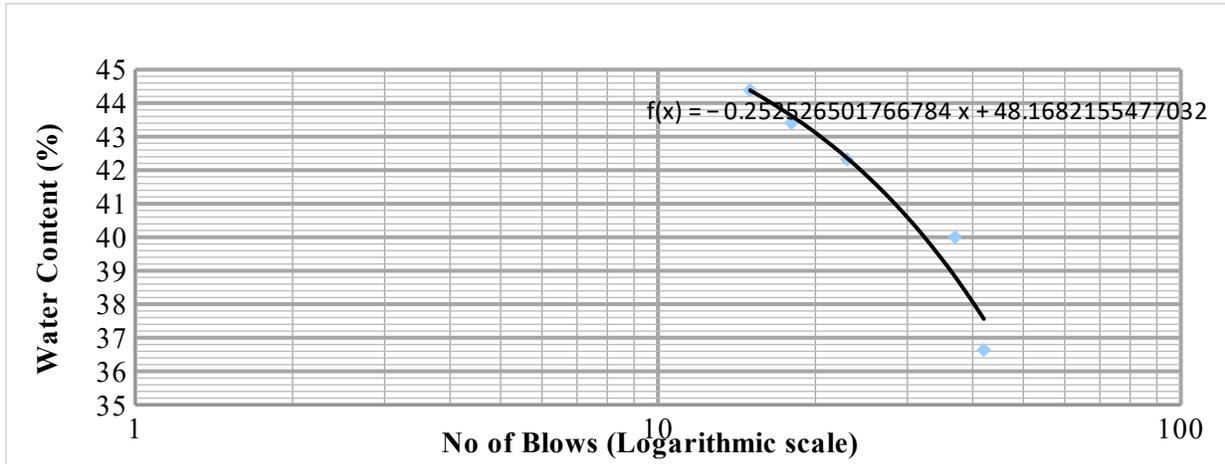


Figure 4.2: Liquid Limit Curve

Table 4.3: Plastic Limit Determination of Laterite

WEIGHT OF CAN (g)	CAN + WET SAMPLE (g)	WET SAMPLE (g)	CAN + DRY SAMPLE (g)	DRY SAMPLE (g)	WEIGHT OF WATER(g)	MOISTURE CONTENT (%)
15.78	17.71	1.93	17.38	1.60	0.33	20.63
14.42	16.29	1.87	15.95	1.53	0.34	22.22
14.60	16.54	1.94	16.22	1.62	0.32	19.75

$$\text{PLASTIC LIMIT} = \frac{(20.63+22.22+19.75)}{3} = 20.87\%$$

$$\text{Plasticity Index (PI)} = \text{LL}-\text{PL} = 41.86-20.87 = 20.99\%$$

The values obtained for the liquid limit, plastic limit and plasticity index are 41.86%, 20.87% and 20.99% respectively. These however, indicate that the laterite soil has a high plasticity. The Federal Ministry of Works Standard and Specification for road and bridges (1997) states that the plasticity index of sub-grade material should not exceed 55% and the liquid limit of sub-grade material should not exceed 80%. The liquid limit result obtained indicates that the mixtures satisfy the requirement for pavement construction and can also be used as a sub-grade material.

4.1.3 Specific Gravity

Table 4.4: Specific Gravity Determination of Laterite

	EMPTY BOTTLE (W1)	BOTTLE + DRY SAMPLE (W2)	BOTTLE + SAT. SOIL (W3)	BOTTLE + WATER (W4)	SPECIFIC GRAVITY
TRIAL 1	24.56	42.14	89.93	79.26	2.55
TRIAL 2	24.51	44.01	89.85	77.42	2.76
TRIAL 3	24.60	34.90	84.87	79.26	2.20
AVERAGE SPECIFIC GRAVITY					2.50

The value of specific gravity from for the laterite suggests the presence of clay or silt which actually can be of advantage at the sub-grade and sub-base level of road construction. According to the Federal Ministry of work Standard Specification for roads and bridges (1997) a good sub-grade material should have specific gravity value ranging from 2.5 to 2.75. The value obtained satisfy this requirement.

4.1.4 Slump Test

Table 4.5: Slump Test Result for Concrete at varying percentages of Laterite

Percentage Replacement	Slump Type
---------------------------	------------

of Laterite (%)	
0	Zero Slump
5	Zero Slump
10	Zero Slump
15	Zero Slump

The values for slump after the slump test reveals that there was no slump. This shows that the concrete used for the production of pavement has very little workability.

4.1.5 Compressive Strength

This test was carried out to determine the Compressive strength of the coarse aggregates in concrete in concrete mix of ages 7days, 14days, and 21days respectively, the compressive strength of the concrete cubes are calculated as the ratio of the compressive strength at axial load failure to the supporting area of the cube faces. The derived results considered in the following analysis is the cube crushing strength i.e. mean compressive strength test.

Table 4.6: Average Compressive Strength Results for Concrete produced at varying percentages of Laterite

Percentages of Laterite (%)	Average Compressive Strength (N/mm²)
0	20.12
5	19.94
10	20.47
15	21.68
20	19.86

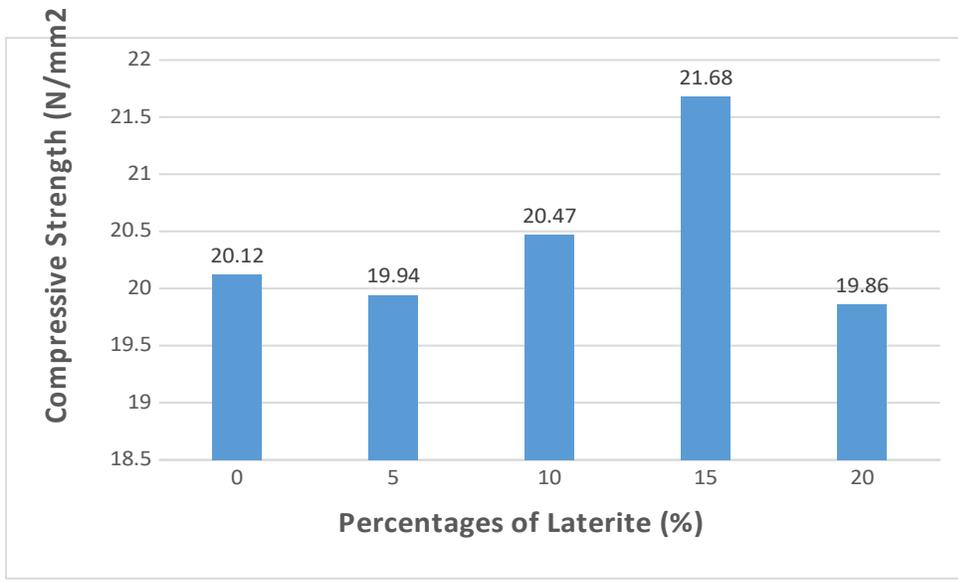


Figure 4.3: Compressive Strength Results for Concrete produced at varying percentages of Laterite

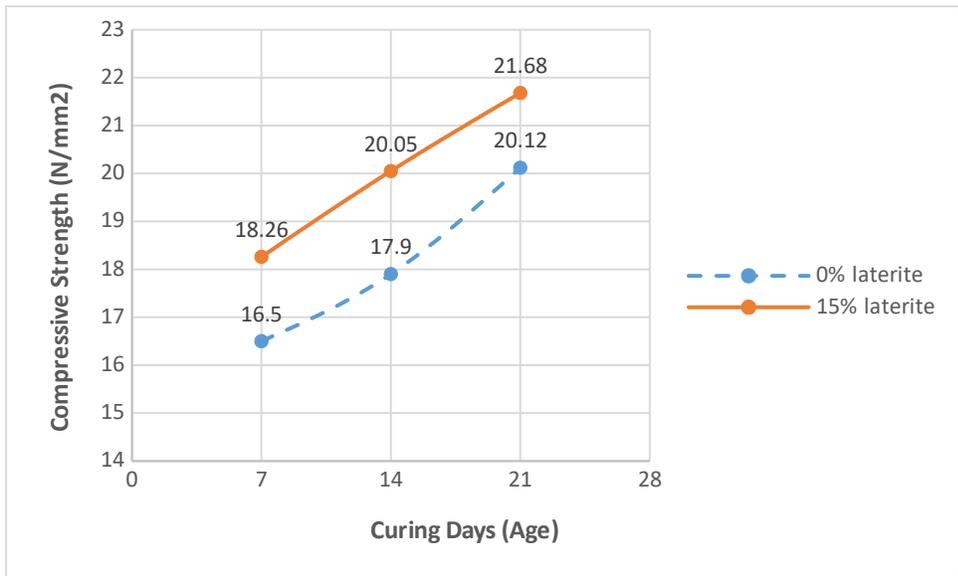


Figure 4.4: Compressive Strength Results for Concrete produced at varying intervals of Curing Days at 0% and 15% Laterite

Table 4.7: Average Compressive Strength Results for Concrete produced at varying intervals of Curing Days at 0% Laterite

Curing Days (Age)	Average	Compressive
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	Strength (N/mm²)
7	16.5
14	17.9
21	20.12

Table 4.8: Average Compressive Strength Results for Concrete produced at varying intervals of Curing Days at 15% Laterite

Curing Days (Age)	Average Compressive Strength (N/mm²)
7	18.26
14	20.05
21	21.68

It was observed that the compressive strength of the concrete increased with curing days which agrees with findings obtained by Nevile (2012) which stated that concrete gains over 60% of its compressive strength at 21 days of curing. On partial replacement of sand with laterite, an improvement in compressive strength of the hardened laterized concrete was recorded as the average compressive strength increased from 20.12N/mm² to 21.68N/mm² at 15% of laterite addition, beyond 15% laterite content, the compressive strength of the hardened laterized concrete decreased. The 15% gives the optimum for the partial replacement of the sharp sand with laterite. The initial improvement in compressive strength of the hardened laterized concrete could be attributable to the low content of laterite which makes it possible for the concrete to be compacted at high density while the later decrease could be due to high amount of fines associated with the laterite sample which makes it difficult for the concrete to be compacted so as to achieve improved compressive strength of the hardened laterized

concrete. This finding is in agreement with works of Tumingam and Alwi, (2019) and Apah and Ogunbode, (2012).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the findings obtained on effect of partial replacement of laterite with sand on strength properties of concrete, the following conclusion can be drawn:

1. The specific gravity of laterite, sand and granite are 2.66, 2.55 and 2.6 respectively and as a result, these samples are classified as normal weight aggregate.
2. The particle size distribution test of the aggregate classified laterite, sand and granite as Clayey sand, Silty sand and Clayey gravel according to Unified Soil Classification System and A-7-6, A-2-4 and A-1-b according to AASHTO Classification System.
3. The liquid limit, plastic limit and plasticity index of laterite are 41.86, 20.87 and 20.99% respectively.
4. The density of sand and laterite in its loosed state was 1133.3 and 1333.67kg/m³ while the density in its compacted state was 1523.33 and 1487kg/m³ respectively.
5. The compressive strength of the hardened concrete increased from 22.06N/mm² to 22.39N/mm² at 20% laterite content but beyond 20% laterite content, the compressive strength of the hardened laterized concrete decreased. It was also observed that compressive strength increased with curing days.
6. A direct relationship was established between the compressive strength and weight of the hardened laterized concrete as both properties of the hardened concrete undergo an improvement at similar percentages of laterite replacement.
7. The laterite sample employed in the study was adjudged as partly effective as slight improvement in density and strength properties of the hardened concrete was observed.

5.2 Recommendations

The recommendation on strength properties of concrete containing laterite as partial replacement of sand in concrete are as follows:

1. Concrete produced with partial replacement of sand with laterite can only be feasible and effective at 20% addition of laterite content to sharp sand.
2. The physical and chemical properties of laterite should be investigated prior to its incorporation into the concrete.
3. The recommendation 1 should be subjected to further investigation so as to ascertain whether the additional materials could be added which could result to an enhanced improvement in strength and density properties of the laterized concrete.

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APPENDIX A

Particle Size Distribution Test

Table A1: Sieve Analysis Result for Laterite

Particle Diameter (mm)	weight of soil retained(g)	% weight of soil retained	cummulative % weight retained	Percent Finer (%)
2	8.92	1.78	1.78	98.22
1.18	10.24	2.05	3.83	96.17
0.85	3.22	0.64	4.47	95.53
0.6	7.38	1.48	5.95	94.05
0.425	21.16	4.23	10.18	89.82
0.3	51.19	10.24	20.42	79.58
0.15	98.21	19.64	40.06	59.94
0.075	107.87	21.57	61.63	38.36
Tray	191.81	38.36	100	0
	500			

Table A2: Sieve Analysis Result for Sharp Sand

Sieve Sizes (mm)	Mass Retained (g)	% Mass Retained	Cum Retained %	Cum % Finer
2	16.42	5.47	5.47	94.53
1.18	13.07	4.36	9.83	90.17
0.85	20.89	6.96	16.79	83.21
0.6	22.74	7.58	24.37	75.63
0.425	38.75	12.92	37.29	62.71
0.3	47.76	15.92	53.21	46.79
0.15	70.04	23.35	76.55	23.45
0.075	3.27	1.09	77.64	22.36
Tray	0.68	0.23	77.87	22.13

APPENDIX B

ATTERBERG LIMIT TEST

Table B1: Liquid Limit Determination of Laterite

NUMBER OF BLOWS	WEIGHT OF CAN (g)	CAN + WET SAMPLE (g)	WET SAMPLE (g)	CAN + DRY SAMPLE (g)	DRY SAMPLE (g)	WEIGHT OF WATER (g)	MOISTURE CONTENT (%)
15	13.83	18.84	5.01	17.30	3.47	1.54	44.38
18	16.21	25.13	8.92	22.43	6.22	2.70	43.41
23	15.08	21.47	6.39	19.57	4.49	1.90	42.32
37	17.91	22.39	4.48	21.11	3.20	1.28	40.00
42	17.15	24.87	7.72	22.80	5.65	2.07	36.64

LIQUID LIMIT = 41.86%

Table B2: Plastic Limit Determination of Laterite

WEIGHT OF CAN (g)	CAN + WET SAMPLE (g)	WET SAMPLE (g)	CAN + DRY SAMPLE (g)	DRY SAMPLE (g)	WEIGHT OF WATER(g)	MOISTURE CONTENT (%)
15.78	17.71	1.93	17.38	1.60	0.33	20.63
14.42	16.29	1.87	15.95	1.53	0.34	22.22
14.60	16.54	1.94	16.22	1.62	0.32	19.75

$$\text{PLASTIC LIMIT} = \frac{(20.63+22.22+19.75)}{3} = 20.87\%$$

$$\text{Plasticity Index (PI)} = \text{LL} - \text{PL} = 41.86 - 20.87 = 20.99\%$$

APPENDIX C

COMPRESSIVE STRENGTH TEST

Table C: Compressive Strength Results for Concrete produced at varying percentages of Laterite

SPECIMEN		AVERAGE WEIGHT (KG)	CROSS SECTIONAL AREA (mm ²)	AVERAGE COMPRESSIVE STRENGTH (N/ mm ²)	MAXIMUM COMPRESSIVE STRENGTH (N/ mm ²)
SAND/LAT (%)	TIME (DAYS)				
100/0	7	8.1	22500	16.5	20.12
	14	8.1	22500	17.9	
	21	8.3	22500	20.12	
95/5	7	8.1	22500	16.2	19.94
	14	8.1	22500	17.03	
	21	8.3	22500	19.94	
90/10	7	8.1	22500	17.80	20.47
	14	8.1	22500	19.24	
	21	8.3	22500	20.47	
85/15	7	8.1	22500	18.26	21.68
	14	8.1	22500	20.05	
	21	8.3	22500	21.68	
80/20	7	8.1	22500	17.20	19.86
	14	8.1	22500	17.75	
	21	8.3	22500	19.86	