

**INVESTIGATION OF WATER-CEMENT RATIOS ON CONCRETE
INCORPORATING SAWDUST**

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CERTIFICATION

This is to certify that the research project on “INVESTIGATION OF WATER-CEMENT RATIOS ON CONCRETE INCORPORATING SAWDUST” was carried out by Etim Akpan Mary Chinemerem with registration number (NAU/2014464238) 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. Dr. Okonkwo 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.

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Date

APPROVAL PAGE

This research thesis on “INVESTIGATION OF WATER-CEMENT RATIOS ON CONCRETE INCORPORATING SAWDUST” was carried out by Etim Akpan Mary with registration number (NAU/2014464238) has satisfied all the requirements of this university for the award of Bachelor’s degree (B.Eng) in Civil Engineering, Nnamdi Azikiwe University, Awka.

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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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Who deserves to be acknowledged first, if not the Most High God whose guidance and protection had been with me throughout my academic life as a student.

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ABSTRACT

This research addresses a comparative study on the Investigation of water-cement ratios incorporating sawdust. There is environmental nuisance and degradation occasioned by indiscriminate disposal of sawdust. There is also growing concerns about the depletion of non-renewable natural resources like sand. In response to these problems, researches have been carried out on the usage of sawdust to supplement sand as fine aggregate in concrete. This research examines the effects of water-cement ratios on the engineering properties of concrete produced using sawdust as partial replacement of sand. Standard mixes were prepared without sawdust to serve as control and then sawdust mixes were prepared using 15% replacement of sand with sawdust. The mixes were prepared with varying water-cement ratios of 0.4, 0.45, 0.5, 0.55 and 0.6 with the corresponding mix ratios of 1:3:6, 1:2:4, 1:1.5:3, 1:1:2 and 1:0.75:1.5 respectively. The results revealed that the slump values increased as the water-cement ratio increased. The results indicate that for a water cement ratio of 0.4 and 0.5, the sawdust concrete attains good properties with compressive strength values of 22.82N/mm and 21.56N/mm respectively at 28 days. However by increasing the water cement ratio to 0.6, the sawdust concrete recorded a low value for the various properties of concrete with compressive strength value of 14.15N/mm at 28 days. This is due to the decomposition of the lignocellulolytic components such as carbohydrates, lignin, cellulose. Therefore, at 15% replacement of sand with sawdust, it is recommended to use water-cement ratio not exceeding 0.5 due to the water absorption rate of the sawdust concrete.

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CHAPTER ONE

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. Different alternative waste materials and industrial by-products such as sawdust, rice husk ash, fly ash, bottom ash, recycled aggregates, 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.

Sawdust 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 the by-product of wood working operation 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 sawdust.

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).

Sawdust is a by-product of wood working operation and It can be used for partial replacement of sand in light weight concrete. Sawdust mixed with concrete has low bulk density, better heat preservation and heat insulation property.

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.

Wood working generates a by-product known as sawdust. Sawdust has other useful application until it was known to be useful in concrete. A reduction in the use and cost of Sand can be achieved through the use of sawdust as a partial replacement for Sand.

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 sawdust as a partial replacement of Sand.

1.3 AIMS AND OBJECTIVES

To study the dry and wet properties of sawdust concrete and vary the water cement ratio and sawdust particle size.

The objectives of this research is to investigate the effects of water-cement ratio on the fresh and hardened properties of concrete produced using sawdust as the partial replacement of sand and ascertain the water-cement ratio at which the sawdust concrete attains its optimal properties.

1.4 SIGNIFICANCE OF THE STUDY

This research tends to benefit both the public and private client. A reduction in the use of Sand as partial replacement with sawdust in concrete production will go a long way in reducing this wood working by-product (sawdust) and put them in use in the construction industry, bring about reduction in quantity of sand and also brings about reduction in weight of concrete.

The cost of sand 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 sand and also sawdust material are easily sourced and less costly.

The study will provide information on the partial replacement of Sand with sawdust in concrete production.

1.5 SCOPE OF STUDY

This study would lead to the determination of the compressive strength of concrete test and Concrete workability (slump test) with varying water- cement ratio and also sieve analysis. The concrete mix proportions to be used are 1:3:6, 1:2:4, 1:1.5:3 and 1:1:2, it was batched by weight and volume with water-cement ratios of 0.4, 0.45, 0.5, 0.55 and 0.6. The freshly mixed concrete would be cast in a concrete cube of 150mm x 150mm x150mm. The concrete cubes would be cured for 7days, 14 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 a highly attractive successful utilization of waste materials depends on its economically competitive with alternative natural materials (Nazar, 2013).The selection and combination of

supplementary cementitious 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:

- i. Relatively low tensile strength when compared to other building materials.
- ii. Low ductility.
- iii. Low strength-to-weight ratio.
- iv. 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 (nonstructural)

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/m³. 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/ft³, whereas the density of regular weight concrete ranges from 140 to 150 lb/ft³. 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 / ft³ for non-air-entrained concrete, but is less for air-entrained concrete. (The weight of concrete plus steel reinforcement is often assumed as 150 lb / ft³). 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/ft³ can be produced.

Concrete made with limonite or magnetite can develop densities of 210 to 224 lb/ft³ and compressive strengths of 3200 to 5700 psi. With barite, concrete may weigh 230 lb/ft³ 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/ft³ 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 strength between 20 MPa to 50MPa.

High strength concrete

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

Ultra high strength concrete

Ultra high strength concrete 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:

- i. It is a relatively cheap material and has a relatively long life with few maintenance requirements.
- ii. It is strong in compression.
- iii. Before it hardens it is a very pliable substance that can easily be shaped.
- iv. 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:

- i. Bleeding
- ii. Harshness
- iii. Segregation
- iv. 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 fines, 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 ease 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

- i. Water content which is paramount
- ii. Type of grading of aggregates
- iii. Cement\aggregate ratio
- iv. Presence of admixtures
- v. Fineness of cement
- vi. Temperature
- vii. Time.

Workability test

Workability of a concrete is tested with the following methods;

- i. Slump test
- ii. Compacting factor test
- iii. Vebe test
- iv. Flow table test
- v. 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 batches of the same mix. The mould for the slump test was a frustum of a cone, 300mm high.

Types of Slump Test

- i. True slump
- ii. Collapse slump
- iii Shear slump
- iv Zero slump

The procedure for the experiment includes:

- i. The internal surface of the mould was thoroughly cleaned and applied with a light coat of oil.
- ii. The mould was placed under a smooth, horizontal and non-absorbed surface. With the
- iii. smaller opening at the top.
- iv. The mould was filled in three layers with freshly mixed concrete each approximately to one-third of the height of the mould.
- v. Each layer was then tamped 25 times with a steel rounded end and tamping rod (strokes are distributed evenly over the cross-section).
- v. After the top layer was tamped, the concrete was struck off the level with a trowel.
- vi. The mould was removed from the concrete immediately by raising it slowly in the vertical direction.
- vii. The difference in level between the heights if the mould and that of the highest point of the subsided concrete was measured.
- vi. 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 denser 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 of 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 pores leading to permeability in concrete. To achieve impermeable concrete, a low water cement ratio is used, use of dense and well 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 sawdust, 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 satisfactorily to the wet surface of the aggregate than the dry surface.
2. To prepare a plastic mixture of the various ingredients and to impart 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 nonspecialty 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, NO_x, 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.



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 aluminoferrite. 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 ($3 \text{ CaO} \cdot \text{Al}_2\text{O}_3$) formed.

The major raw material for the clinker-making is usually limestone (CaCO_3) mixed with a second material containing clay as source of alumino-silicate. Normally, an impure limestone which contains clay or SiO_2 is used. The CaCO_3 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 $5\mu\text{m}$ diameter, and 5% of particles above $45\mu\text{m}$. 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 $320\text{--}380\text{ m}^2\cdot\text{kg}^{-1}$ for general purpose cements, and $450\text{--}650\text{ m}^2\cdot\text{kg}^{-1}$ 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 ($\text{Ca}(\text{OH})_2$) 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 75 μ m 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

- i. It should be clean and coarse.
- ii. It should be free from any organic or vegetable matter.
- iii. Maximum permissible clay content should be 8% in sand.

- iv. It should be chemically inert.
- v. It should contain sharp, angular grains.
- vi. It should be able to mix with binding materials easily.
- vii. 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 than 150 μ m 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 H₂O, 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 H₂O 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 SAWDUST

Sawdust is a by-product of wood working operation which is generated from the mechanical processing of various raw woods in the saw mill industry. The mechanical properties of sawdust is necessary for the design of concrete containing sawdust as partial replacement of cement. The increase in moisture content will increase the pour and consolidation density while the modulus of elasticity of sawdust will decrease. Angle of internal friction for sawdust is also a strong negative correlation with moisture content.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 INTRODUCTION

This research is aimed at determining the dry and wet properties of sawdust concrete varying the water-cement ratio. 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 sawdust in a proper proportion.

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.



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 1/2 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.



3.2.3 Sand (Fine Aggregate)

The fine aggregate used for this project work is sharp 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.



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 SAWDUST

Sawdust is partially replacing Sand in the concrete mixture. The sawdust was bought at Timber close to Eke-Awka market and the sawdust gotten was suitable for the practical.

3.3 METHODOLOGY

3.3.1 Test and Analysis of Concrete Specimens

The concrete used for this study was prepared using mix ratio 1:3:6, 1:2:4, 1:1.5:3, 1:1:2 and 1:0.75:1.5 for different water cement ratios of 0.4, 0.45, 0.5, 0.55 and 0.6 respectively for target strength of 31.56N/mm while batching of material was done by weight and volume using 15% replacement of Sand and Sawdust. A replicate of 3 (150 by 150 by 150) cubes were cast for each water cement ratio and for each curing period for both 0% and 15% replacement making a total of 120 cubes.

However, dry mix method was used for concrete constituent before the addition of water. The homogenized mixture was then introduced into 150mm by 150mm by 150mm metal moulds in three layers and compacted with the tamping rod for 25 strokes per layer and the top finish with the trowel and label accurately. The concrete was demoulded after 24 hours and immersed in a curing tank, while compressive strength was performed after 7, 14 and 28 days.

3.3.2 Methods and Test Equipments

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

- i. Weighing machine/weighing balance.

- ii. B.S Sieves
- iii. Moulds
- iv. Rammer/Tamping rod
- v. Universal testing machine (compressive strength test).
- vi. 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 25mm² 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

- i. A representative weighed sample is poured in sieve
- ii. The sample is sieved using a set of IS sieve agitated by the mechanical shaker
- iii. On completion of sieving, the material on each sieve is weighed
- iv. Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.
- v. 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 = (mass retained/total mass of sample) X 100
Cumulative % retained on any sieve = sum of % retained on all sieves with greater aperture
Percentage finer than any sieve = 100% - (cumulative % retained)

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

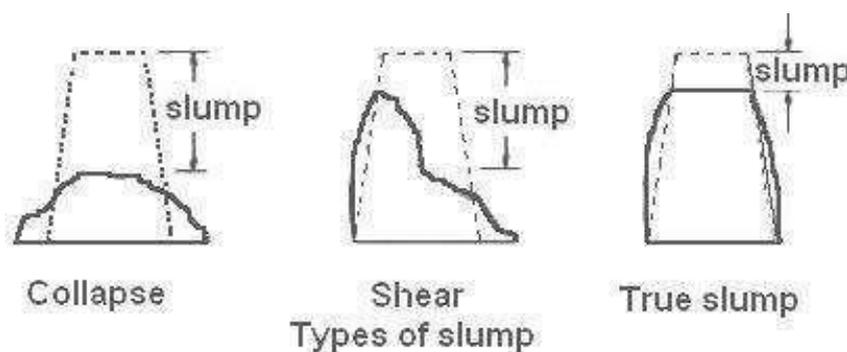
Types of Slump

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 lump cone.



Procedure

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

- ii. Set the cone on a horizontal non-porous and non-absorbent base plate.
- iii. Collect a sample of concrete to perform the slump test.
- iv. Fill the cone fully by pouring freshly mixed concrete in three equal layers.
- v. 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.
- vi. Now fill 2/3 and again tamp 25 times, just into the top of the first layer.
- vii. Fill to overflowing, tamp again 25 times just into the top of the second layer. Top up the cone till it overflows.
- viii. Level off the surface with the steel rod using a rolling action.
- ix. Clean any concrete around the base and top of the cone.
- x. Carefully lift the cone straight up without disturbing the cone-shaped concrete.
- xi. Place the cone beside the concrete and place the plumb horizontally on top of the cone and across the slumped concrete.
- xii. Measure the difference between the height of the cone and the concrete sample. Take several measurements with measuring scale.



3.3.3 Mix Proportion

The concrete material was batched by weight and volume. The ratio of the mixes were 1:3:6, 1:2:4, 1:1.5:3, 1:1:2 and 1:0.75:1.5 with the water cement ratios of 0.4, 0.45, 0.5, 0.55, 0.6. 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 and 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 sand was replaced with Sawdust. Then the freshly mixed concrete is thoroughly mixed.

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.

3.3.5 Compressive strength test

The concrete cubes are tested for their compressive strength at the 7th, 14th 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:

Compressive strength= Load(KN)/Sectional area of cube

3.3.6 Proportioning of the Constituent Materials:

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

- i. Density of concrete = 2400kg/m³
- ii. Volume of cube used = 0.15m x 0.15m x 0.15m = 0.003375m³
- iii. Mass = Density x volume
- iv. Mass = 2400kg x 0.003375m³
- v. Mass = 2400kg x 0.003375 = 8.1kg.

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 Sawdust, workability test and compressive strength test.

4.1.1 Particle size distribution

Figure 4.1 and 4.2 reveals the particle size distribution analysis carried out on: Sand and Sawdust

in accordance with the guidelines specified by BS 1377;part 2,1990.

- i. Using uniformity coefficient (C_u) = D_{60}/D_{10}
- ii. Coefficient of Curvature (C_c) = $D_{30}^2/D_{60} \cdot D_{10}$

Table 4.1: Particle size distribution analysis for Sand (Fine aggregate)

Sieve Size (mm)	Weight Retained (g)	Percentage Weight Retained (g)	Cumulative Percentage Retained (%)	Cumulative Percentage 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
Tray	1.42	0.284	100.00	0
Total	500			

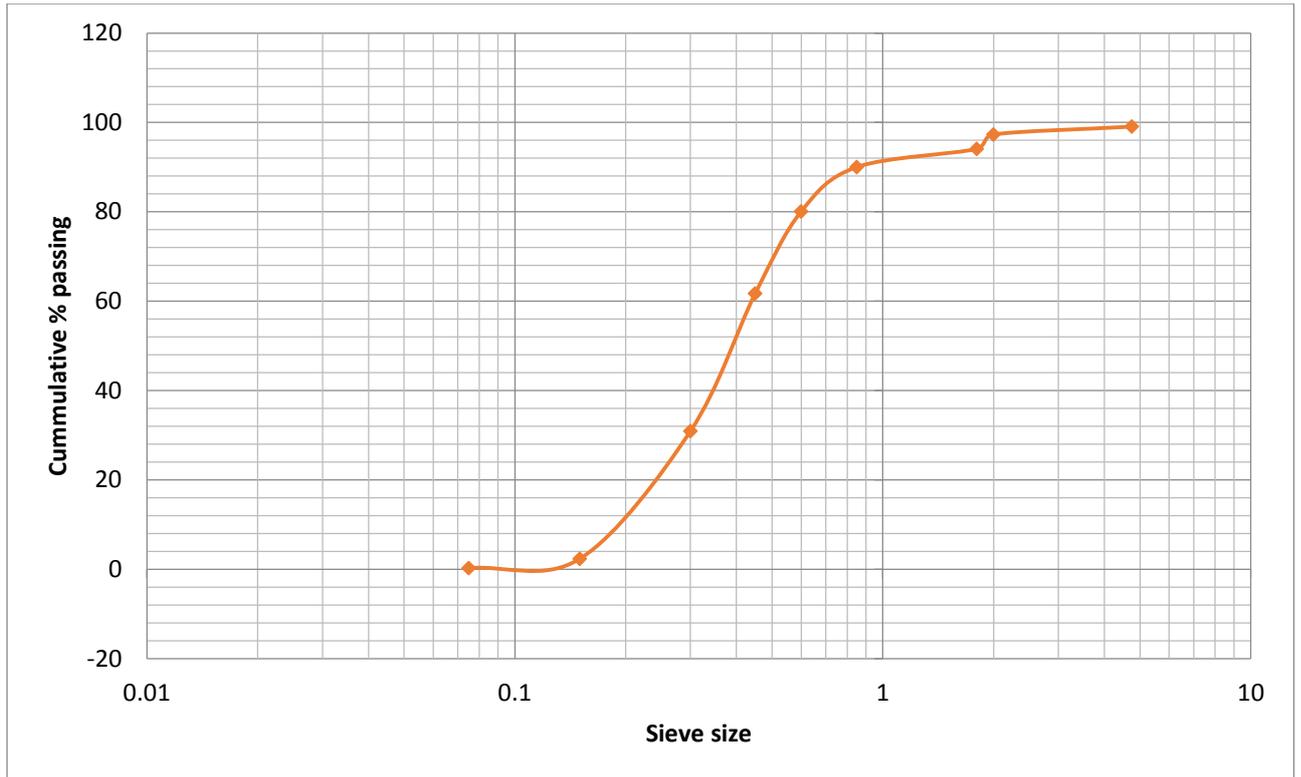


Figure 4.1: Particle Size Distribution analysis for Sand

Analysis from Figure 4.1:

A Coefficient of Uniformity for Sand

$$Cu = D_{60}/D_{30} = 0.45/0.3 = 1.5$$

B Coefficient of curvature for Sand

$$Cc = (D_{30})^2 / D_{60} * D_{10} = 0.09 / 0.09 = 1.0$$

Table 4.2: Particle size distribution analysis for Sawdust

Sieve size (mm)	Weight Retained(g)	Percentage Weight Retained(g)	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

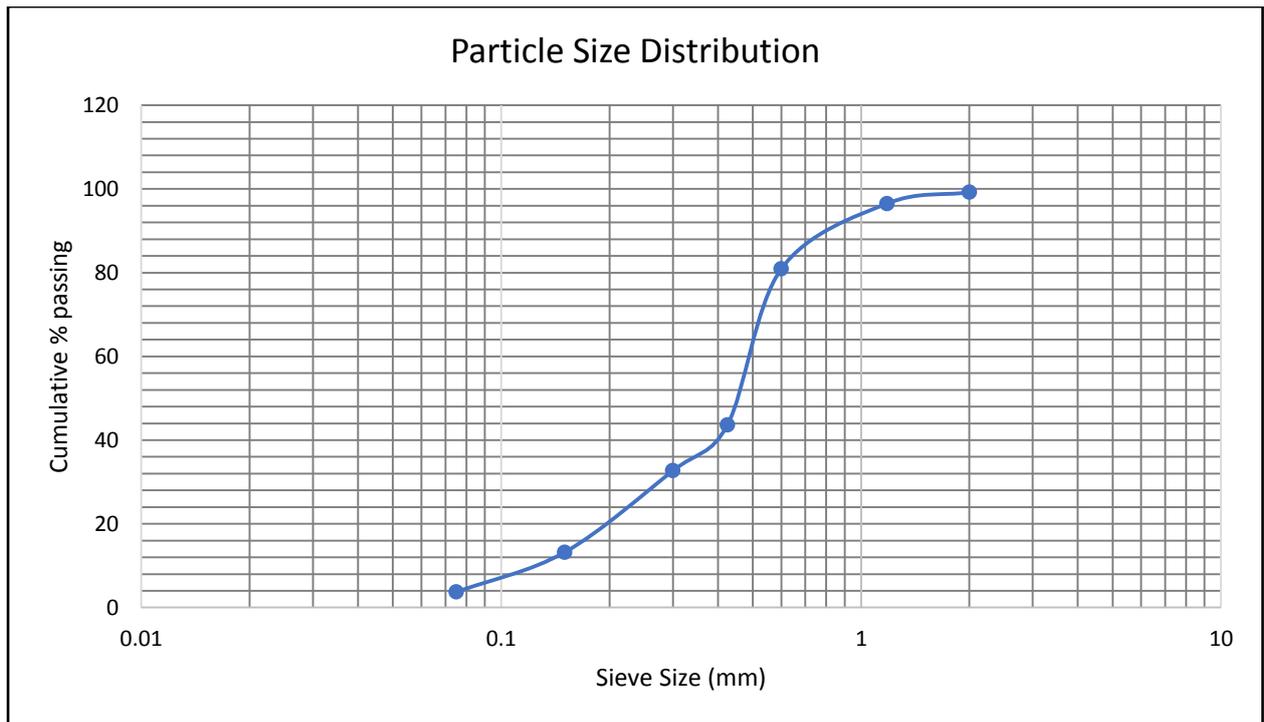


Figure 4.2: Particle size distribution analysis for Sawdust

Analysis from Figure 4.2:

A Coefficient of Uniformity for Sawdust

$$Cu = D_{60}/D_{30} = 0.49/0.28 = 1.75$$

B Coefficient of curvature for Sand

$$Cc = (D_{30})^2 / D_{60} * D_{10} = 0.078 / 0.147 = 0.5$$

4.1.2 Slump Test

Table 4.3: Comparative Variation of slump of concrete with water-cement ratio

Water Cement Ratio	Slump Value For Standard Concrete Control (mm)	Slump Value For Sawdust Concrete 15% (mm)
0.4	19	18.3
0.45	21.5	20.5
0.5	24.8	23.0
0.55	26.5	25.5
0.6	28.5	27.5

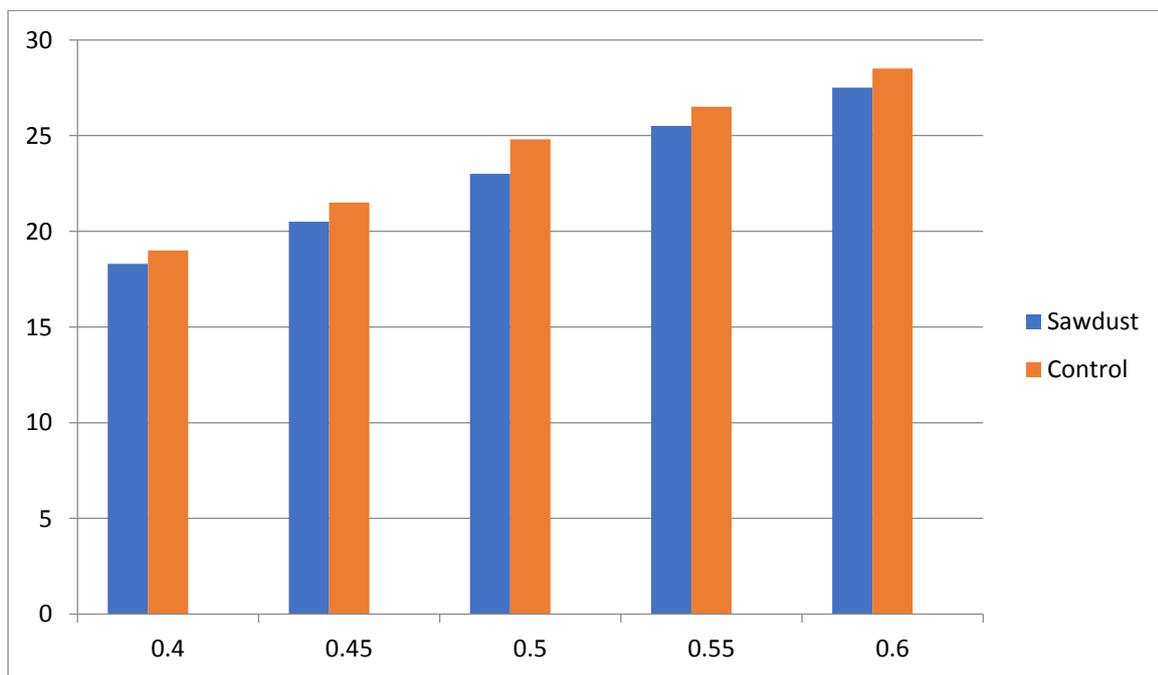


Figure 4.3 : Comparative Variation of slump of concrete with water-cement ratio

The values obtained from the slump test corresponds to the design range of 10 – 30mm. It can be Seen from figure 4.3 that the slump increases as the water cement ratio increases for both 0% and 15% replacement of sand and sawdust.

The slump of 0% is higher than those of 15% replacement showing that workability is reduced in sawdust concrete. This is attributable to increase in surface area as well as high water absorption of Sawdust introduced in the concrete.

4.1.4 Compressive strength of concrete

Table 4.4 Compressive strength of standard concrete and Sand-Sawdust concrete with varying Water-cement ratio

Water-Cement ratio	Compressive Strength of Control			Compressive strength of Sand-sawdust concrete (15%)		
	7 days	14 days	28 days	7 days	14 days	28 days
0.4	20.37	24.5	31.26	16.07	16.46	22.83
0.45	18.3	22.15	25.93	12.81	12.96	16.96
0.5	20.74	24.59	31.48	14.96	20.37	21.56
0.55	17.63	18.81	23.78	11.63	19.41	15.63
0.6	15.9	17.41	23.63	11.02	17.26	14.15

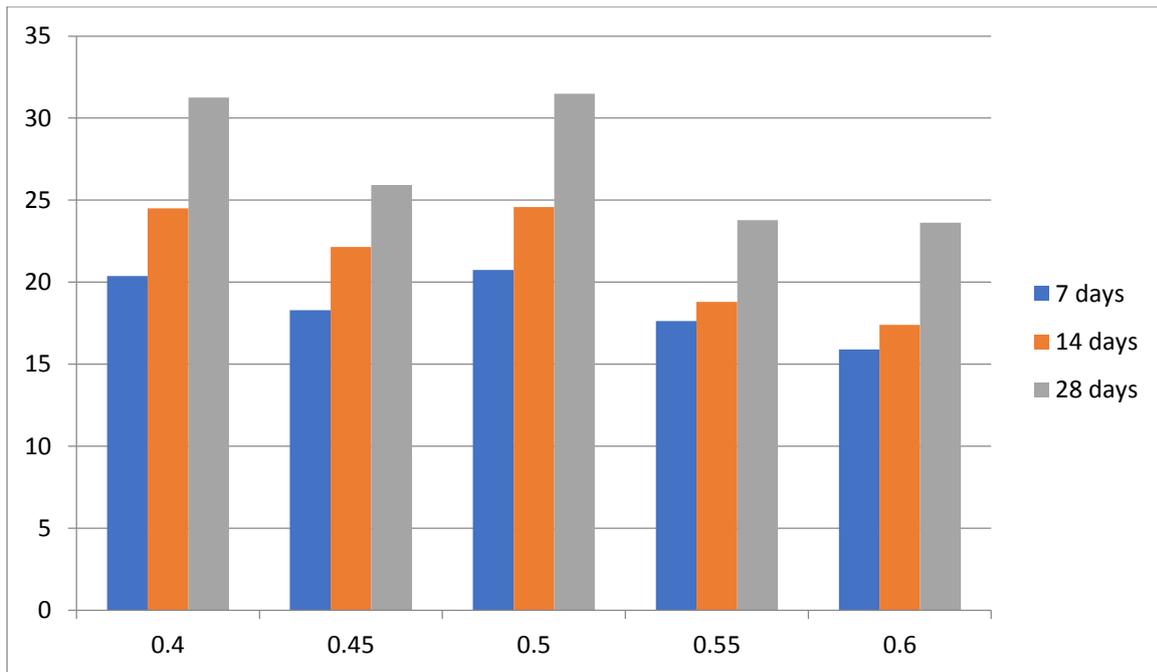


Figure 4.4 Compressive strength of standard concrete versus water-cement ratio

The compressive strength of concrete increases with increase in age. 0.4 and 0.5 water-cement ratio have the values of 31.26 N/mm² and 31.48 N/mm² which are above the target mean strength which makes them the optimum water cement ratio. The compressive strength of concrete reduces as the water cement ratio increases above 0.5. However, the strength of 0.4 water cement ratio increased by 16.2 % within 14 –28 days curing. Nevertheless, for 0.6 and 0.55 water cement ratio the strength of the concrete reduced by 10.8% after 14 days curing. Water cement ratio of 0.5 showed a continuous, progressive and approximately uniform increase in the strength as the curing period increases.

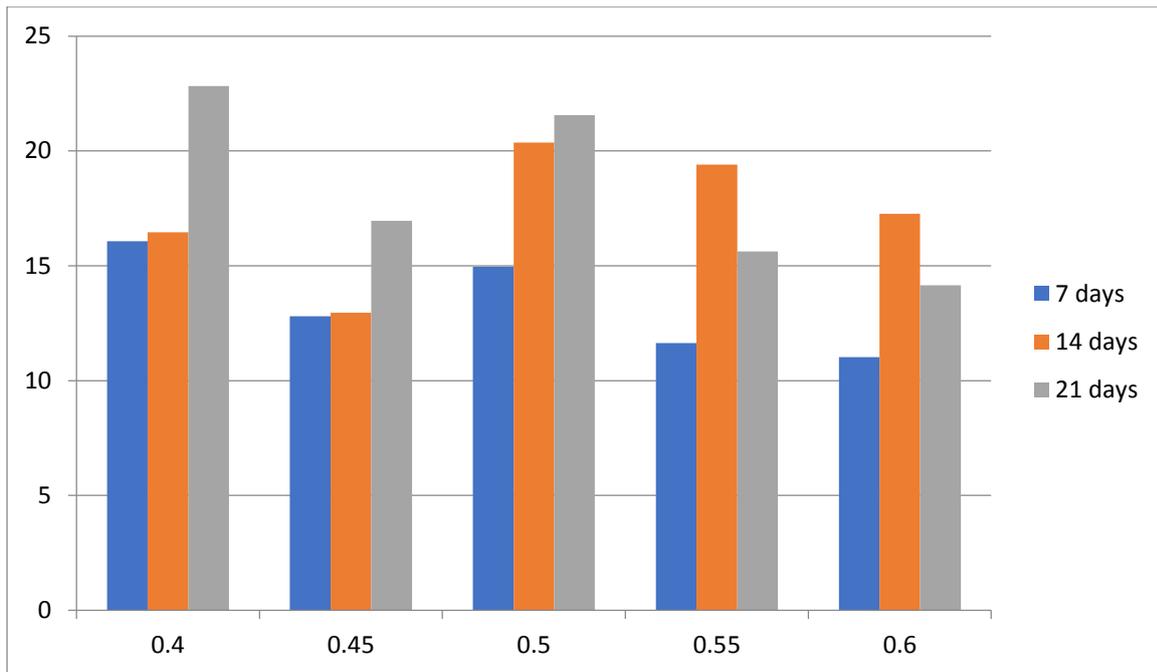


Figure 4:5 Compressive strength of sand-sawdust concrete versus water-cement ratio

However, the highest value of sawdust concrete is 22.83 N/mm² at 0.4 water-cement ratio while that of standard concrete is 31.48 N/mm² at 0.5 water/cement ratio which shows that the strength decreased by 16%. There is an anomalous variation in the compressive strength of the sawdust concrete at 14 and 28 days curing period for 0.55 and 0.6 water/cement ratio, this can be attributed to the fact that sawdust is a lignocellulolistic material that decomposes in the presence of water. This component that decomposes affects the overall strength of the concrete. Also, sawdust differs in its physical properties from sand and the way sand will easily mix with cement is different from the way sawdust mix. This also infers that sawdust content which increased the water absorption of concrete. Hence, leaving very little for hydration, thereby caused corresponding decrease in compressive strength.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1 CONCLUSIONS

The following conclusion can be drawn from the foregoing results and discussions:

1. Concrete with 15% sawdust and 0% sawdust replacement yielded the optimal result at water cement ratio of 0.4 and 0.5 respectively, which implies that water-cement ratio above 0.5 is not recommended.
2. The slump value increased as the water cement ratio increased from 0.4 to 0.6 for both 0% and 15% which entails that workability increases. Hence, ease of compaction is enhanced.
3. The sand-sawdust concrete has higher capacity to absorb water than the standard concrete; hence, should be used in the superstructure, lightweight and ecofriendly structures preferably.
4. The compressive strengths of both standard and sand-sawdust concrete were appreciably high above the designed strength for 0.4 and 0.5 water-cement ratios.
5. The utilization of this wood material for construction work will in turn reduce its effect as environmental pollutant and emission of gases which causes global warming when they are being burned or allowed to decay thereby facilitating a healthy environment.

5.2 RECOMMENDATION

Owing to the lignocellulolistic nature of sawdust and its higher water absorption rate, sawdust concrete should be used for superstructure in addition to its usage for lightweight and eco-friendly structures. Its usage in substructure is not encouraged.

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