EFFECT OF PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH CRUSHED COCONUT SHELL ON MECHANICAL PROPERTIES OF CONCRETE

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CERTIFICATION

This is to certify that the project topic titled “EFFECTS OF PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH CRUSHED COCONUT SHELL ON MECHANICAL PROPERTIES OF CONCRETE” was undertaken by Mbachu Kelechi Robert with registration number (NAU/2017224044) in the Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

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APPROVAL PAGE

This research work “EFFECTS OF PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH CRUSHED COCONUT SHELL ON MECHANICAL PROPERTIES OF CONCRETE” has been assessed and approved by department of civil engineering Nnamdi Azikiwe University.

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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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ABSTRACT

The study was carried out to evaluate the effect of partial replacement of coarse aggregate with crushed coconut shell on mechanical properties of concrete. Granite was partially replaced with crushed coconut shell in an increasing order of 5%, 10%, 15%, 20% and 25% by weight of granite. The concrete and concrete was subjected to various testing. The tests include: sieve analysis test, specific gravity test, slump test, compressive strength test. Results obtained from sieve analysis test revealed that sand, granite and crushed coconut shell was classified as A-2-6, A-1-a and A-1-b according to AASHTO Soil Classification System, SM, GC and GM according to Unified Soil Classification System, the specific gravity was 2.55 and 2.61, slump test results of the fresh concrete revealed that the slump of the concrete decreased from 0% addition of crushed coconut shell to 25% addition of crushed coconut shell to the concrete, the hardened density and compressive strength of the concrete decreased 0% addition of crushed coconut shell to 25% addition of crushed coconut shell to the concrete. The study therefore discourages the use of coconut shell as a constituent in concrete since the compressive strength of the concrete was undermined.

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G_S – Specific Gravity

AASHTO – American Association of State Highway and Transportation Officials

USCS – Unified Soil Classification System

ASTM – American Society for Testing and Material

BSL – British Standard Light

BSH – British Standard Heavy

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

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

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

C_U – Coefficient of Uniformity

C_C – Coefficient of Curvature

SC – Clayey Sand

SM – Silty Sand

GM – Silty Gravel

GC—Clayey Gravel

GW—Well Graded Gravel

GP—Poorly Graded Gravel

SP—Poorly Graded Sand

SW—Well Graded Sand

CL – Inorganic Clay of Low Plasticity (lean clay)

CH—Inorganic Clay of High Plasticity (fat clay)

ML- Silt of low Plasticity

MH – Silt of High Plasticity

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Concrete is one of the most globally utilized man-made materials for building construction (Danraka, 2015). Its great resourcefulness and relative low cost in meeting wide range of demands has made it a keen building material (Sashidar and Rao, 2014). Concrete is the premier civil engineering construction material (Mukhtyar and Kumar, 2018). Concrete manufacturing involves consumption of ingredients like cement, aggregates (coarse and fine), water and admixtures (Mukhtyar and Kumar, 2018). Among all the ingredients of concrete, aggregates constitute the major part of concrete as they occupy 70-85% by volume of the concrete mix (Mukhtyar and Kumar, 2018). These aggregate are produced during quarrying of limestone especially in regions where limestone is present in substantial quantities. Recent increase in concrete production cost due to high cost of transportation of coarse aggregate to regions where the material is relatively scarce is a major source of concern to professional in the building industry. Moreover, there are severe negative environmental impact associated with quarrying of limestone ranging from noise pollution, impaired air quality and emission of dust and particles into the atmosphere. The aforementioned problems have necessitated the exploration of environmentally friendly alternative for the production of concrete Uchechi, et al., (2017).

The high cost of construction materials has been a source of concern for all stakeholders in the construction industry (Yusuf, et al., 2020). The costs of these materials keep rising day by day, thereby leading to high cost of construction (Yusuf, et al., 2020). However, with the quest for affordable housing system for both the rural and urban population of Nigeria and other developing countries, various proposals focusing on cutting down the cost of conventional construction materials have been put forward. One of the suggestions in the forefront has been the sourcing, development and use of alternative, non-conventional local materials including the possibility of using some agricultural wastes and residues as construction materials (Yusuf, et al., 2020).

Many agricultural and industrial by-products recognized as potential replacement of conventional aggregate in concrete are light weight aggregate Uchechi, et al., (2017). Advantages of light weight aggregate concrete over conventional concrete include decreased dead load, lower rate of depletion of natural resources, lower thermal conductivity, and reduced construction costs. There is a continuing trend towards the use of more lightweight concrete in applications such as prestressed concrete and high -rise buildings (Neville and Brooks, 2010). Some agricultural by-products such as coconut shell have been identified as potential replacement of aggregate in concrete. However, agricultural by-products have not been fully utilized as coarse aggregates in building sustainable concrete structures in Nigeria (Yusuf, et al., 2020).

Coconuts are mainly cultivated in the coastal clays and sands and sporadically distributed in other areas (Danraka, 2015). The shells are regarded as waste and therefore disposed off in large amount which lead to environmental problems in most of tropical countries particularly in Africa (Danraka, 2015). Coconut shell has high strength and modulus properties (Varma and Shrivastava, 2021). Coconuts are being naturally available in nature and since its shells are non-biodegradable; they can be used readily in concrete, which may fulfill almost all the qualities of the original form of concrete (Varma and Shrivastava, 2021). Coconut shell is often used as a composite in concrete because of the characteristics found in it better than material that commonly used in production of concrete (Bansal, et al., 2014). Some researchers have concluded that coconut shell can be used for producing lightweight concrete and can be used at different proportion for required concrete strength (Danraka, 2015). In an investigation conducted by Kakade and Dhawale, (2015), it was revealed that the 28th day compressive strength of coconut shell concrete with 25% volume replacement with coconut shell aggregate under full water curing was 21.31MPa equivalent to grade 20 concrete. This makes agricultural wastes concrete ideal for building construction if the minimum grade of concrete is achieved since these are generally cheaper than conventional materials.

In other to reduce the adverse environmental consequence associated with production of coarse aggregate, ensure economy in concrete production process through utilization of locally available materials and reduce volume of agricultural waste generated, this study will investigate the effect of partial replacement of coarse aggregate with crushed coconut shell on mechanical properties of concrete.

1.2 Statement of Problem

There is a growing need to ensure rational use of earth resource in the production of concrete. Concrete production incorporate the use of fine aggregate (sand), coarse aggregate (granite), cement and water in their correct proportion. Coarse aggregate as one of the components of concrete is produced during quarrying of limestone. There are severe negative environmental impact associated with quarrying of limestone ranging from noise pollution, impaired air quality and emission of dust and particles into the atmosphere. Moreover, cost of concrete production have risen significantly as a result of high cost of transportation of coarse aggregate to regions where the material are present in negligible quantities. These developments have necessitated the exploration of environmentally friendly alternatives for production of concrete. The utilization of agricultural by-product as a partial replacement for coarse aggregate in the production of concrete constitutes a viable option.

In other to reduce the adverse environmental consequence associated with production of coarse aggregate, ensure economy in concrete production process through utilization of locally available materials and reduce volume of agricultural waste generated, this study will explore the effect of partial replacement of coarse aggregate with crushed coconut shell on mechanical properties of concrete.

1.3 Aim and Objectives of Study

The aim of the study is to assess the effect of partial replacement of coarse aggregate with crushed coconut shell ash on mechanical properties of fresh and hardened concrete while the objectives are:

I. To evaluate the efficacy and feasibility of using crushed coconut shell as a partial substitute for coarse aggregate in concrete.

II. To evaluate the index properties of aggregates (coarse and fine) and additives used for concrete production.
III. To partially replace coarse aggregate in concrete with crushed coconut shell and evaluate it effect on the mechanical properties of the fresh and hardened concrete mix.
IV. To ascertain the maximum amount of crushed coconut shell required to yield optimum compressive strength of the hardened concrete.
V. Test the finished concrete for workability, density and compressive strength.
VI. Compare and make evaluative deduction on the mechanical properties of both the plain cement (conventional concrete) and non conventional concrete (coconut shell concrete).

1.4 Scope of Study

The study is basically experimental and will employ the use of crushed coconut shell as a partial substitute for coarse aggregate in concrete. Concrete produced will be in the ratio of 1: 2: 4 and water to cement ratio of 0.55. Coarse aggregate (granite) will be partly replaced with crushed coconut shell in a stepped increase of 5% to 25% by weight of coarse aggregate. Concrete produced with 0% partial replacement of coarse aggregate with crushed coconut shell will be used as control. Concrete produced will be subjected to laboratory investigation. Laboratory investigations are: Particle size distribution test (sieve analysis), Specific gravity test, Slump (workability) test, Compressive strength test. Results obtained from slump, compressive test will be used as tool for making evaluative deduction on the fresh and hardened properties of plain cement (non coconut shell concrete) and coconut shell concrete.

1.5 Significance of Study

Key findings obtained from the effect of partial replacement of coarse aggregate with crushed coconut shell on the fresh and hardened mechanical coconut shell concrete will e significant in the following ways:

I. Reduce concrete production cost through utilization of relatively cheaper and locally available materials.

II. Facilitate high rate of construction work.

III. Ensure environmental protection through reduction in noise and dust and particle emission associated with quarrying of limestone during production of coarse aggregate.

IV. Mitigate waste management problems in both rural and urban areas through reduction in volume of agricultural waste (coconut shell) generated.

V. Ensure rational use of earth constituents in concrete production.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

Concrete is the most versatile heterogeneous construction material and the most valuable construction material for infrastructural development of any nation (Mukhtyar and Kumar, 2018). Civil engineering practice and construction works around the world depend to a very large extent on concrete. Concrete is a synthetic construction material made by mixing cement, fine aggregates, coarse aggregates and water in the proper proportions (Mukhtyar and Kumar, 2018). Aggregates serve as inert filler materials while at the same time improving concrete workability, volume stability and durability. Different alternative site materials and industrial by-products such as fly ash, bottom ash, recycled aggregates, foundry sand, clay sand, crumb rubber, glass will be replaced with natural aggregate and investigated properties of the concretes (Mukhtyar and Kumar, 2018). Apart from above mentioned site materials and industrial by-products, few studies identified that coconut shells, the agricultural by product can also be used as aggregate in concrete.

Presently, many engineers and scientists are in process to find various natural as well as modernized ways for the production of construction materials especially concrete. They are also keen in maintaining its quality and strength and therefore various other materials are used as a replacement of a particular material in the making of concrete. One such material is coconut shell which can be used in concrete making by partially replacing coarse aggregate which is a very important component in concrete. Coconuts being naturally available in nature and since its shells are non-biodegradable in; they can be used readily in concrete which fulfill almost all the qualities of the original form of concrete (Harle, 2017). Natural sources are depleting by rapid rate; there should be some way to stop it somewhere. One way to overcome this problem is to replace the coarse aggregates used in the production of concrete by coconut shell which are readily available in nature (Harle, 2017). Use of this non-biodegradable material in concrete would not only make the construction cost less since coconut shells would require less costing as compared to the coarse aggregates but also re-use the waste material and help in environmental aspect.

Use of coconut shell aggregate in concrete as structural lightweight concrete is recommended. Coconut shell aggregate is a possible construction material and Use of this non-biodegradable material in concrete would not only make the construction cost less since coconut shells would require less costing as compared to the coarse aggregates but also re-use the site material and help in environmental aspect (Mukhtyar and Kumar, 2018). A potential exists for the use of coconut shells as replacement of conventional aggregate in both conventional reinforced concrete and plain cement concrete construction (Mukhtyar and Kumar, 2018). The use of coconut shells as partial replacement for conventional aggregates should be encouraged as an environmental protection and construction cost reduction measure.

This section will focus essentially on literatures relevant to the investigation of fresh and hardened properties of concrete produced with partial replacement of coarse aggregate with crushed coconut shell.

2.2 History of Concrete

The first major concrete users were the Egyptians in around 2,500BC and the Romans from 300BC the Romans found that by mixing pink sand like material which they obtained from Pozzuoli with their normal lime-based concretes they obtained a stronger material. The pink sand turned out to be fine volcanic ash and they had unintentionally produced the first pozzolanic cement. Pozzolanna is any siliceous and aluminous material which possesses little or no cementitious value in itself but will, if finely divided and mixed with water, chemically react with calcium hydroxide to form compounds with cementitious properties (Harle, 2017).

2.3 Concrete Production Process

2.3.1 Batching

The correct measurement of the various materials used in the concrete mix is called batching. Errors in batching are partly responsible for the variation in the quality of concrete. Concrete can be batched in two ways:

a) By volume batching and
b) By mass (weight) batching

Weigh-batching of materials is always preferred than volume batching. When weigh-batching is not possible and the aggregates are batched by volume, such volume measures to be regularly checked for the weight-volume ratio.

2.3.2 Mixing

This is the practical means of producing fresh concrete and placing it in the form so that it can harden into the structural or building material referred to as concrete‘. The sequence of operation is that the correct quantities of cement, aggregates and water, possibly also admixture are batched and mixed in a concrete mixer which produces fresh concrete. This is transported from the mixer to its final location. The fresh concrete is then placed in the forms, and compacted so as to achieve a dense mass which is allowed and helped, to harden. The objective of mixing of concrete is to coat the surface of all aggregate particles with cement paste and to blend all ingredients of concrete into a uniform mass. Mixing of concrete is done either by hand or by machine.

Mixers performances shall be checked for conformity to the requirements of the relevant standards. Concrete shall be mixed for the required time; both under-mixing and over-mixing shall be avoided.

2.3.3 Transportation

After mixing, concrete shall be transported and placed at site as quickly as possible without segregation, drying, etc. as soon as concrete is discharged from the mixer, internal as well as external forces starts acting to separate the dissimilar constituents (Gambhir, 2004). If over-weight concrete is confined in restricting forms, the coarser and heavier particles tend to settle and finer and lighter materials tend to rise. If concrete is to be transported for some distance over rough ground the runs shall be kept as short as possible since vibrations of this nature can cause segregation of the materials in the mix. For the same reason concrete should not be dropped from a height of more than 1m. If this is unavoidable a chute shall be used. The green concrete shall be handled, transported and placed in such a manner that it does not get segregated. The time interval between mixing and placing the concrete shall be reduced to the minimum possible.

2.3.4 Placing

The formwork and position of reinforcement shall be checked before placing concrete to make sure that they are clean and free of any detritus, such as ends of tying wire. The fresh concrete shall be deposited as close as possible to its ultimate position (Gambhir, 2004). Care need to be taken when discharging concrete from skips to avoid dislodging the reinforcement or over filling the formwork. When filling columns and walls, care shall be taken that the concrete does not strike the face of the formwork, which might affect the surface finish of the hardened concrete. For deep sections the concrete shall be placed in uniform layers, typically not more than about 500 mm thick, each layer being fully compacted.

2.3.5 Compaction

Compaction of concrete is the process adopted for expelling the entrapped air form the concrete. In the process of placing and mixing of concrete, air is likely to get entrapped in the concrete. If this air is not detrained out fully, the concrete losses strength considerably. Anticipated targets of strength, impermeability and durability of concrete can be achieved only by thorough and adequate compaction. One per cent of the air voids left in concrete due to incomplete compaction can lower the compressive strength by nearly five percent (Gambhir, 2004).

2.3.6 Curing

Curing of concrete is the process of maintaining satisfactory moisture content and a favorable temperature in concrete during the period immediately after the placement of concrete so that hydration of cement may continue till the desired properties are developed sufficiently to meet the requirements of service. The reasons for curing concrete are to keep the concrete saturated or as nearly saturated as possible, until the originally water filled space in the fresh cement paste has been filled to the desired extent by the product of hydration of cement, to prevent the loss of water by evaporation and to maintain the process of hydration, to reduce the shrinkage of concrete and to preserve the properties of concrete. Concrete derives its strength by the hydration of cement particles. The hydration of cement is of momentary action but a process continuing for a long time. The rate of hydration is fast to start with but continues over a long time at a decreasing rate. Curing is usually requires for at least 7 days after the day the concrete is placed, this may vary in certain special circumstances (Onwuka and Omerekpe, 2003). Adequate curing is essential for the handling and development of strength of concrete. The curing period depends upon the shape and size of member, ambient temperature and humidity conditions, type of cement, and the mix proportions. Nevertheless, the first week or ten days arc the most critical, as any drying out during this young age can cause irreparable loss in the quality of concrete. Generally, the long-term compressive strength of concrete moist cured for only 3 days or 7 days will be about 60 per cent and 80 per cent, respectively, of the one moist cured for 28 days or more (Gambhir, 2004).

2.3.7 Formwork

Formwork is a structure, usually temporary, used to contain poured concrete and to mould it to the required dimensions and support until it is able to support itself. It consists primarily of the face contact material and the bearers that directly support the face contact material. Proper removal of formwork is an important factor to achieve good quality of concrete during the service life.

2.3.8 Inspection and Testing

Inspection and testing play a vital role in the overall quality control process. Inspection could be of two types, quality control inspection and acceptance inspection. For repeated operations early inspection is vital, and once the plant has stabilized, occasional checks may be sufficient to ensure continued satisfactory results. The operations which are not of repetitive type would require, on the other hand, more constant scrutiny. Apart from the tests on concrete materials, concrete can be tested both in the fresh and hardened states. The tests on fresh concrete offer some opportunity for necessary corrective actions to be taken before it is finally placed. These include tests on workability, unit weight or air content (if air-entrained concrete is used).

2.4 Constituents of Concrete

Chudley and Greeno, (2006) assert that the proportions of each of concrete materials control the strength and quality of the resultant concrete. Fresh concrete is a plastic mass, which can be moulded into any desired shape. This is its main advantage as a construction material (Gupta and Gupta, 2004). They further assert that aggregate, coarse and fine combined occupy about 70% space in a given mass of concrete and the rest 30% space is filled by water, cement and air voids. Bert-Okonkwor, (2012) in his definition described concrete as a mixture of Portland cement, fine aggregate coarse aggregate, air and water. Sharma, (2008) concludes in stating that concrete is a heterogeneous mix consisting of the following materials: cement, aggregate (coarse and fine), water and admixture (when necessary). Below are descriptions of some of these components of concrete.

2.4.1 Cement

Cement is a binder material, a substance made of burned lime and clay which after mixing with water, set and harden independently and can bind other materials together Ezeokonkwo, (2014). According to (Onwuka and Omerekpe, 2003), cement as a hydraulic binders react exothermically with water to form hard strong masses with extremely low solubility. They consist of chemical compounds such as calcium silicate and calcium aluminates. Cement is a cementitious material which has adhesive and cohesive properties necessary to bound inert aggregates into a solid mass of adequate strength and durability. Neville, (1993) also adds that cement is the binding material constituent of concrete which reacts chemically with water and aggregate to form a hardened mass on hydrating. Iheama, (2010) further defines it as a finely pulverized product resulting from calcination of natural argillaceous limestone at a temperature below the fusion. In addition to this Ivor, (1995), defines cement as a mixture of compounds, consisting mainly of silicates and aluminates of calcium, formed out of calcium oxide, silica, aluminium oxide and iron oxide. Hydraulic cements are of four types: Portland cement, Blended Portland Cement, and Portland cement with addictives and High Alumina Cement. Cement varying chemical composition and physical characteristics exhibit different properties on hydration. The cement of desired properties can be produced by selecting suitable mixture of raw materials. The various types of Portland cement used in the construction industry are: Ordinary Portland Cement(OPC), Rapid Hardening Portland Cement(RHPC), Sulphate resisting Portland Cement(SRPC), Low Heat Portland Cement(LHPC), Blast Furnace Portland Cement(BFPC), Portland Pozzolana Cement(PPC), Modified Portland Slag Cement(MPC).

Many authors (Ezeokonkwo, 2014: Anosike, 2010: Gupta and Gupta, 2004: Iheama, 2010) agreed to the fact that on the addition of water to cement, hydration takes place, liberating a large quantity of heat. On hydration of cement, the gel is formed which binds the aggregate particles together and provides strength and water tightness to concrete on hardening. Thus cement has the property of setting and hardening underwater by a chemical reaction with it. Portland cement is a substance which binds together the particles of aggregates (usually sand and gravel) to form a mass of high compressive strength concrete. It is a combination of limestone or chalk with clay mixed in a proportion depending on the type of cement desired. Portland cement is the most common type of cement generally used around the world because it is a basic ingredient of concrete, mortar and stucco. It is a fine powder produced by grinding Portland cement clinker more than 90%, and a limited amount of calcium sulphate which controls the set time. Portland cement clinker is a hydraulic material which consist at least two-thirds by mass of calcium silicates (3CaO.SiO2 and 2CaO.SiO2).

Okereke, (2003), Portland cement is manufactured by firing a controlled mixture of chalk or limestone ($CaCO_3$) and substances containing silica and alumina such as shale in a kiln at 1500°c temperature. They are heated to clinker and grounded to a fine powder with a small proportion of gypsum (calcium sulphate) which regulates the rate of setting when the cement is mixed with water. Anosike, (2010) also states that the manufacture of PC consists of the following three distinct processes: Mixing, Burning and Grinding. Mixing can be done by dry-process or wet-process. The wet process is the most common. The main difference between the wet and dry production process is the larger amount of water expelled from the kiln during the production process.

2.4.1.1 Chemical Composition of Portland Cement

Anosike, (2010), the ordinary and rapid hardening PC can be tested by the methods given in I.S. 4032. The results of the tests should comply with the following chemical requirements:

a) The ratio of the percentage of lime to the percentage of silica, alumina and ironoxide when calculated by the following formula:

$$\frac{CaO - 0.7SO_3}{SiO_2 \ +1.2AL_2O_3 \ 0.65 \ Fe_2O_3} \qquad [2.1]$$

It should be between 0.66 and 1.02.

b) The Ratio of the percentage of alumina to iron oxide should not be less than 0.66.

c) Weight of insoluble residue should not be more than 2%.

d) Weight of magnesia should not exceed 6%.

e) Total sulphur content calculated as sulphuric anhydride (SO_3) should not exceed 2.75 or 3.0%.

f) Total loss of ignition should not be more than 2%.

According to Shetty, (2005), the raw materials used in the manufacture of Portland cement consist mainly of lime (Cao), silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3). The four compounds are usually regarded as the major constituents of cement. They are described in abbreviated form by cement chemists as follows: CaO = C; SiO_2 = S; Al_2O_3 = A; and Fe_2O_3 = F. Likewise, H_2O in hydrated cement is denoted by H, and SO_3 by S. In addition to the main compounds listed above, there exist minor compounds, such as MgO, TiO_2, Mn_2O_3, K_2O and Na_2O; they usually amount to not more than a few per cent of the mass of cement. Two of the minor compounds are of particular interest: the oxides of sodium and potassium, Na_2O and K_2O, known as the alkalis. They have been found to react with some aggregates, the products of the reaction causing disintegration of the concrete, and have also been observed to affect the rate of the gain of strength of cement (Neville, 2005). The relative proportions of these oxide compositions are responsible for influencing the various properties of cement; in addition to rate of cooling and fineness of grinding. Table 2.0 shows the approximate oxide composition limits of ordinary Portland cement.

Table 2.0 Oxide Composition Limit of Ordinary Portland Cement (OPC) (Shetty, 2005).

Oxide	Approximate Percentages
CaO	60-67
SiO_2	17-25

AL_2O_3	3.0-8.0
Fe_2O_3	0.5-6.0
MgO	0.1-4.0
Alkalis(K_2O, N_2O)	0.4-1.3
SO_3	1.3-3.0

The oxides present in the raw materials when subjected to high clinkering temperature combine with each other to form complex compounds. The identification of the major compounds is largely based on R.H. Bogue's work and hence it is called ―Bogue's Compounds. The four compounds usually regarded as major compounds are tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A) and tetracalciumalumino ferrite (C_4AF). Shetty, (2005). The Bogue's formula used in calculating the percentage of the various compounds is given as follows: $C_3S = 4.07 (CaO) – 7.60 (SiO_2) – 6.72 (Al_2O_3) – 1.43 (Fe_2O_3) – 2.85 (SO_3)$ $C_2S = 2.87 (SiO_2) – 0.754 (3CaO.SiO_2)$ $C_3A = 2.65 (Al_2O_3) – 1.69 (Fe_2O_3)$ $C_4AF= 3.04 (Fe_2O_3)$.

2.4.1.2 Properties of Cement

a) Fineness of Cement

Fineness is a vital property of cement which influences the rate of reaction of cement with water (hydration). The fineness of the cement affects the rate of hydration. It also affects its place ability, workability and water content of a concrete mix much like the amount of cement used in concrete. For a given weight of a finely ground cement, the surface area of the particles is greater than for a coarsely ground cement. The advantages of finer cement include:

a) Increases the rate of hydration
b) More rapid and greater strength development,
c) Reduced bleeding rate of concrete
d) Improving the workability of concrete.

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence fastens the development of strength. Fineness of cement is determined by permeability. For example, in the blaine air permeability method, a known volume of air is passed through cement. The time is recorded and the specific surface is calculated by a formula. Fineness is expressed in terms of specific surface of the cement (Cm^2/gr). For OPC specific surface area is 2600 -3000 Cm^2/gr. This test is conducted as per BS EN196-6:1995.

Neville and Brooks, (2004), three methods of determining the fineness of cement are by sieve analysis, by specific surface area method and by LEA and nurse method.

b) Soundness of Cement

Soundness is referred to as the volume stability of cement paste. The cement paste should not undergo large changes in volume after it has set. Free CaO and MgO may result in unsound cement (Chanadan. 2019). Upon hydration, C and M (calcium and magnesium) will form CH and MH with volume increase thus cracking. (Gartener, et al. 1989), since unsoundness is not apparent until several months or years, it is necessary to provide an accelerated method for its determination which includes:

a) Lechatelier Method where only free CaO can be determined.

b) Autoclave Method where both free CaO and MgO can be determined.

In the soundness test a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is sped up and can be detected. Soundness means the ability to resist volume expansion. For ordinary Portland cement, BS-EN 197 part1 (2000) has specified a maximum expansion of 10mm. The work of Chowdhury et al., (2015) indicated that the soundness of cement was improved with the addition of saw dust ash as partial replacement. In the research, cement was replaced by the ash within the range of 5% to 30% and the soundness was found to increase with an increase in the ash content.

c) Setting Time of Cement

Setting time refers to a change from liquid state to solid state. During setting time, cement paste acquire some strength (Gartener, et al. 1989). The water content has a marked effect on time of setting. In acceptance test for cement, the water content is regulated by bringing the paste to a standard condition of wetness and this is referred to as “normal consistency”. Normal consistency of OPC ranges from 20-30% by weight of concrete. Vicat apparatus is used to determine normal consistency. Normal consistency is that condition for which the penetration of a standard weighed plunger into the paste is 10mm in 30sec. In practice, the terms initial set and final set are used to describe arbitrary chosen time of setting. Initial set indicates the beginning of a noticeable stiffening and final set may be regarded as the start of hardening (or complete loss of plasticity). It is the also the period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat’smould 5 mm to 7 mm from the bottom of the mould. Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression. The setting time test is carried out using the Vicat apparatus as per BS-EN 196 part3 (1995). The results of the test should comply with the requirements of BS-EN 197 part1 (2000), which recommend a minimum of 60 minutes and a maximum of 10 hours as the initial and final setting times of ordinary Portland cement respectively. (Gartener, et al. 1989) summarized the factors affecting setting time as:

a) Temperature and Humidity.
b) Amount of water
c) Chemical composition of cement
d) Fineness of cement (the finer the cement, the faster the setting)

Marthong, (2012), investigated that the addition of saw dust ash in OPC grade 42.5 had increased the initial and final setting times. This was attributed to the low rate of hydration in the paste containing the saw dust ash.

2.4.2 Aggregate

Ezeokonkwo, (2014), the term aggregate includes the natural sand, gravels and crushed stone used in making concrete. Bert-Okonkwor, (2012) describes the term aggregate, as inert materials like gravel, crushed stones, broken bottles which are mixed with cement and water to make concrete. (Merritt, 1983: Rangwala, 2005), in their contribution describe aggregates as inert or chemically inactive materials which form the bulk of concrete and are bound together using cement as a binder. In any concrete, aggregates (fine and coarse) usually occupies about 70-75% (Gupta and Gupta, 2004: Neville and Brooks, 2004). The aggregates have to be graded so the whole mass of concrete acts as a relatively solid, homogeneous, dense combination with the smallest particles acting as inert filler for the voids that exist between the larger particles (Nawy, 2002). This statement gives us the suggestion that the selection and proportioning of aggregates should be given due attention as it not only affects the strength but the durability and structural performance of the concrete also.

Aggregates are considered clean if they are free of excess clay, silt, mica, organic matter, chemical salts and coated grains Ezeokonkwo, (2014). In addition to that, (Merritt, 1983: Rangawala, 2005: Neville, 1993), support the idea that an aggregate should be physically sound if it retains dimensional stability under temperature or moisture change and resists weathering without decomposition. Ezeokonkwo, (2014) concludes that for an aggregate to be considered adequate in strength, aggregate should be able to develop the full strength of the cementing matrix. Anosike, (2010), aggregates provide better strength, stability and durability to the structure made out of cement concrete than cement paste alone.

Aggregate is not truly inert because its physical, thermal and chemical properties influence the performance of concrete. While selecting aggregate for a particular concrete, the economy of the mixture, the strength of the hardened mass and durability of the structure must first be considered (Gupta and Gupta, 2004).

2.4.3 Water

Water used in the concrete reacts with cement and causes it to set and harden. It also facilitates mixing, placing and compacting of fresh concrete. Abruckle, (2007), states that mixing water for concrete is required to be fit for drinking or to be taken from an approved source. Findings in previous works (Ezeokokwo, 2014: Bert-Okonkwo, 2012: Neil and Ravrinda, 1996) suggest that, to achieve the required workability and strength of concrete in both its fresh and hardened state, the water used for mixing and curing needs to be of appropriate quality, that is, it should be free from impurities such as suspended solids, organic matter and salts which may adversely affect the setting, hardening, strength and durability of the concrete.

Water is used in the production of concrete, washing of aggregates, mortar and bricks formation. Water is also used for construction operations like casting, painting, terrazzo finishing, plastering and other operations. After casting of concrete, water is poured on the concrete to give it strength in a process known as curing. After completion of the building, water is used for cleaning the building in readiness for inspection, handing-over and occupancy. As a result of these facts, it is obvious that water is very important in building construction and related activities. Neil and Ravindra, (1996) further define water to cement ratio (w/c) as the weight of water divided by the weight of cement.

According to (BS8110: Part 1, 1997), the amount of water required in a concrete mix is the minimum for complete hydration of cement. If such concrete is fully compacted without segregation, it would develop the maximum attainable strength at a given age. The BS8110, (1997) further states that the water-cement ratio of approximately 0.25 weight is required for full hydration of cement. Omuvwie and Mosaku, (2010) suggest that if the water is not properly managed, it can turn around to inflict serious structural damage to the building over time and that such damage can lead to structural failure of the building and eventual collapse aside of the economic drain on client, safety risks as well as aesthetic devaluation.

2.4.4 Admixture

Admixtures are not a primary constituent of concrete. They are added to concrete if necessary and not all the time. Brantley and Brantley, (2004) admixtures are those chemicals that can be added to the concrete mix to achieve special purposes or meet certain construction conditions. Admixtures are mixed into the concrete to change or alter its properties.

The use of admixtures should offer improvement in the properties of concrete by adjusting the proportions of cement and aggregates. However, it should not affect adversely any property of concrete. An admixture should be used only after assessing its effect on the concrete to be used under an intended situation. It should also be known that admixtures are no substitute for good workmanship i.e. the effect of bad workmanship cannot be improved by the use of admixtures.

Gupta and Gupta, (2004) and Anosike, (2010) suggest that admixtures perform the following functions:

a) Accelerate the initial setting and hardening of concrete.
b) Retard the initial setting of concrete
c) Increase the strength of concrete
d) Improve the workability of fresh concrete
e) Improve the durability of concrete
f) Reduce the heat of evaluation
g) Control the alkali-aggregate expansion
h) Aid in the curing of concrete
i) Improve wear resistance to concrete
j) Reduce shrinkage during the setting of concrete

Bamibgoye et al., (2016) undertook particle size distribution analysis, slump test and compressive strength on hardened concrete in exploiting economics of gravel as a substitute to granite in concrete production. Sulymon et al. (2017) reported that sources of gravel greatly influence compressive, flexural and split-tensile strength of concrete David, et al., (2018).

2.5 Properties of Fresh Concrete

2.5.1 Workability

It is vital that the workability of concrete is matched to the requirements of the construction process (Reynolds and Steadman, 2008). The ease or difficulty of placing concrete in sections of various sizes and shapes, the type of compaction equipment needed the complexity of the reinforcement, the size and skills of the workforce are amongst the items to be considered (Reynolds and Steadman, 2008). In general, the more difficult it is to work the concrete; the higher should be the level of workability. But the concrete must also have sufficient cohesiveness in order to resist segregation and bleeding (Shetty, 2005). Concrete needs to be particularly cohesive if it is to be pumped, or allowed to fall from a considerable height.

2.5.2 Plastic Cracking

There are two basic types of plastic cracks, plastic settlement cracks, which can develop in deep sections and, often follow the pattern of the reinforcement and plastic shrinkage cracks which are most likely to develop in concrete slabs (Reynolds and Steadman, 2008). Both types form while the concrete is still in its plastic state, before it has set or hardened and, depending on the weather conditions, within about one to six hours after the concrete has been placed and compacted (Reynolds and Steadman, 2008). They are often not noticed until the following day. Both types of crack are related to the extent to which the fresh concrete bleeds.

Fresh concrete is a suspension of solids in water and, after it has been compacted, there is a tendency for the solids (both aggregates and cement) to settle. The sedimentation process displaces water, which is pushed upwards and, if excessive, appears as a layer on the surface. This bleed water may not always be seen, since it can evaporate on hot or windy days faster than it rises to the surface. Bleeding can generally be reduced, by increasing the cohesiveness of the concrete (Reynolds and Steadman, 2008). This is usually achieved by one or more of the following means: increasing the cement content, increasing the sand content, using finer sand, using less water, air-entrainment, using rounded natural sand rather than an angular crushed one. The rate of bleeding will be influenced by the drying conditions, especially wind, and bleeding will take place for longer on cold days. Similarly, concrete containing a retarder tends to bleed for a longer period of time, due to the slower stiffening rate of the concrete, and the use of retarders will, in general, increase the risk of plastic cracking.

Plastic settlement cracks, caused by differential settlement, are directly related to the amount of bleeding (Reynolds and Steadman, 2008). They tend to occur in deep sections, particularly deep beams, but they may also develop in columns and walls. This is because the deeper the section, the greater the sedimentation or settlement that can occur. However, cracks will form only where something prevents the concrete ‘solids’ from settling freely. The main danger from plastic cracking is the possibility of moisture ingress leading to corrosion of any reinforcement (Reynolds and Steadman, 2008). If the affected surface is to be covered subsequently, by either more concrete or a screed, no treatment is usually necessary. In other cases, often the best repair is to brush dry cement (dampened down later) or wet grout into the cracks the day after they form, and while they are still clean; this encourages natural or autogenous healing.

2.5.3 Early Thermal Cracking

The reaction of cement with water, or hydration, is a chemical reaction that produces heat (Reynolds and Steadman, 2008). If this heat development exceeds the rate of heat loss, the concrete temperature will rise. Subsequently the concrete will cool and contract. If the contraction of the concrete were unrestrained, there would be no cracking at this stage. However, in practice there is nearly always some form of restraint inducing tension, and hence a risk of cracks forming. The restraint can occur due to both external and internal influences. Concrete is externally restrained when, for example, it is cast onto a previously cast base, such as a wall kicker, or between two already hardened sections, such as in infill bay in a wall or slab, without the provision of a contraction joint. Internal restraint occurs, for example, because the surfaces of an element will cool faster than the core, producing a temperature differential. When this differential is large, such as in thick sections, surface cracks may form at an early stage. Subsequently, as the core of the section cools, these surface cracks will tend to close in the absence of any external restraints. Otherwise, the cracks will penetrate into the core, and link up to form continuous cracks through the whole section.

The main factors affecting the temperature rise in concrete are the dimensions of the section, the cement content and type, the initial temperature of the concrete and the ambient temperature, the type of formwork and the use of admixtures (Reynolds and Steadman, 2008). Thicker sections retain more heat, giving rise to higher peak temperatures, and cool down more slowly.

2.6 Properties of Hardened Concrete

2.6.1 Tensile Strength

The direct tensile strength of concrete, as a proportion of the cube strength, varies from about one-tenth for low-strength concretes to one-twentieth for high-strength concretes (Reynolds and Steadman, 2008). The proportion is affected by the aggregate used, and the compressive strength is therefore only a very general guide to the tensile strength (Reynolds and Steadman, 2008). For specific design purposes, in regard to cracking and shear strength, analytical relationships between the tensile strength and the specified cylinder/cube strength are provided in codes of practice. The indirect tensile strength (or cylinder splitting strength) is seldom specified nowadays. Flexural testing of specimens may be used on some airfield runway contracts, where the method of design is based on the modulus of rupture, and for some precast concrete products such as flags and kerbs.

2.6.2 Shrinkage

Withdrawal of water from hardened concrete kept in unsaturated air causes drying shrinkage (Reynolds and Steadman, 2008). If concrete that has been left to dry in air of a given relative humidity is subsequently placed in water (or a higher relative humidity), it will swell due to absorption of water by the cement paste. However, not all of the initial drying shrinkage is recovered even after prolonged storage in water. For the usual range of concretes, the reversible moisture movement represents about 40%–70% of the drying shrinkage. A pattern of alternate wetting and drying will occur in normal outdoor conditions. The magnitude of the cyclic movement clearly depends upon the duration of the wetting and drying periods, but drying is much slower than wetting. The consequence of prolonged dry weather can be reversed by a short period of rain. More stable conditions exist indoors (dry) and in the ground or in contact with water (e.g. reservoirs and tanks).

Shrinkage of hardened concrete under drying conditions is influenced by several factors in a similar manner to creep (Reynolds and Steadman, 2008). The intrinsic shrinkage of the cement paste increases with the water/cement ratio so that, for a given aggregate proportion, concrete shrinkage is also a function of water/cement ratio. The relative humidity of the air surrounding the member greatly affects the magnitude of concrete shrinkage according to the volume/surface area ratio of the member (Reynolds and Steadman, 2008). The lower shrinkage value of large members is due to the fact that drying is restricted to the outer parts of the concrete.

2.6.3 Creep

The increase in strain beyond the initial elastic value that occurs in concrete under a sustained constant stress, after taking into account other time-dependent deformations not associated with stress, is defined as creep (Reynolds and Steadman, 2008). If the stress is removed after some time, the strain decreases immediately by an amount that is less than the original elastic value because of the increase in the modulus of elasticity with age (Reynolds and Steadman, 2008). This is followed by a further gradual decrease in strain. The creep recovery is always less than the preceding creep, so that there is always a residual deformation.

The creep source in normal-weight concrete is the hardened cement paste. The aggregate restrains the creep in the paste, so that the stiffer the aggregate and the higher its volumetric proportion, the lower is the creep of the concrete. Creep is also affected by the water/cement ratio, as is the porosity and strength of the concrete (Shetty, 2005). For constant cement paste content, creep is reduced by a decrease in the water/cement ratio. The most important external factor influencing creep is the relative humidity of the air surrounding the concrete. For a specimen that is cured at a relative humidity of 100%, then loaded and exposed to different environments, the lower the relative humidity, the higher is the creep. The values are much reduced in the case of specimens that have been allowed to dry prior to the application of load. The influence of relative humidity on creep is dependent on the size of the member. When drying occurs at constant relative humidity, the larger the specimen, the smaller is the creep. This size effect is expressed in terms of the volume/surface area ratio of the member. If no drying occurs, as in mass concrete, the creep is independent of size.

Creep is inversely proportional to concrete strength at the age of loading over a wide range of concrete mixes (Reynolds and Steadman, 2008). Thus, for a given type of cement, the creep decreases as the age and consequently the strength of the concrete at application of the load increases. The type of cement, temperature and curing conditions all influence the development of strength with age.

2.6.4 Compressive Strength

The strength of concrete is specified as a strength class or grade, namely the 28-day characteristic compressive strength of specimens made from fresh concrete under standardized conditions (Reynolds and Steadman, 2008). The results of strength tests are used routinely for control of production and contractual conformity purposes. The characteristic strength is defined as that level of strength below which 5% of all valid test results is expected to fall.

In principle, compressive strengths can be determined from cores cut from the hardened concrete. Core tests are normally made only when there is some doubt about the quality of concrete placed (e.g. if the cube results are unsatisfactory), or to assist in determining the strength and quality of an existing structure for which records are not available. Great care is necessary in the interpretation of the results of core tests, and samples drilled from in situ concrete are expected to be lower in strength than cubes made, cured and tested under standard laboratory conditions.

2.7 Quality of Concrete

Like all other engineering operations, concrete mixed at site requires special quality control which should be carried out during preparation, batching, mixing and placing of the concrete mix (Oyenuga, 2011). The quality control of concrete should aim at producing a uniform material which provides properties particularly desirable for the work. The basic reason for quality control includes: ensuring that workmanship does not fall below a certain specified standard and limiting the overall variation in the quality of concrete (Oyenuga, 2011). Variations in concrete quality are due to a large number of factors which includes: variation batching, mixing variation, variation in quality of cement, variation in degree of compaction and variation in curing.

2.7.1 Factors Affecting Quality of Concrete

In view of the different processes involved in the manufacture of concrete, the problems of quality control are diversified and their solution elaborated. The factors involved are the personnel, the materials and equipment, the workmanship in all stages of concreting, i.e. batching of materials, mixing, transportation, placing, compaction, curing, and finally testing and inspection. It is therefore necessary to analyze the different factors causing variations in the quality and the manner in which they can be controlled.

2.7.1.1 Materials

For a uniform quality of concrete, the ingredients (particularly the cement) shall preferably be used from a single source. When ingredients from different sources are used, the strength and other characteristics of the materials are likely to change and, therefore, they should only be used after proper evaluation and testing.

2.7.1.2 Portland Cement

Cement is any material that hardens and becomes strong adhesive after application in plastic form. Cement is the binding constituent of concrete. Similar types of cement from different sources and at different times from the same source exhibit variations in properties of concrete, especially in compressive strength. This variation in the strength of cement is related to the composition of raw materials as well as variations in the manufacturing process. The cement shall be tested initially once from each source of supply and, subsequently, at every two months interval. Adequate storage under cover is necessary for protection from moisture. Set cement with hard lumps is to be rejected.

2.7.1.3 Aggregates

In any concrete, aggregates (fine sand and Coarse) usually occupies about 70-75% and between 60 – 80% of the total volume of the concrete mass. The aggregates have to be graded so the whole mass of concrete acts as a relatively solid, homogeneous, dense combination with the smallest particles acting as inert filler for the voids that exist between the larger particles. This therefore suggests that the selection and proportioning of aggregates shall be given due attention as it not only affects the strength, but the durability and structural performance of the concrete also. Further, the aggregate is cheaper than cement and thus it is cheaper to use as much quantity of aggregate and as little of cement as possible. Aggregates provide better strength, stability and durability to the structure made out of cement concrete than cement paste alone. Aggregate is not truly inert because its physical, thermal and chemical properties influence the performance of concrete. While selecting aggregate for a particular concrete, the economy of the mixture, the strength of the hardened mass and durability of the structure must first be considered. Grading, maximum size, shape, and moisture content of the aggregate are the major source of variability. Aggregate shall be separately stock piled in single sizes. The graded aggregate should not be allowed to segregate.

2.7.1.4 Water

The water used for mixing concrete shall be free from silt, organic matter, alkali, and suspended impurities. Sulphates and chlorides in water should not exceed the permissible limits. Generally, water fit for drinking may be used for mixing concrete.

2.7.1.5 Personnel

The basic requirement for the success of any quality control plan is the availability of experienced, knowledgeable and trained personnel at all levels. The designer and the specification-writer should have the knowledge of construction operations as well. The site engineer shall be able to comprehend the specification stipulation .Everything in quality control cannot be codified or specified and much depends upon the attitude and orientation of people involved. In fact, quality must be a discipline imbibed in the mind and there shall be strong motivation to do everything right the first time.

2.7.1.6 Equipments

The equipment used for batching, mixing and vibration shall be of the right capacity.

Weigh-batchers shall be frequently checked for their accuracy.

2.7.1.7 Workmanship

The activities involved in the workmanship in all stages of concreting, i.e. batching of materials, mixing, transportation, placing, compaction, curing and finally testing and inspection.

2.7.1.8 Ready Mixed Concrete

If instead of being batched and mixed on site, concrete is delivered for placing from a central plant, it is referred to as ready-mixed or pre-mixed concrete. This is used for large batches with lorry transporters up to 6m3 capacity. It has the advantage of eliminating site storage of materials and mixing plant, with the guarantee of concrete manufactured to quality-controlled standards. Placement is usually direct from the lorry therefore site-handling facilities must be co-ordinate with deliveries. Advantages of Ready-Mix Concrete:

(a) Close quality control of batching which reduces the variability of the desired properties of the hardened concrete.

(b) Use on congested sites or in highway construction where there is little space for a mixing plant and aggregate stockpiles.

(c) Use of agitator trucks to ensure care in transportation, thus preventing segregation and maintaining workability

(d) Convenience when small quantity of concrete or intermittent placing is required.

The disadvantage of ready-mix concrete is that it is costlier by about 10 – 15% than concrete mixed at project site. But this is often off-set by savings in site organization, in supervisory staff, and in cement content.

2.7.1.9 Concrete Mix Ratio

When making concrete it's important to use the correct concrete mixing ratios to produce a strong, durable concrete mix. Mixing water with the cement, sand, and stone will form a paste that will bind the materials together until the mix hardens. The strength properties of the concrete are inversely proportional to the water/cement ratio. Basically this means the more water you use to mix the concrete (very fluid) the weaker the concrete mix. The less water you use to mix the concrete (somewhat dry but workable) the stronger the concrete mix. Accurate concrete mixing ratios can be achieved by measuring the dry materials using buckets or some other kind of measuring device. By measuring the mixing ratios you will have a consistent concrete mix throughout your entire project.

2.8 Coconut Shell

Coconuts are mainly cultivated in the coastal clays and sands and sporadically distributed in other areas (Danraka, 2015). The shells are regarded as waste and therefore disposed off in large amount which lead to environmental problems in most of tropical countries particularly in Africa (Danraka, 2015). Coconut shell has high strength and modulus properties (Varma and Shrivastava, 2021). Coconuts are being naturally available in nature and since its shells are non-biodegradable; they can be used readily in concrete, which may fulfill almost all the qualities of the original form of concrete (Varma and Shrivastava, 2021). Coconut shell is often used as a composite in concrete because of the characteristics found in it better than material that commonly used in production of concrete (Bansal, et al., 2014). Some researchers have concluded that coconut shell can be used for producing lightweight concrete and can be used at different proportion for required concrete strength (Danraka, 2015). In an investigation conducted by Kakade and Dhawale, (2015), it was revealed that the 28th day compressive strength of coconut shell concrete with 25% volume replacement with coconut shell aggregate under full water curing was 21.31MPa equivalent to grade 20 concrete. This makes agricultural wastes concrete ideal for building construction if the minimum grade of concrete is achieved since these are generally cheaper than conventional materials.

2.9 Review of Past work

Mukhtyar and Kumar, (2018) investigated the use of coconut shell as a partial replacement for coarse aggregate in concrete. Coarse aggregate (granite) was partially replaced with coconut shell in an increasing percentage of 2.5, 5 and 10% by weight of concrete. Fresh and hardened mechanical properties of the concrete were investigated. Findings revealed that the slump, flexural and compressive strength of the coconut shell concrete was comparable to conventional (plain cement) concrete.

Danraka, (2015) evaluated the effectiveness of coconut shell as ingredient in concrete. The study examined the effect of coconut shell as fine and coarse aggregate replacement on the behavior of concrete with respect to some vital properties. The coconut shell concrete was designed for characteristic strength of 30MPa with the incorporation of coconut shell as replacement for fine and coarse aggregate at 10%, 20% and 30% of volume fractions respectively. The workability, compressive strength as well as densities and water absorption of 96 cured concrete samples were evaluated at 7, 14, 21 and 28 days respectively. The results showed that increase in replacement of coconut shell volume fractions yielded increase in workability and water absorption with corresponding decrease in the mechanical properties of the concrete; however 28 day compressive strength of 25MPa and density of 1874 kg/m^3 was obtained for 30% respective replacement of fine and coarse aggregates.

Yusuf, et al., (2020) investigated the effect of coconut shell and fiber on compressive strength of concrete. The strength properties (density, compressive and tensile strengths) of coconut shell concrete (CSC) produced by replacing conventional coarse aggregate with 0, 20, 40, 60, 80 and 100% CS at mix ratio of 1:11/2:3, and water/cement (w/c) ratio of 0.5 were determined. Another set of CSC produced at the same proportions were reinforced with fibre (1, 2, 3 and 4% by weight of cement) and the strengths re-determined. A total of 18 samples of 150 mm CSC cubes and 72 samples of 100 x 200 mm fibre-reinforced CSC cylinders, respectively were produced and tested after 28 days of curing for compressive strength and tensile strength, correspondingly. Results show that the physical properties of CS conformed to specifications for lightweight aggregates, confirming that CS as a lightweight aggregate suitable for the production of lightweight concrete. Results also suggested that the strength properties of CSC decreased with increase in proportion of CS. However, the strength properties increased with increase in the proportion of CF, implying that CF served as a good reinforcement in CSC. In addition, for each proportion of CF, the strength properties of

CSC decreased with increased proportion of CS. The use of CF is, therefore recommended as reinforcement in concrete.

Tukiman and Mohd, (2009) investigated the effect of partial replacement of coarse and fine aggregate in concrete with coconut shell and grinded palm kernel shell on compressive strength of concrete. five different concrete mixes with different the combination of natural material content namely 0%,25%,50%,75% and 100%.Three sample specimen will be prepared for each concrete mixes. The parameters will be tested are flexural strength, compressive strength, tensile strength, modulus of elasticity, durability and deflection crack behavior. Effect of aggregate content to workability was also examined. Findings obtained from the study suggest that the combination of coconut shell and grained palm kernel shell has potential as lightweight aggregate in concrete. Also, using the combination of coconut shell and grained palm kernel as aggregate in concrete can reduce the material cost in construction because of the low cost and abundant agricultural waste.

Veeresh and Sunil, (2021) assessed the effect of partial replacement of coarse aggregate with coconut shell and complete replacement of fine aggregate with Robo sand on mechanical properties of concrete. In this investigation, M25 (1: 11/2: 3) grade of concrete with combination of coconut shell content as Coarse aggregate in the proportion of 0%, 5%, 10%, 20% and 25% will be replaced and Robo sand (stone dust) as fine aggregate with full 100% replacement of natural sand, sample specimens are prepared and will be tested for workability, compressive strength and split tensile strength for 7,14 and 28 days respectively. Results obtained suggest that the compressive, workability and split tensile strength of the coconut shell and Robo sand concrete can be compared to that of corresponding normal concrete.

Polusani and Varaigyam, (2020) evaluated the effect of egg shell powder and coconut shell aggregate on M40 and M50 grades of concrete. The properties of concrete with 5% replacement of cement with egg shell powder and 2.5%, 5%, 10% partial replacement of coarse aggregate with coconut shell for M40 and M50 grades of concrete were studied. A total of 72 cubes were casted and their properties such as workability, compressive strength, impact strength, density of concrete were evaluated. The results were analyzed and compared with the conventional concrete. The results showed that the compressive strength of coconut shell mix concrete existed to be more or less equivalent to the conventional concrete.

Arivalagan and Sudharkar, (2020) conducted a study on optimum use of coconut shell as partial replacement of coarse aggregate in light weight concrete. The concrete made with coconut shell was found to be durable in terms of its resistance in water, acidic, alkaline and salty. Density of coconut shell is in the range of 550 - 650kg/m3 and these are within the specified limits for lightweight aggregate. Coarse aggregate was replaced by crushed coconut shells in three different percentages such as 5%, 10%, 20%, 30%, 40% and 50% .The physical characteristic properties of concrete such as compressive strength, split tensile strength and flexural strength using the mix made by replacing coarse aggregate with coconut shell aggregate were studied in the present research work and mixes were compared with normal concrete properties. The results from the study were expected to promote the use of coconut shell as a substitute for conventional light weight coarse aggregates.

Bansal, et al., (2014) studied the partial replacement of coarse aggregate with coconut shell. The replacement of coarse aggregate of coconut shell by 5% and 10%. Design mix used is M20 grade and testing of specimens are conducted after 7 and 28 days of curing. Test conducted are: slump test, compressive and flexural strength test. Results obtained suggest that the workability, flexural and compressive strength of the concrete increased to at 5 and 10% addition of coconut shell to the concrete. Ultimately, concrete produced with partial replacement of coarse aggregate with coconut shell was termed as light weight concrete.

Abubakar and Abubakar, (2011) conducted an exploratory study of coconut shell as coarse aggregate in concrete. Physical and mechanical properties of coconut shell and crushed granite rock were determined and compared. A total of 72 concrete cubes of size 150x150x150mm with different mix ratios of 1:2:4, 1:11/2 :3 and 1:3:6 were casted, tested and their physical and mechanical properties determined. Aggregate crushing value (ACV) for coarse aggregate is 21.84 and 4.71 for coconut shell. Elongation and flakiness index are 58.54 and 15.69 respectively for gravels, while for coconut shell is 50.56 and 99.19 respectively. Compressive strength in N/mm2 of coconut shell at 7,14,21 and 28 days with mix ratios of 1:2:4, 1:11/2:3, and 1:3:6 are (8.6, 8.9,6.4,),(9.6,11.2,8.7),(13.6,13.1,10.7) and (15.1,16,5,11) respectively, likewise (19.1,18.5,9.6), (22.5, 23.0, 10.4), (26.7, 24.9, 12.9) and (28.1, 30.0, 15) respectively for gravel. Since the concrete strength of coconut shell with mix ratio 1:11/2:3, attained 16.5N/mm2 at 28 days it can be used in plain concrete. Hence cost reduction of 48% will be achieved.

Harle, (2019) investigated the effect of partial replacement of coarse aggregate with coconut shell on mechanical properties of concrete. The density, slump and compressive strength of concrete are tested. The replacement of coarse aggregate by coconut shell by 0%, 10%, 20% and 30%. The tests were carried out and the results obtained suggested that the replacement more than 20% leads to lightweight aggregate concrete. The slump found out to be increases as the percentage replacement increased. Similarly the density is reduced as the percentage replacement increased. The compressive strength found to be decreases as the percentage replacement increases.

Verma and Shrivastava, (2021) conducted an experimental investigation on the use of coconut shell as partial substitute for coarse aggregate in concrete. In present study, compressive strength of concrete of M20 grades has studied by replacing natural coarse aggregates at 0%, 5%, 10%, 20% and 30%, by weight with coconut shell. Compressive strength of coconut shell concrete has been evaluated on 7, 14, 21 and 28 days. The compressive strength of coconut shell concrete was

reduced as percentage replacement increased. Concrete mixtures were tested and compared in terms of compressive strength of the conventional concrete. The study result shows that Coconut Shell Concrete (CSC) can be used as light weight concrete.

2.0 Summary of Past Research Findings

Researchers	Test Conducted	Percentages of Coconut Shell Used	Concrete Density Classification	Curing Days (Age	Water to Cement Ratio and Concret	Results Obtained

					e Mix Ratio	
Yusuf, et al., (2021)	Compressive Strength, Split Tensile Strength, Slump Test.	20, 40, 60, 80 and 100% by weight of Coarse Aggregate	Light Weight Concrete.	7, 14, 21 and 28 days	1: 11/2 : 3 and 0.5	Compressive Strength, Split Tensile Strength decreased while Workability increased with increasing percentages of coconut shell.
Danraka, (2015)	Compressive Strength, Slump and Water Absorption Test.	10, 20 and 30% by weight of coarse aggregate.	Light Weight Concrete.	7, 21 and 28 days.	1: 2: 4 and 0.55	Compressive strength decreased while workability and water absorption increased with increasing proportion of coconut shell ash.
Polusini and Vairagyam, (2020)	Compressive Strength, Slump and Water Absorption Test.	2.5, 5, 10% by weight of coarse aggregate.	Light Weight Concrete.	7, 14, 21 and 28 days.	1: 1.5: 3 and 0.6.	Compressive strength decreased while workability and water absorption increased with increasing proportion of coconut shell ash.
Veeresh and Sinul, (2021).	Compressive Strength, Flexural Strength, Slump and Water	5, 10, 15, 20 and 25% by weight of coarse aggregate.	Light Weight Concrete.	7, 14 and 21 days.	1: 2: 4 and 0.6	Compressive strength decreased while workability and water absorption increased with increasing proportion of coconut

	Absorption Test.					shell ash.
Abubakar and Abubakar, (2011)	Flexural Strength, Split Tensile Strength, Compressive Strength, Slump and Water Absorption Test.	2.5, 5, 7.5, 10, 12.5 and 15% by weight of coarse aggregate.	Light Weight	7, 14, 21, and 28 days.	1: 11/2: 3 and 0.55.	Compressive strength, Split Tensile Strength and Flexural Strength decreased while workability and water absorption increased with increasing proportion of coconut shell ash.

Building on identified gaps from past works on the effect of partial replacement of coarse aggregate with coconut shell on mechanical properties of concrete, the current study will adopts the use of 5% addition of coconut shell to the coarse aggregate during the production of the concrete. Strength, density and workability of the coconut shell concrete will be evaluated and conclusion will be drawn based on findings obtained.

CHAPTER THREE

MATERIALS AND METHODS

This section presents the materials and methods used to actualize the research goal. Relevant standards were employed to ascertain how the materials collected be analyzed and also the various laboratory tests to be conducted. All Tests such as sieve analysis test for fine, coarse aggregate, specific gravity of fine and coarse aggregate, bulk density test of fine aggregate, slump or workability test of fresh concrete, water absorption test, compressive strength of hardened concrete were carried out at Civil Engineering Laboratory Nnamdi Azikiwe University Awka Anambra State.

3.1 Collection and Preparation of Materials

3.1.1 Water

Water sample used for the experimental study was collected within the school environment. The water sample passed all the necessary requirement for use as ingredient of concrete based on the fact that it is colourless, devoid of suspended solid particles, contains infinitesimal trace of dissolved solid particles with no trace of turbidity after being subjected to laboratory testing. The water was collected in two gallons

3.1.2 Fine Aggregate (Sand)

Sand sample used in producing the concrete was provided at a construction site at Nnamdi Azikiwe University Campus. The sand was Sieved through 5.0mm test sieve to remove larger particles and then air-dried to a saturated state of an aggregate. The sample passed the necessary requirement for use as ingredient of concrete based on the fact that it is gritty with particle sizes visible to the naked eyes, physical properties of the sand samples were determined prior to its incorporation into the concrete. Index properties of the sand sample were determined prior to its incorporation into the concrete.

3.1.3 Coarse Aggregate

Granite samples designated as GT was procured from Infrastructure Development Company (popularly known as IDC) located along Enugu-Onitsha express way. After procurement, the granite samples were conveyed to the laboratory unit of Department of Civil Engineering Nnamdi Azikiwe University Awka Anambra State where the index properties of the aggregate were determined. The granite sample passed all the necessary physical test in that, it has high crushing strength, it is relatively large in size (within range of 4.75mm to 20mm) and is a representative of granite (chippings) in color. The granite sample will be partially admixed with coconut shell in a stepped increase of 5% to 30% by weight of coarse aggregate.

3.1.4 Cement

Ordinary Portland cement (Dangote cement) was used for the experimental study. This cement is designated as OPC. The cement was purchased at Onitsha Market in Anambra State. Upon purchase, the cement was conveyed to school laboratory where it was kept in a cool dry place preparatory for various laboratory testing. The cement sample satisfy the requirement for use as one of the major component of concrete in that, it was not caked or baked through visual inspection and quick setting time.

3.1.5 Coconut Shell (CS)

Coconut shell used for the experimental study designated as CS was procured from a local coconut trader in Awka Anambra State. Coconut shells after purchase was conveyed to a crushing site where it was crushed and sieved through 20mm opening to assume the gradation of coarse aggregates. After crushing, the crushed coconut shell was conveyed to Civil Engineering Laboratory Nnamdi Azikiwe University Awka Anambra State. The crushed coconut shell was stored in an empty cement bag preparatory to various laboratory testing.

Plate 3.1: Coconut Shell Before and After Crushing.

3.2 Laboratory Investigation

This section presents the experimental procedure and laboratory tests that were adopted for the study. The tests conducted was conducted for all the constituents of concrete and this include: Sieve analysis test for fine, coarse aggregate and additive (crushed coconut shell), specific gravity of fine, coarse aggregate and additive (crushed coconut shell), bulk and compacted density of fine aggregate, water absorption test, slump (workability) test of fresh concrete and compressive of hardened concrete. The aforementioned tests were conducted at Civil Engineering Laboratory, Nnamdi Azikiwe University Awka Anambra State. Below is a detailed description of test procedures apparatus and computation of test results.

3.2.1 Particle Size Distribution (Sieve Analysis) Test

Sieve analysis is a procedure used to assess the particle size distribution of a granular material (sand, gravel). The size distribution is often of critical importance to the behaviour of the material during use. Sieve analysis can performed on any type of non-organic or organic granular material including sand, crushed rock, clay, granite, feldspar and a wide range of manufactured powders, grains and seed down to minimum size depending on the exact method. The standard grain size analysis test determines the relative proportion of different grain sizes as they are distributed among certain size ranges.

The particle size distribution (PSD) or sieve analysis were perform for coarse aggregate (granite), fine aggregate (sand) and additive (quarry dust) in order to determine the grading of each material in accordance with BS 812-103 (1990).

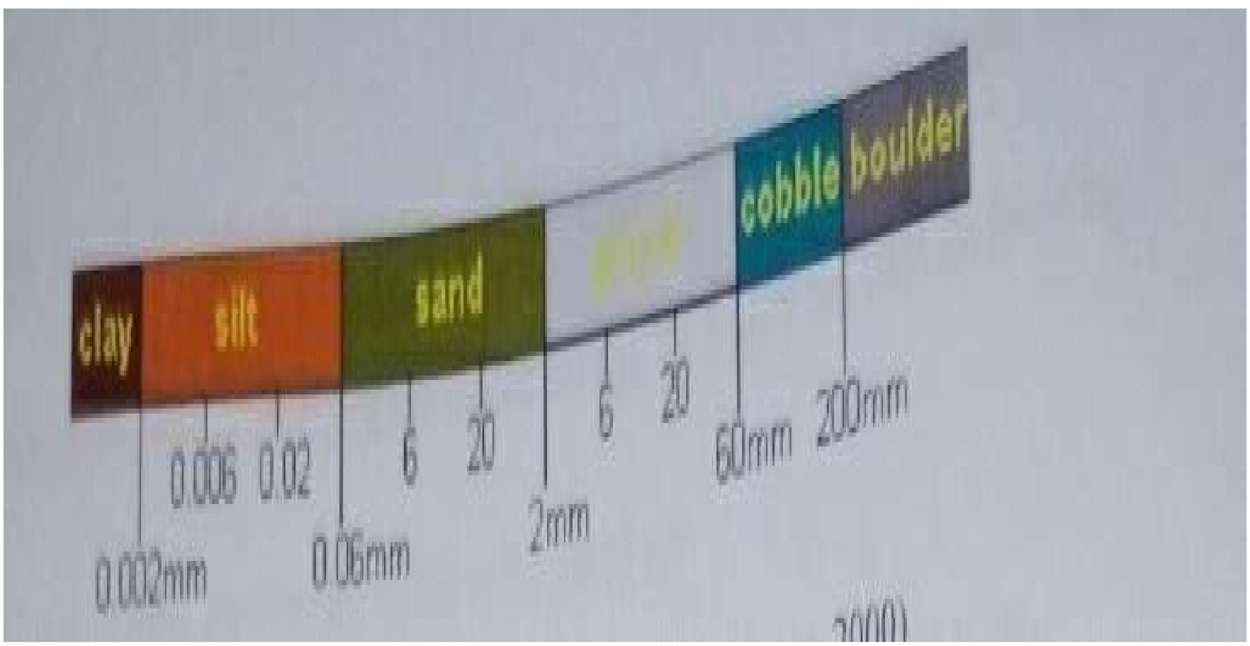


Plate 3.2 Ranges for grain Sizes of different Soil type (Atkinson, 2000).

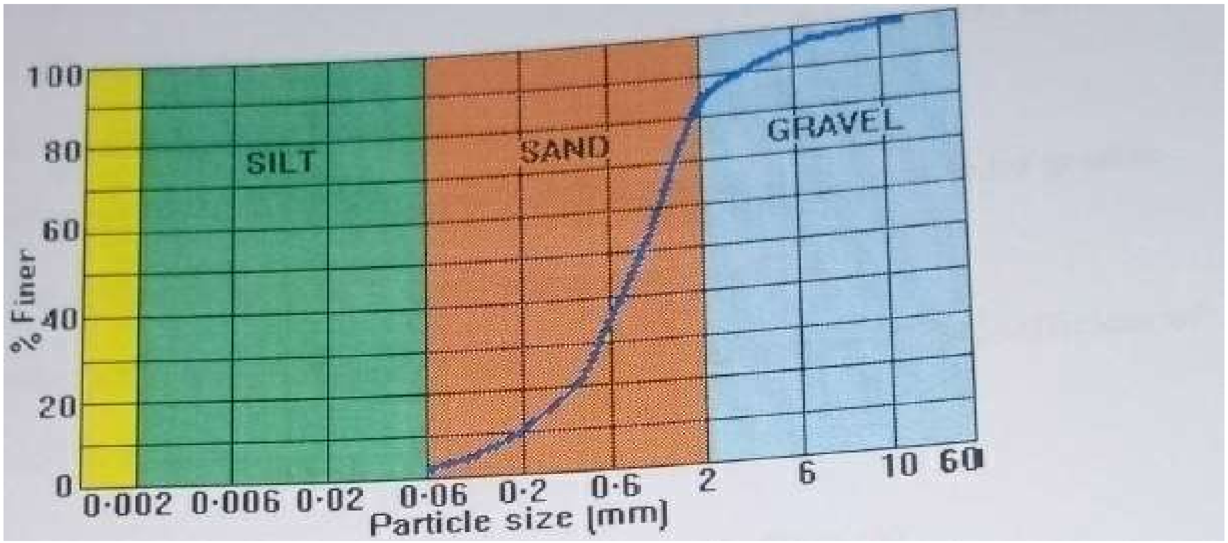


Plate 3.3 Grading Curve Ranges for Different Soil Types (Atkinson, 2000).

For a soil to be well graded the value of coefficient of uniformity (Cu) has to be greater than 4 and 6 for gravel and sand respectively, while the Coefficient of Curvature (C_v) should be in the range of 1 to 3.

The apparatus needed for this experiment is listed below:

I. Stack of sieves including pan and cover.

II. Mechanical sieve shaker.

III. Weighing balance of 0.01g sensitivity.

IV. Hand brush

V. Mortar and pestle (Used for crushing if the sample is conglomerated or lumped)

VI. Thermostatically controlled Oven (With temperature of about 80^{O}C-110^{O}C).

VII. Masking tape for identification of sample.

VIII. Exercise book and pen for recording of result.

IX. The calculation for attaining Coefficient of uniformity and Coefficient of curvature are outlined below.

$$\text{Percentage retained (\%)} = \frac{\text{mass of soil retained in the sieve(g)}}{\text{total mass of soil sample(g)}} \times 100$$

$$\text{Cumulative percentage retained} = \sum \text{Percentage retained (\%)}$$

Cumulative Percentage Finer (%) = 100-Cummulative percentage retained.

$$\text{Coefficient of Curvature} = \frac{D60}{D10}$$

$$\text{Coefficient of Uniformity} = \frac{(D30)2}{D10 \times D60}$$

Where

D10= particle size such that 10% of the soil is finer than the size

D30= particle size such that 30% of the soil is finer than the size.

D60= particle size such that 60% of the soil is finer than the size.

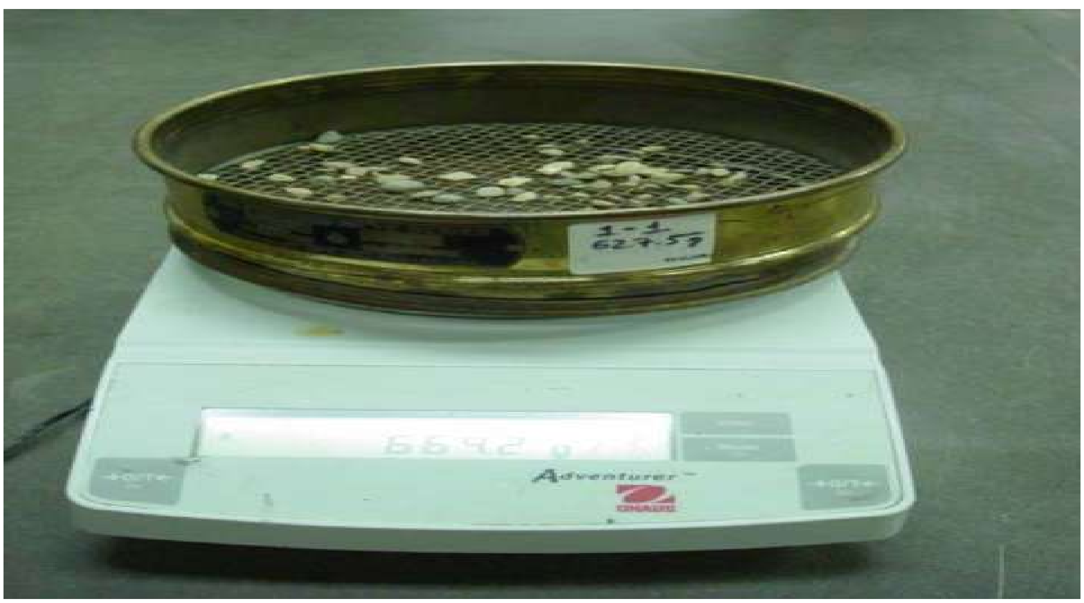


Plate 3.4 Apparatus for Particle Size Distribution Test (Sieve Analysis).

Plate 3.5 Apparatus for Particle Size Distribution Test (Sieve Analysis).

Test Procedure

I. Clean properly the stack of sieves to be used for the experiment using hand brush.

II. Weigh about 500g of air-dried soil sample on a weighing balance.

III. Pour the weighed soil sample into 75um sieve and wash under a steady supply of water until clear water start coming out from the sieve after passing through the soil sample.

IV. After washing pour the washed soil sample into a pre-weighed plate and dry it inside the thermostatically controlled oven at a controlled temperature of 80-110^{O}C for 16-24hrs.

V. Remove the sample from the oven and determine it weight (net weight) by deducting the weight of plate from the weight of plate and soil.

VI. Arrange the stacks of sieve in the ascending order, place in a mechanical sieve shaker, and thereafter pour the sample and connect the shaker for about 10-15 minute.

VII. Disconnect the sieve shaker and determine the mass retained on each of the sieve sizes.

VIII. Determine the percentage retained, Cumulative percentage retained and Cumulative percentage finer.

IX. Plot the graph of sieve Cumulative percentage finer against sieve sizes.

X. Determine D10, D30 and D60 from the plotted graph.

XI. Determine the Coefficient of Curvature and Coefficient of Uniformity and classify the soil using the American Association of State Highway and Transportation Official (AASHTO) and Unified Soil Classification System (USCS) respectively.

3.2.2 Specific Gravity of Fine Aggregate Test

Specific gravity is the ratio of mass of unit volume of soil at a stated temperature to mass of equal volume of gas-free distilled water at the same temperature (Krishna, 2002). Also as defined by (Braja, 2006), Specific gravity can be defined as the ratio of unit weight of a material to unit weight of water. The specific gravity of soil solids is often needed for various calculations in soil mechanics. It can be determined accurately in the soil laboratory.

The apparatus employed for this experiment includes:

I. Density bottle of 50ml capacity and a stopper.

II. Desiccator containing anhydrous silica gel.

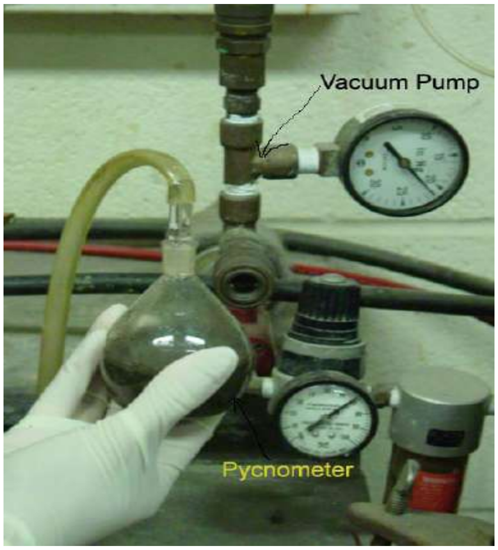
III. Thermostatically controlled oven with temperature of about 80-110^{O}C.

IV. Weighing balance of 0.01g sensitivity.

V. Mantle heater.

VI. Plastic wash bottle.

VII. Distilled water.



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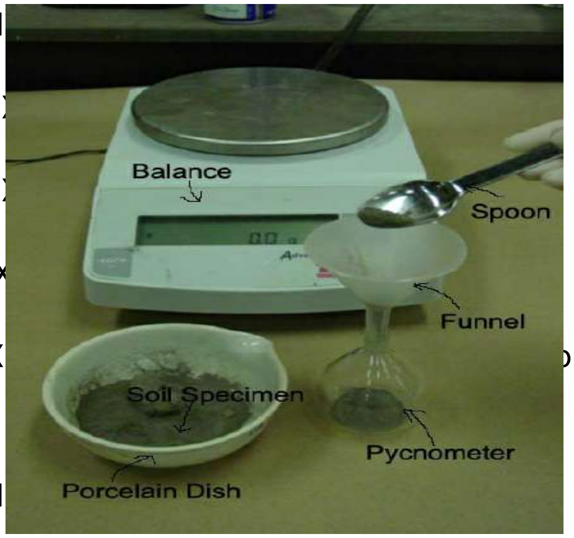


XI ... for recording of result.

Plate 3.6 Apparatus used for Specific Gravity Test.

3.2.3 Specific Gravity of Coarse Aggregate Test

Specific gravity is the ratio of mass of unit volume of soil at a stated temperature to mass of equal volume of gas-free distilled water at the same temperature (Krishna, 2002). Also as defined by (Braja, 2006), Specific gravity can be defined as the ratio of unit weight of a material to unit weight of water. The specific gravity of soil solids is often needed for various calculations in soil mechanics. It can be determined accurately in the soil laboratory.

The apparatus employed for this experiment includes:

I. Density bottle of 50ml capacity and a stopper.

II. Desiccator containing anhydrous silica gel.

III. Thermostatically controlled oven with temperature of about 80-110^{O}C.

IV. Weighing balance of 0.01g sensitivity.

V. Mantle heater.

VI. Plastic wash bottle.

VII. Distilled water.

VIII. Funnel

IX. Thin glass rod for stirring.

X. 425um Sieve.

XI. Dry piece of cloth for cleaning.

XII. Masking tape for identification of sample.

XIII. Exercise book and pen for recording of result.

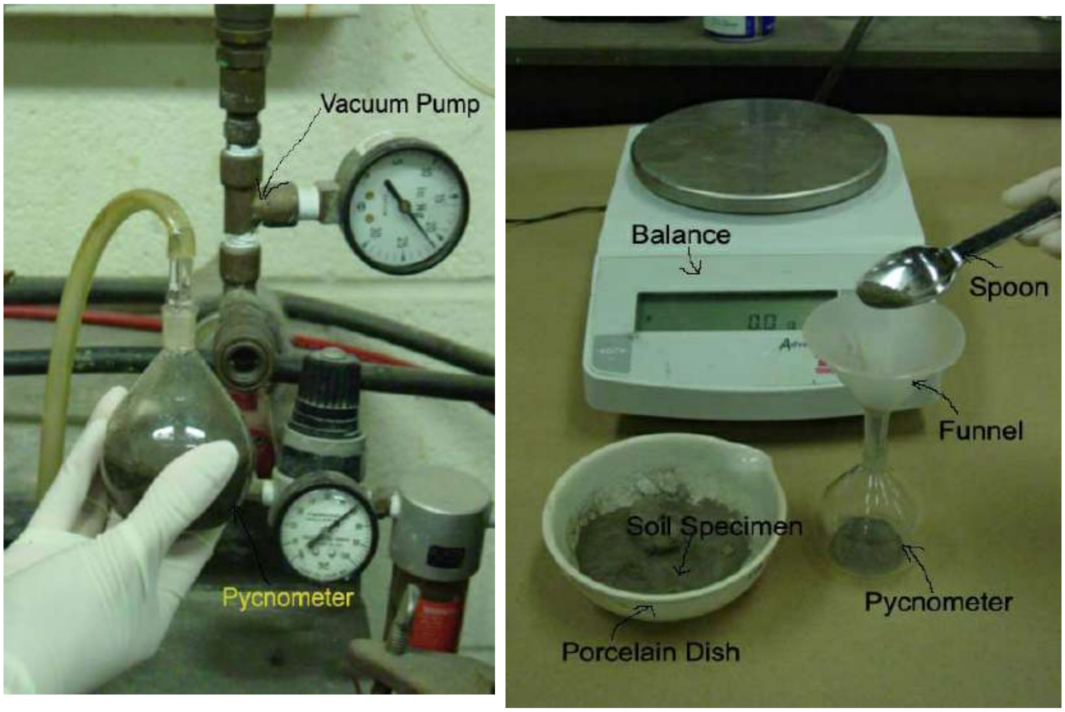


Plate 3.7: Apparatus used for Specific Gravity Test.

3.2.4 Slump (Workability Test)

Slump test is used to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work.

The procedures are as follows:

I. Clean the internal surface of the mold and apply oil.
II. Place the mold on a smooth horizontal non- porous base plate.
III. Fill the mold with the prepared concrete mix in 4 approximately equal layers.
IV. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mold. For the subsequent layers, the tamping should penetrate into the underlying layer.

V. Remove the excess concrete and level the surface with a trowel.

VI. Clean away the mortar or water leaked out between the mold and the base plate.

VII. Raise the mold from the concrete immediately and slowly in vertical direction.

VIII. Measure the slump as the difference between the height of the mold and that of height point of the specimen being tested.

Calculation

Slump = Height of the slump cone – Height of the unsupported concrete.

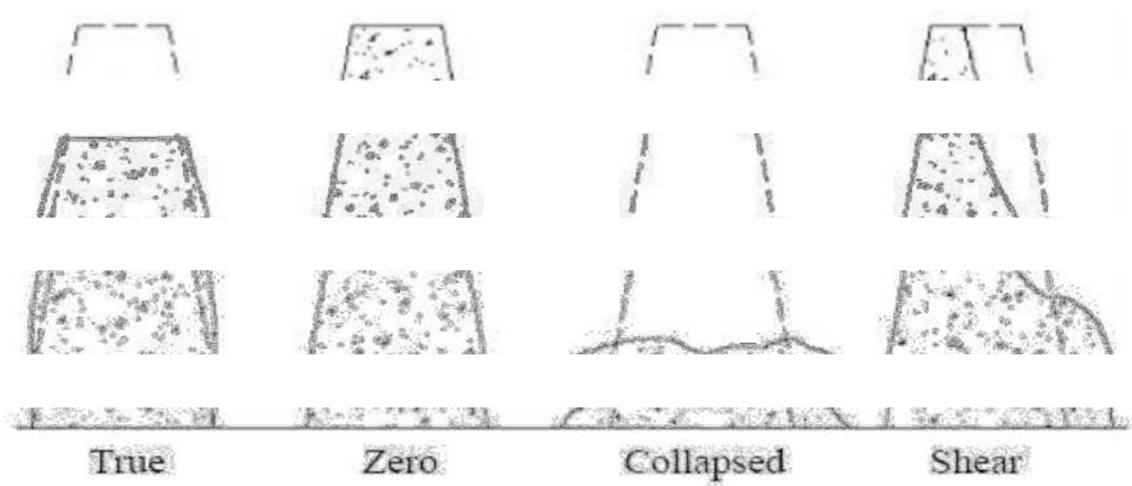


Figure 3.7: Types of Concrete Slump Test Results.

1. **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 above. In a true concrete just subsides shortly and more or less maintain the mould shape. This type of slump is most desirable and represents the reliable condition to get an idea about the workability of concrete.
2. **Zero Slump** – Zero slump is the indication of very low water-cement ratio, which results in dry mixes. This type of concrete is generally used for road construction. In this slump, the concrete maintains the actual shape of the mould as it is said to be stiff, consistent and almost non-workable.

3. **Collapsed Slump** – In the case, fresh concrete collapses completely. 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.
4. **Shear Slump** – In this case, one-half of the cone slide down in an inclined plane, this slump indicates lack of cohesion in the concrete mix. Shear slump may occur in case of a harsh mix.

Figure 3.8: Apparatus used for Slump Test

3.2.5 Compressive Strength of Hardened Concrete

The test method covers determination of compressive strength of cubic concrete specimens. It consists of applying a compressive axial load to molded cubes at a rate which is within a prescribed range until failure occurs.

The Apparatus Used includes:

I. Testing Machine **-** The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The permissible error shall be not greater than ± 2 percent of the maximum load.

II. Cube Moulds - The mould shall be of 150 mm size conforming to IS: 10086-1982.

III. Weights and weighing device

IV. Tools and containers for mixing,

V. Tamper (square in cross section)

Test Procedure

I. Sampling of Materials - Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.

II. Proportioning - The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work.

III. Weighing - The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

IV. Mixing Concrete - The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.

V. Mould - Test specimens cubical in shape shall be 150mm × 150mm × 150mm .If the largest nominal size of the aggregate does not exceed 20mm, 10omm cubes may be used as an alternative. Cylindrical test specimens shall have a length equal to twice the diameter.

VI. Compacting - The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance.

VI. Curing - The test specimens shall be stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27°± 2°C for 24 hours ± ½ hour from the time of addition of water to the dry ingredients.

VII. Placing the Specimen in the Testing Machine - The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression plates.

VIII. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom

IX The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine.

X. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained.

XI. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

The compressive strength of concrete cube is computed as follows:

$$\text{Compressive Strength } (N/mm^2) = \frac{\text{Applied load (N)}}{\text{Area of Cube } (mm \times mm)}$$

Where applied load (N) = Force

Now conversion of applied load from Ton force to KN or N.

1 Ton force = 10kN or 10,000N.

For 220kN = 220× 1000 = 220,000N

Area of cube = 150mm×150mm = 22,500mm^2

Compressive Strength = $\frac{220{,}000N}{22{,}500mm2}$ = 9.78N/mm

Plate 3.9: Universal Testing Machine for Compressive Strength Test.

CHAPTER FOUR

RESULTS AND DISCUSSION

During the experimentation phase of the study, key findings were obtained which was valuable in ascertaining the index properties of the aggregates used for the production of concrete and also for evaluating the effect of partial replacement of coarse aggregates with crushed coconut shell on fresh and hardened mechanical properties of concrete. These results are presented in Table 4.1 below:

4.1 Results

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

Concrete Components/ Properties	Sand	Granite	Crushed Coconut Shell
Specific Gravity	2.55	2.61	----
Percentage Passing Sieve No 200 (0.075mm)	8.03	------	------
Percentage Passing Sieve No 10 (4.75mm)	-----	5.78	1.67
AASHTO Classification System	A-2-6	A-1-b	A-1-a
Unified Soil Classification System	SM	GC	GM
Coefficient of Uniformity	2.8	7.2	2.22
Coefficient of Curvature	0.85	1.44	0.56
Gradation	SP	GP	GP

Table 4.2: Slump Test Result at Varying Percentages of CCS

Percentage Replacement of CCS	Height of Slump Cone (mm)	Height of Collapse	Slump (mm)	Slump Type

0	300	265	35	True slump
5	300	270	30	True slump
10	300	275	25	True slump
15	300	282	18	True slump
20	300	285	15	True slump
25	300	290	10	True slump

Table 4.3: Compressive Strength Test Results at Varying Percentages of CCS

Percentage Replacement of CCS	**Compressive Strength (N/mm^2)**
0	22.96
5	21.06
10	18.94
15	17.43
20	16.02
25	14.91

Table 4.4: Compressive Strength Test Results at Varying Intervals of Curing Days

Curing Days (Age)	**Compressive Strength (N/mm^2)**
7	17.96
28	19.14

Table 4.5: Dry Density Test Results at Varying Percentages of CCS

Percentage Replacement of CCS	Dry Density (kg/m^3)
0	2173
5	2041
10	1956
15	1831
20	1759
25	1653

Table 4.6: Dry Density Test Results at Varying Intervals of Curing Days

Curing Days (Age)	Dry Density (kg/m^3)
7	1873
28	1931

4.2 Analysis of Results

4.2.1 Sieve Analysis

Figure 4.0 is a semi logarithmic graph showing the particle size distribution of sand, quarry dust and granite respectively. The percentage passing through sieve No 200 (0.075mm) sieve for sand was 8.03, coefficient of uniformity and curvature were 2.8 and 0.85 respectively and as a result, sand was classified as A-2-6 according to AASHTO Classification System and SM (sand mixed with silt) according to Unified Soil

Classification System. The percentage passing through sieve No 4 (4.75mm) for crushed coconut shell and granite were 1.67 and 5.78, coefficient of uniformity and curvature were 2.22, 0.56, 7.2 and 1.44 respectively and as a result, crushed coconut shell and granite were classified as A-1-a and A-1-a according to AASHTO Classification System and GM (gravel mixed with silt) and GC (gravely mixed with clay) according to Unified Soil Classification System. The gradation of the aggregates sample revealed that the samples were poorly graded.

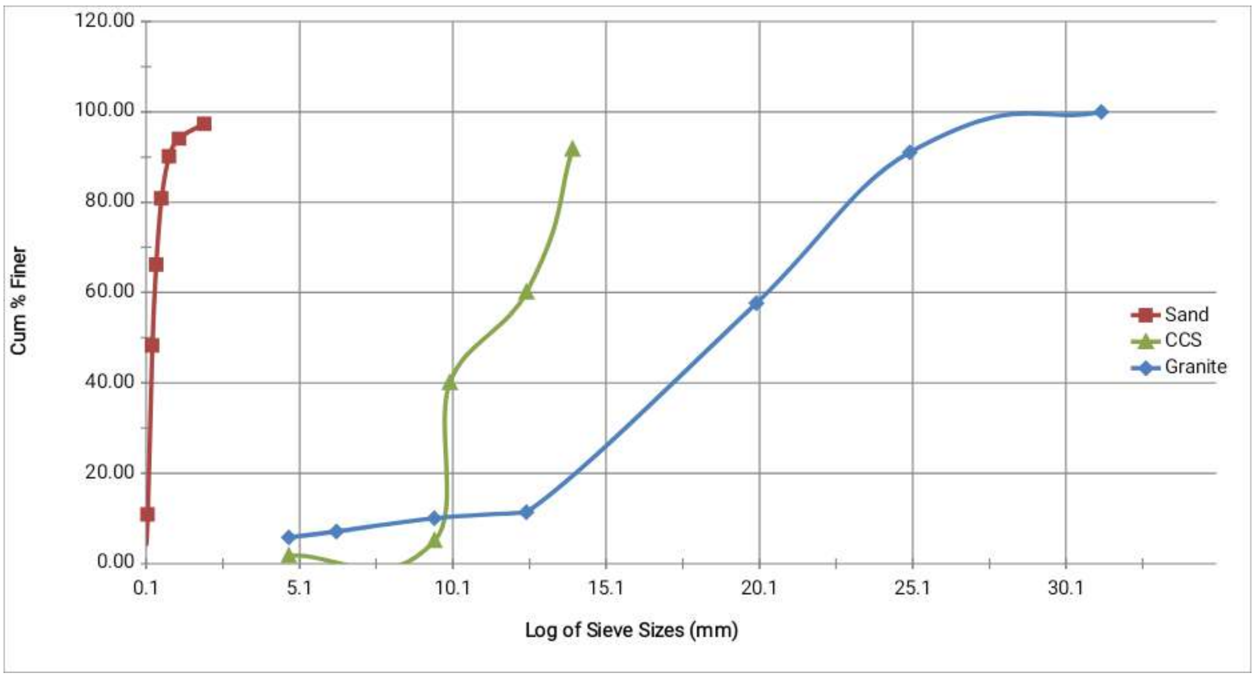


Figure 4.0: Particle Size Distribution Curve for Sand, Granite and Crushed Coconut Shell

4.2.2 Specific Gravity

Table 4.0 and Figure 4.1 show the specific gravity of the aggregates used in the research. The specific gravity of the aggregates and additive (crushed coconut shell) ranged from 1.67 to 2.61. It was observed that granite with a specific gravity of 2.61 produced the highest specific gravity value. The sand and granite samples met ASTM requirement for specific gravity of normal weight concrete which state that the specific gravity of the aggregate must exceed 2.4. While the crushed coconut shell met the ASTM requirement for specific gravity of light weight concrete which state that the specific gravity of the aggregate for light weight concrete production must fall below 2.4. This implies that concrete produced with crushed coconut shell are likely to be light weight.

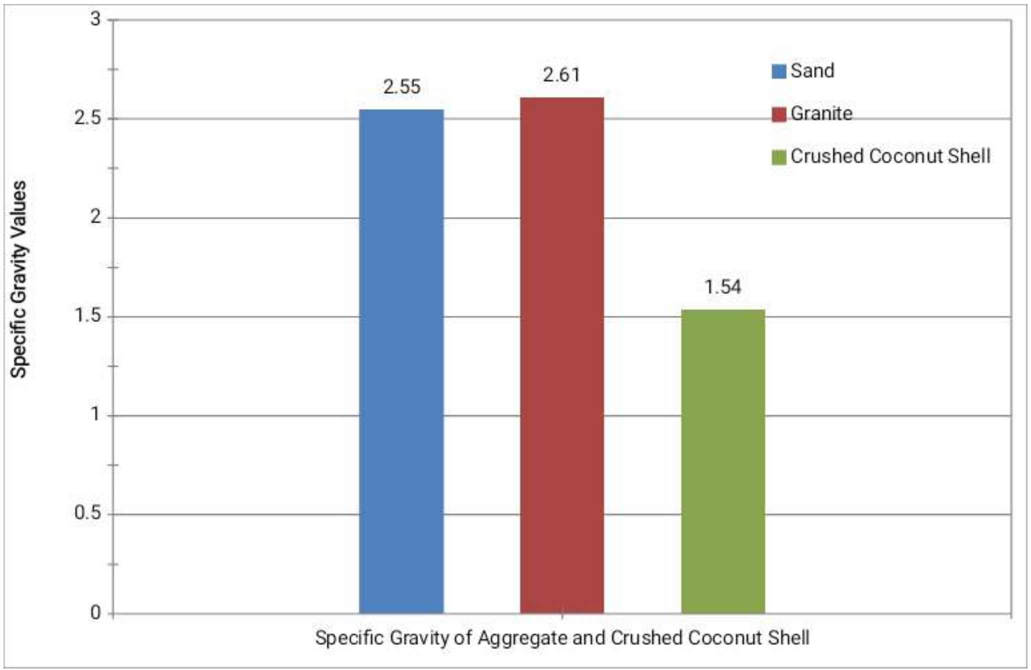


Figure 4.1: Graph Showing the Specific Gravity Values of Aggregate and Concrete Additives.

4.2.3 Slump

Table 4.2 and Figure 4.2 shows the slump of conventional and crushed coconut shell concrete at constant water to cement ration and varying percentages of crushed coconut shell. The optimum slump value was recorded for the control specimen (0% CCS). It was observed that the concrete slump decreased on consistent addition of crushed coconut shell to the concrete. The decline in slump of crushed coconut shell concrete could be attributable to the high water absorption of the crushed coconut shell. The high water absorption of crushed coconut shell reduces the water content required for hydration of cement which invariably reduced the slump of the fresh concrete. This result suggests crushed coconut shell requires more water to cement ratio so as to achieve a workable mix.

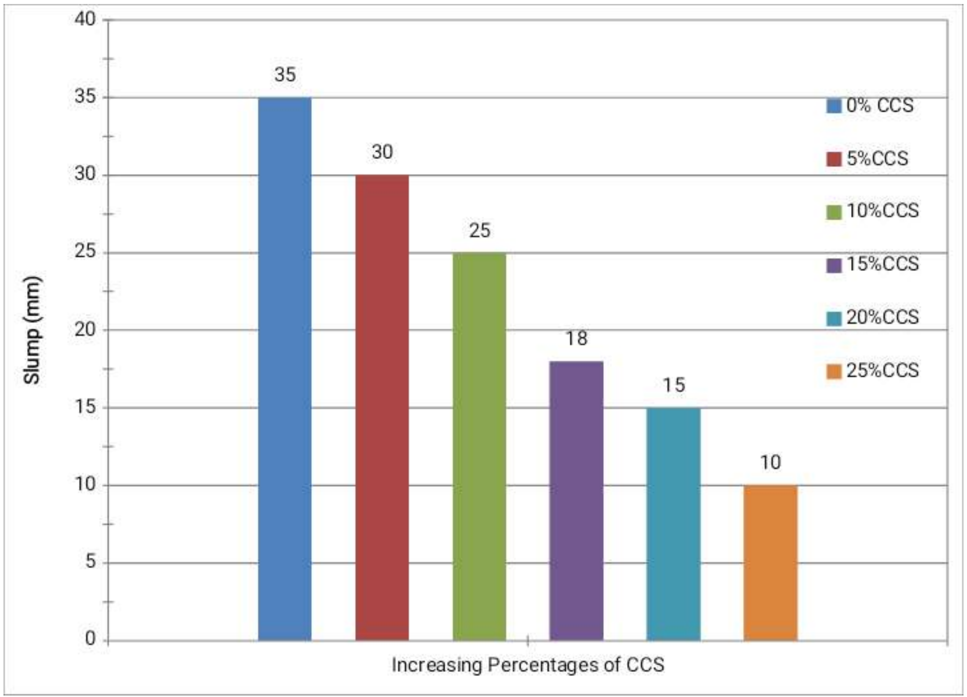


Figure 4.2: Chart Showing the Slump of the Concrete at Varying Percentages of Crushed Coconut Shell

4.2.4 Compressive Strength

Table 4.3 and Figure 4.3 shows the result of compressive strength of the hardened concrete at varying percentages of crushed coconut shell and curing days ranging from 7 and 28 days respectively. The maximum compressive strength was recorded for the control specimen (0% CCS). It was observed that the compressive strength of both the control specimen and modified concrete (crushed coconut shell concrete) increased with curing days. This result is in agreement with the works of Yusuf, et al., (2020). On consistent addition of crushed coconut shell to the concrete, it was observed that the compressive strength decreased. The consistent decline in compressive strength could be attributed to the high water absorption of crushed coconut shell. The high water absorption of crushed coconut shell reduces the density of the concrete which invariably result to decline in compressive strength as density of hardened is an indices of the strength of the concrete. This finding is in agreement with the works of Bansal, et al., (2014), Verma and Shrivastava, (2019), Yusuf, et al., (2020) and Arivalagan, (2020).

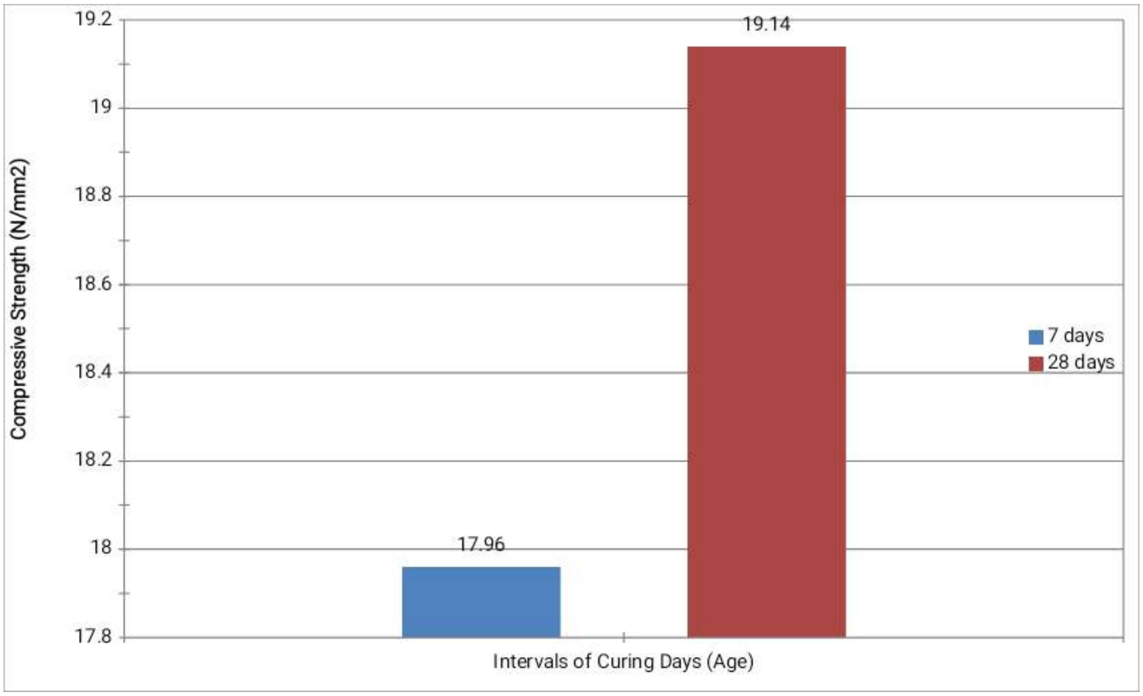


Figure 4.3: Graph of Compressive Strength against Curing Days

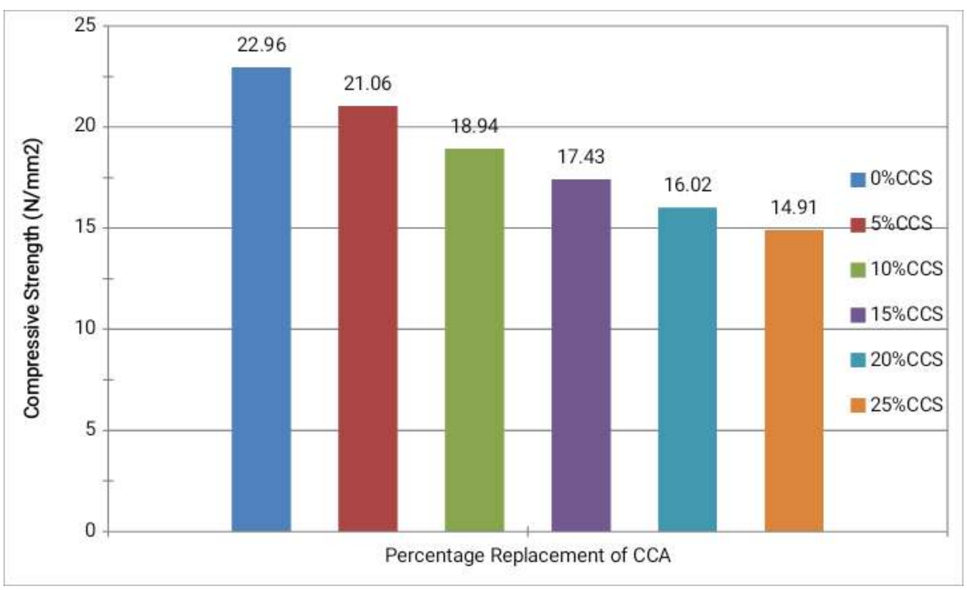
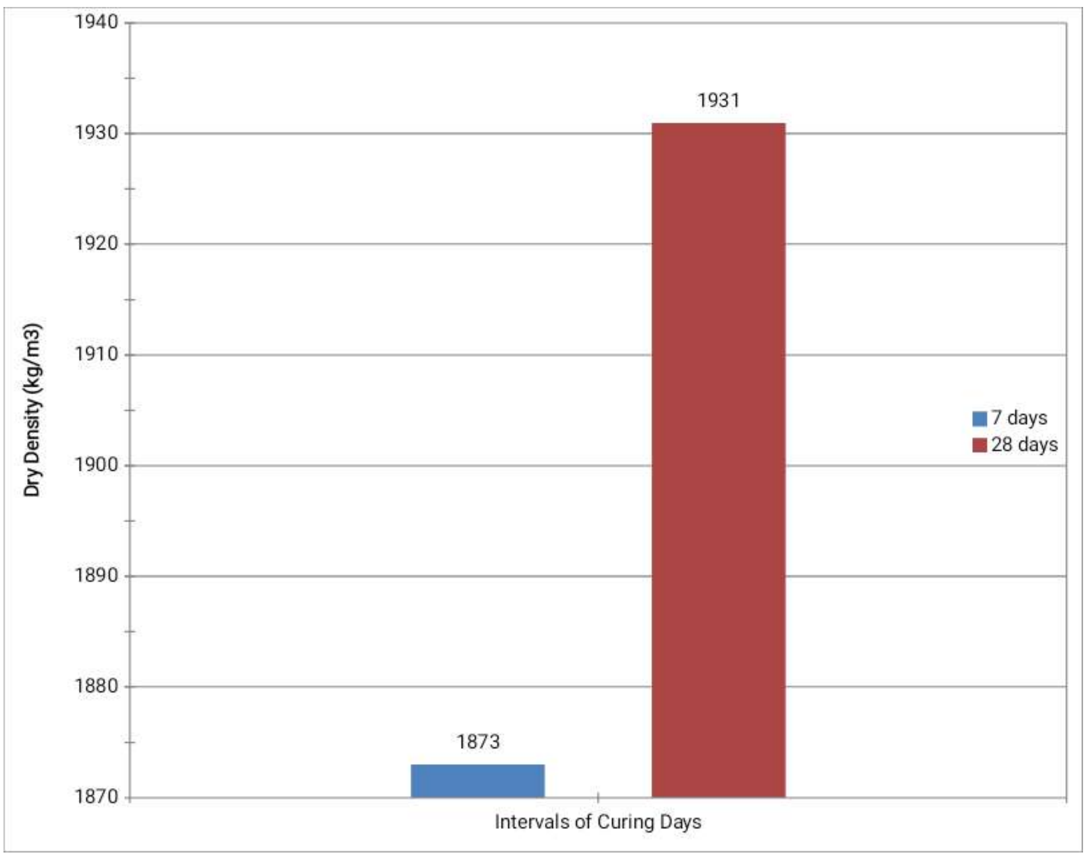


Figure 4.4: Graph of Compressive Strength against Percentage Replacement of Crushed Coconut Shell

4.2.5 Hardened Concrete Density

The results obtained for the hardened concrete density of the convention and crushed coconut shell concrete were similar to that obtained for compressive strength. It was observed that the dry density of crushed coconut shell concrete was lower than that of the control specimen. On consistent addition of crushed coconut shell to the concrete, the dry density of the concrete decreased. It was also observed that the dry density of the concrete increased with curing days. It was also observed that at 20% addition of crushed coconut shell to the concrete, the concrete became light weight as their density was less than 1800kg/m^3 (BSEN, 2011). The consistent decline in dry density of the crushed coconut shell concrete could be attributed to the low density of crushed coconut shell which ultimately affects the density of the finished concrete.

Figure 4.5: Graph of dry density against Curing Days



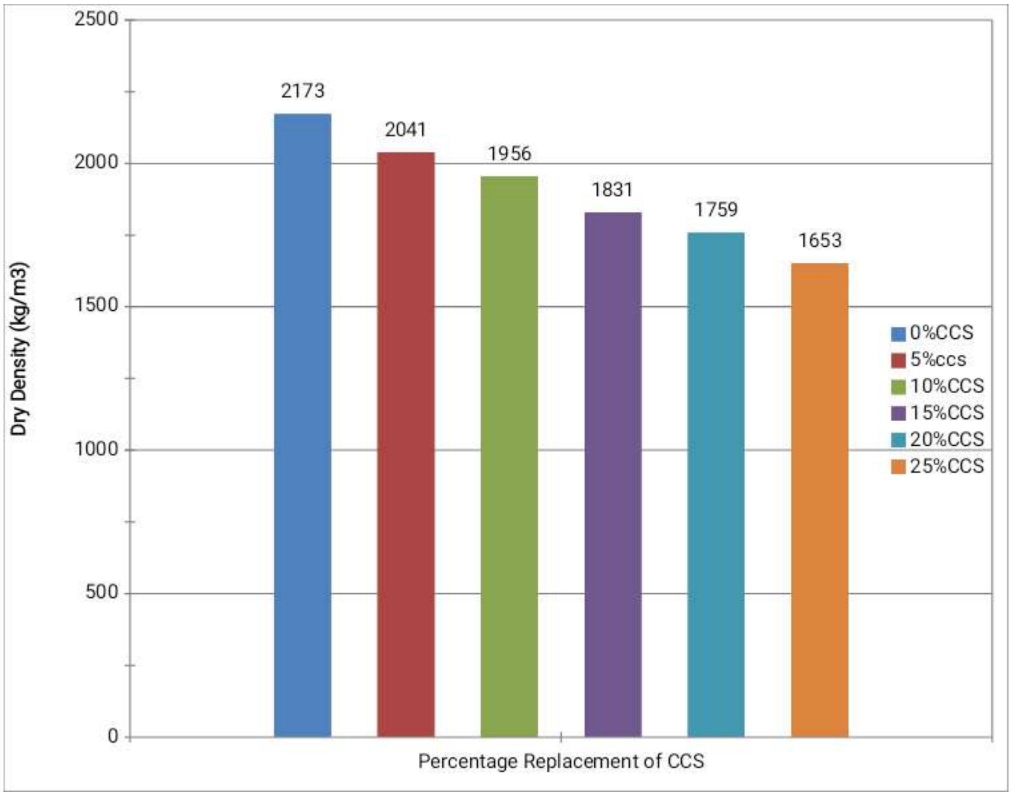


Figure 4.6: Graph of Dry Density against Varying Percentages of Crushed Coconut Shell

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the findings obtained on effect of partial replacement of granite with crushed coconut shell on fresh and hardened mechanical properties of concrete, the following conclusion can be drawn:

1 Preliminary investigation of the aggregate samples used for the production suggests that the aggregates satisfied standard requirement for concrete production.

2 The specific gravity of crushed coconut shell fell below ASTM requirements for normal weight aggregate and as a result will be useful for production of light weight concrete.

3 The slump of the control decreased with increasing percentages of crushed coconut shell.

4 The dry density of the hardened concrete decreased with increasing percentages of crushed coconut shell.

5 The compressive strength of the concrete decreased with increasing percentages of crushed coconut shell with the optimum value of compressive strength obtained for the control specimen (0%CCS).

6 The crushed coconut shell was adjudged as feasible but ineffective alternative for strength improvement in concrete.

5.2 Recommendation

The recommendation on strength enhancement in concrete containing crushed coconut shell as a partial substitute for coarse aggregate in concrete is as follows:

1 Concrete produced with partial replacement of granite with crushed coconut shell can only be used for non structural purpose as violation of this specification could result to loss in structural integrity of the concrete.

2 This study discourages the use of crushed coconut shell either as a partial or

complete additive in enhancement of mechanical properties of concrete particularly when the modified concrete is to serve structural purposes.

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APPENDICES

APPENDIX A

Compressive Strength Tests

Table A1: Compressive Strength Test Result for 0% CCA

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
7 days	1: 2: 4	492.3	21.88	22.30
		504.3	22.41	
		508.5	22.6	
28 days	1: 2: 4	530.4	23.57	23.62
		535.7	23.81	
		528.3	23.48	

Table A2: Compressive Strength Test Result for 5% CCA

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)

7 days	1: 2: 4	455.6	20.25	20.27
		452.3	20.10	
		460.4	20.40	
28 days	1: 2: 4	500.4	22.24	21.84
		490.3	21.79	
		483.5	21.49	

Table A3: Compressive Strength Test Result for 10% CCA

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
7 days	1: 2: 4	424.3	18.86	18.49
		418.5	18.60	
		405.4	18.02	
28 days	1: 2: 4	435.8	19.37	19.39
		440.7	19.59	
		432.4	19.22	

Table A4: Compressive Strength Test Result for 15% CCA

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
7 days	1: 2: 4	380.5	16.91	16.62
		372.7	16.56	
		368.5	16.38	
28 days	1: 2: 4	410.5	18.24	18.23
		411.3	18.28	
		408.6	18.16	

Table A5: Compressive Strength Test Result for 20% CCA

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
7 days	1: 2: 4	350.6	15.58	15.66
		362.5	16.11	
		344.5	15.30	
28 days	1: 2: 4	368.6	16.38	16.37
		370.4	16.46	
		365.8	16.26	

Table A6: Compressive Strength Test Result for 25% CCA

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
7 days	1: 2: 4	320.8	14.26	14.43
		322.5	14.33	
		330.7	14.70	
28 days	1: 2: 4	345.8	15.37	15.39
		344.5	15.31	
		348.8	15.50	

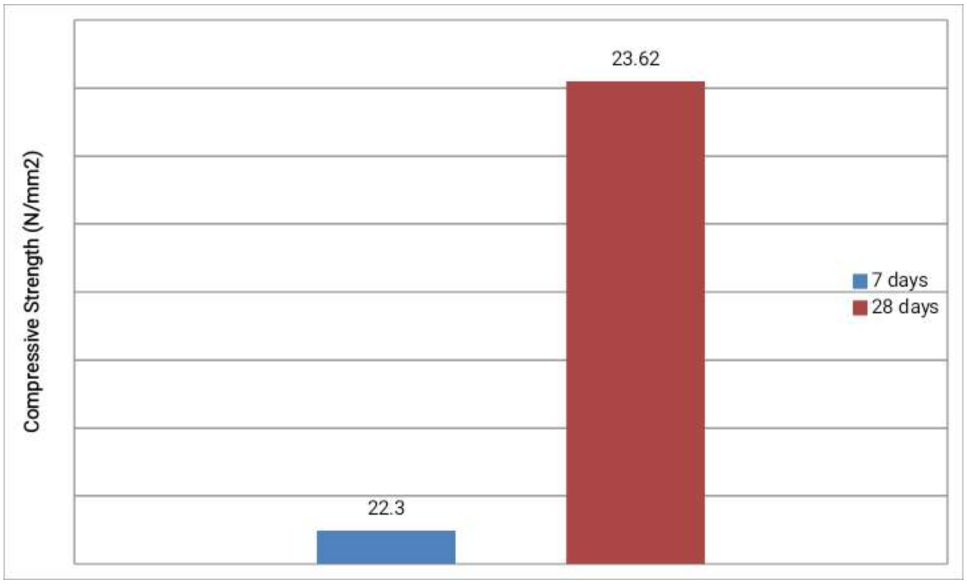

Figure A1: Graph of Compressive Strength against Curing Days at 0%CCS

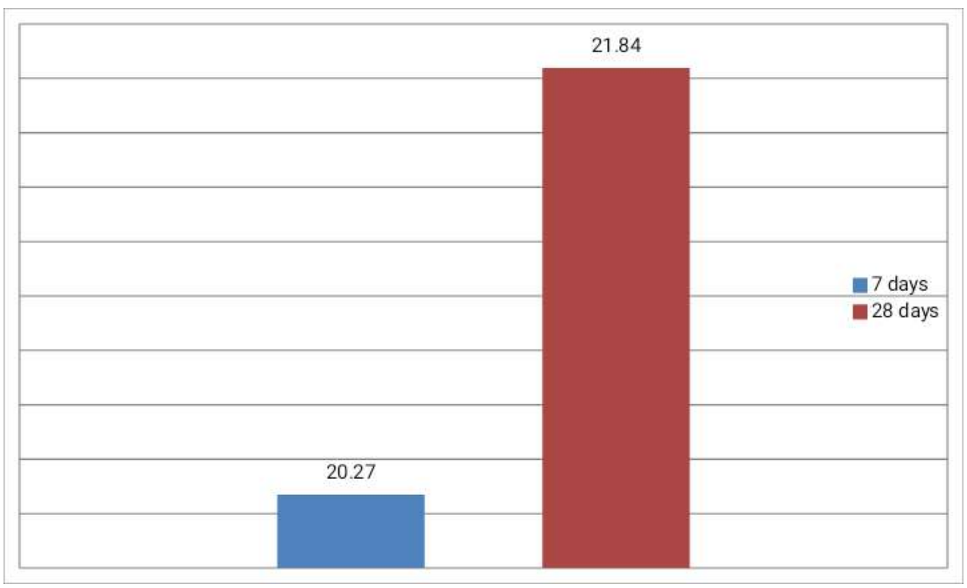

Figure A2: Graph of Compressive Strength against Curing Days at 5%CCS

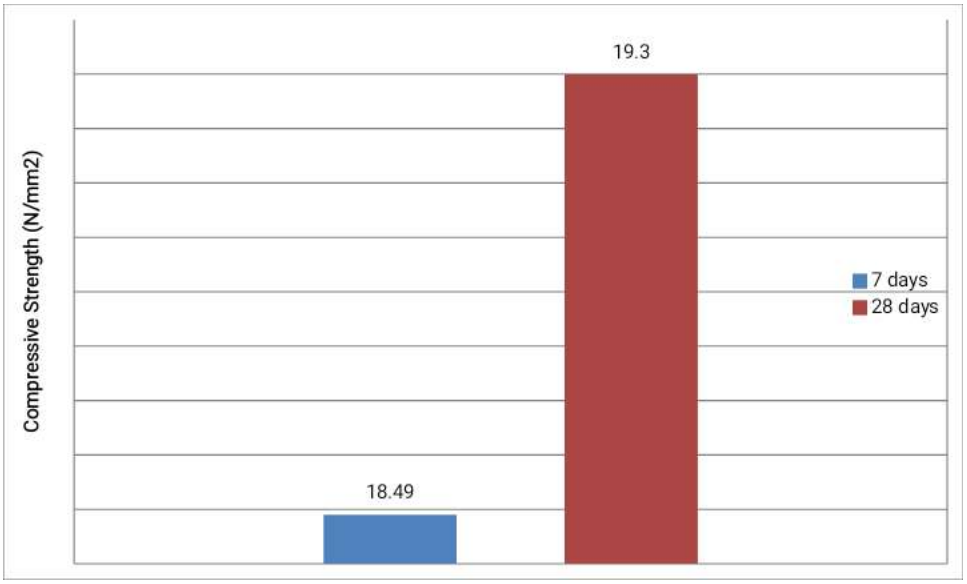

Figure A3: Graph of Compressive Strength against Curing Days at 10%CCS

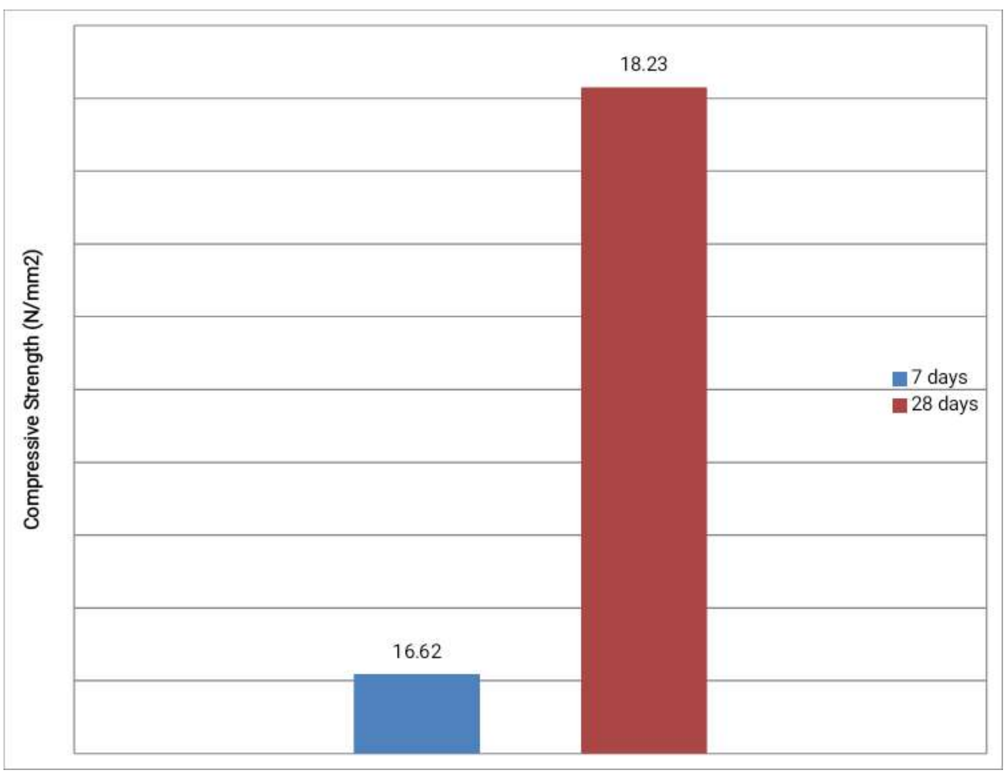

Figure A4: Graph of Compressive Strength against Curing Days at 15%CCS

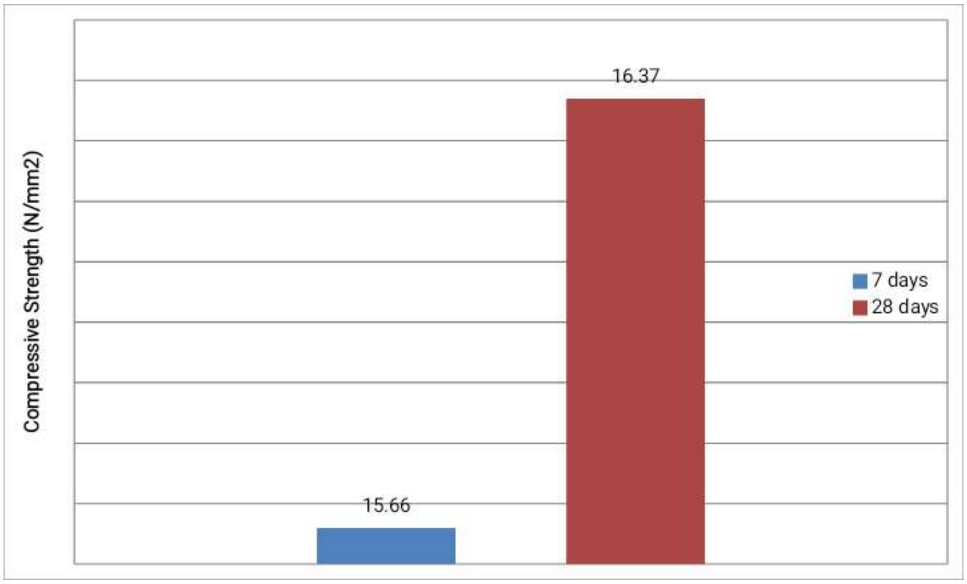

Figure A5: Graph of Compressive Strength against Curing Days at 20%CCS

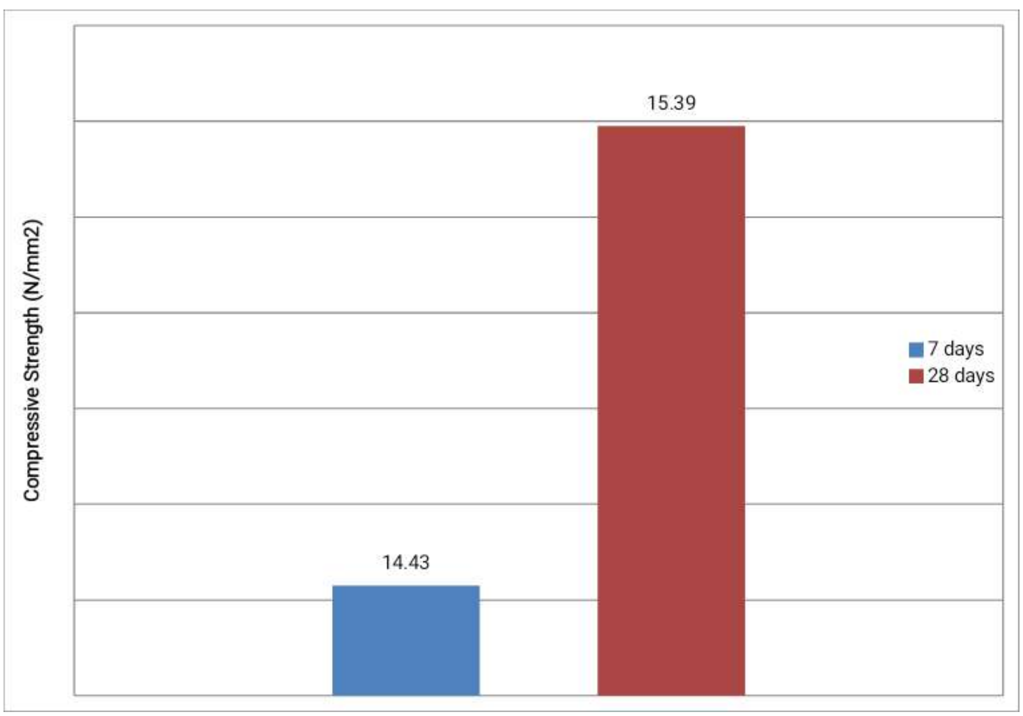

Figure A6: Graph of Compressive Strength against Curing Days at 25%CCS

APPENDIX B

Dry Density Tests

Table B1: Density Test Result for 0% CCS

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
7 days	7.08		2098	
	7.24	7.23	2145	2141
	7.36		2181	
28 days	7.35		2178	
	7.48	7.44	2216	2205
	7.50		2222	

Table B2: Density Test Result for 5% CCS

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
7 days	6.82		2021	
	6.84	6.80	2027	2016
	6.75		2000	
28 days	6.95		2059	
	6.92	6.97	2050	2065
	7.04		2086	

Table B3: Density Test Result for 10% CCS

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
7 days	6.52		1932	
	6.41	6.46	1899	1914
	6.45		1911	
28 days	6.68		1979	
	6.71	6.64	1988	1998
	6.84		2027	

Table B4: Density Test Result for 15% CCS

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
7 days	6.21		1840	
	6.04	6.12	1789	1814
	6.12		1813	
28 days	6.31		1870	
	6.24	6.23	1849	1847
	6.15		1822	

Table B5: Density Test Result for 20% CCS

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)

7 days	5.95	5.9	1763	1748
	5.92		1754	
	5.83		1727	
28 days	6.08	5.97	1801	1770
	5.93		1757	
	5.91		1751	

Table B6: Density Test Result for 25% CCS

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
7 days	5.42	5.41	1606	1604
	5.34		1582	
	5.48		1624	
28 days	5.81	5.74	1721	1701
	5.74		1700	
	5.68		1683	

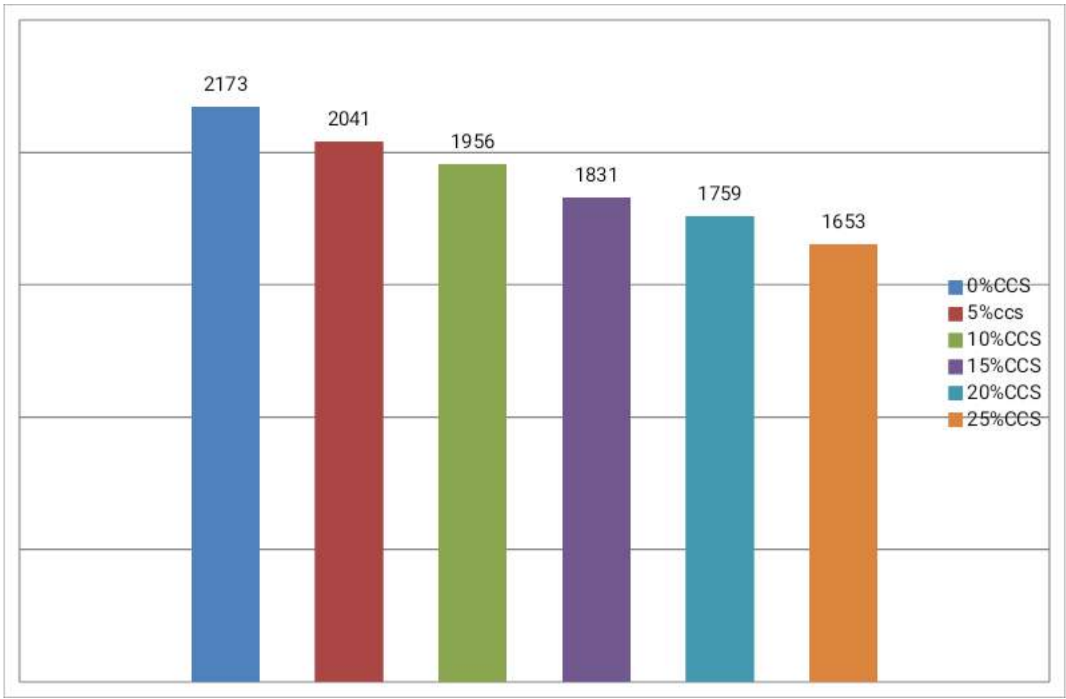

Figure B1: Graph Showing the Dry Density Values at Varying Percentages of CCS

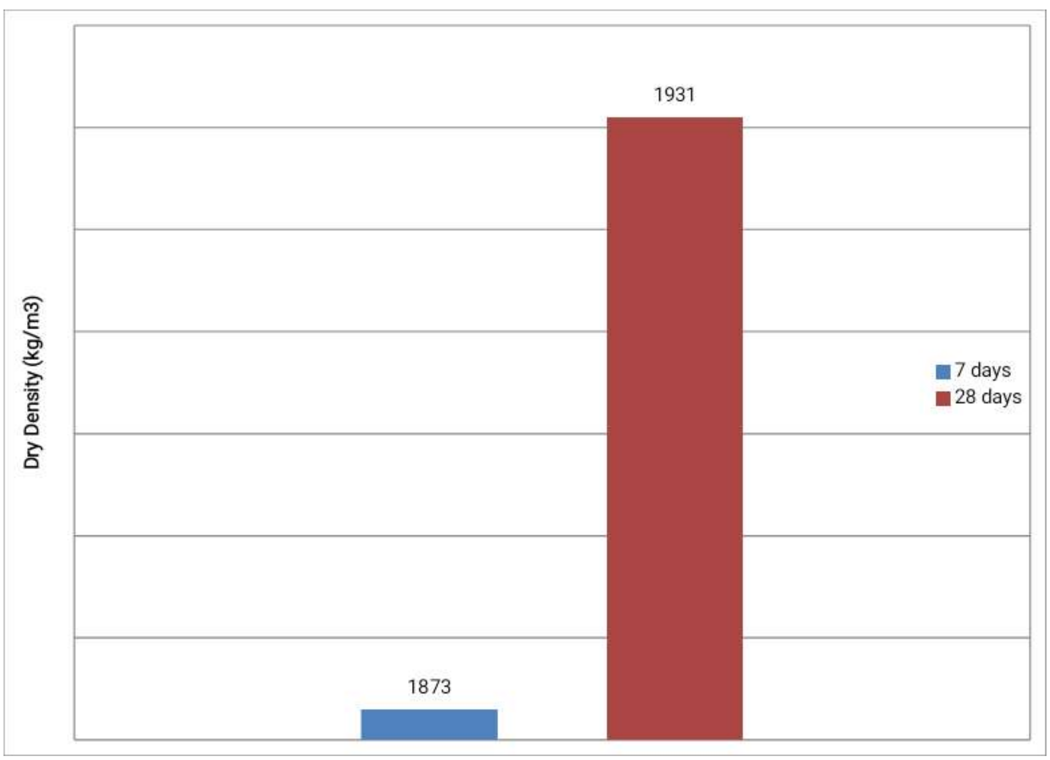

Figure B2: Graph Showing the Dry Density Values at Intervals of Curing Days

APPENDIX C

Slump Tests

Table D1: Slump Test Result at Varying Percentages of CCS

Percentage Replacement of CCS	Height of Slump Cone (mm)	Height of Collapse	Slump (mm)	Slump Type
0	300	265	35	True slump
5	300	270	30	True slump
10	300	275	25	True slump
15	300	282	18	True slump
20	300	285	15	True slump
25	300	290	10	True slump

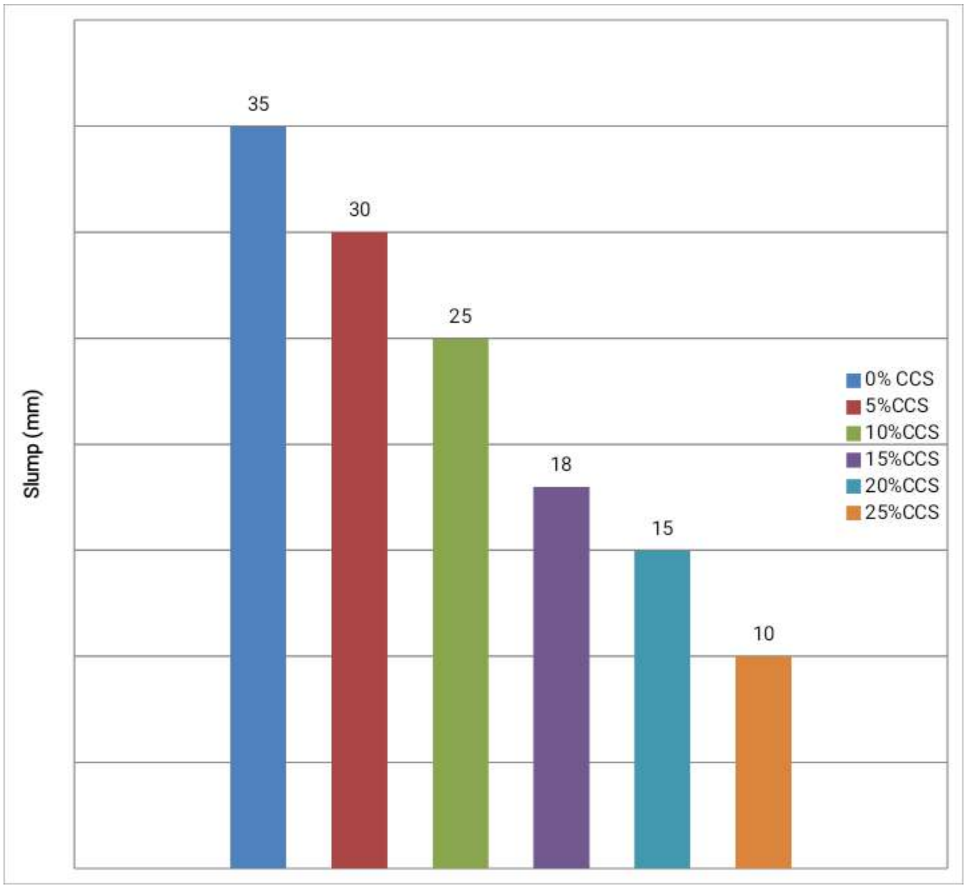

Figure D1: Graph Showing the Slump of the Concrete at Varying Percentages of CCS

APPENDIX D

Sieve Analysis Tests

Table E1: Sieve Analysis Test Result for Sand

Sieve Sizes	Mass Retained (g)	% Mass Retained (g)	Cum % Retained	Cum % Finer
2	7.97	2.66	2.66	97.34
1.18	9.98	3.33	5.99	94.01
0.85	11.73	3.91	9.90	90.10
0.6	27.95	9.32	19.21	80.79

0.425	44.02	14.67	33.89	66.11
0.3	53.69	17.90	51.78	48.22
0.15	112.1	37.37	89.15	10.85
0.075	8.46	2.82	91.97	8.03
Tray	2.3	0.77	92.74	7.26

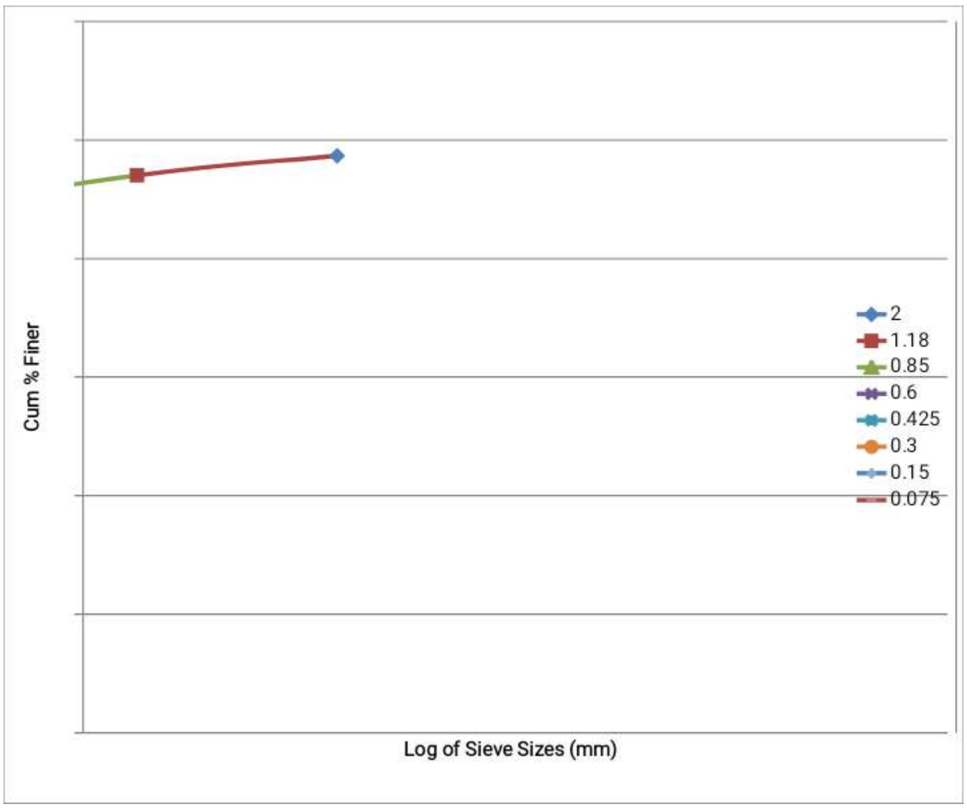

Figure E1: Particle Size Distribution Curve for Sand

Table E2: Sieve Analysis Test Result for Granite

Sieve Sizes	Mass Retained (g)	% Mass Retained (g)	Cum % Retained	Cum % Finer

31.25	0.18	0.02	0.02	99.98
25	98.6	8.96	8.98	91.02
20	367.27	33.39	42.37	57.63
12.5	509	46.27	88.64	11.36
9.5	14.71	1.34	89.98	10.02
6.3	32.11	2.92	92.90	7.10
4.75	14.53	1.32	94.22	5.78
Tray	12.48	1.13	95.36	4.64

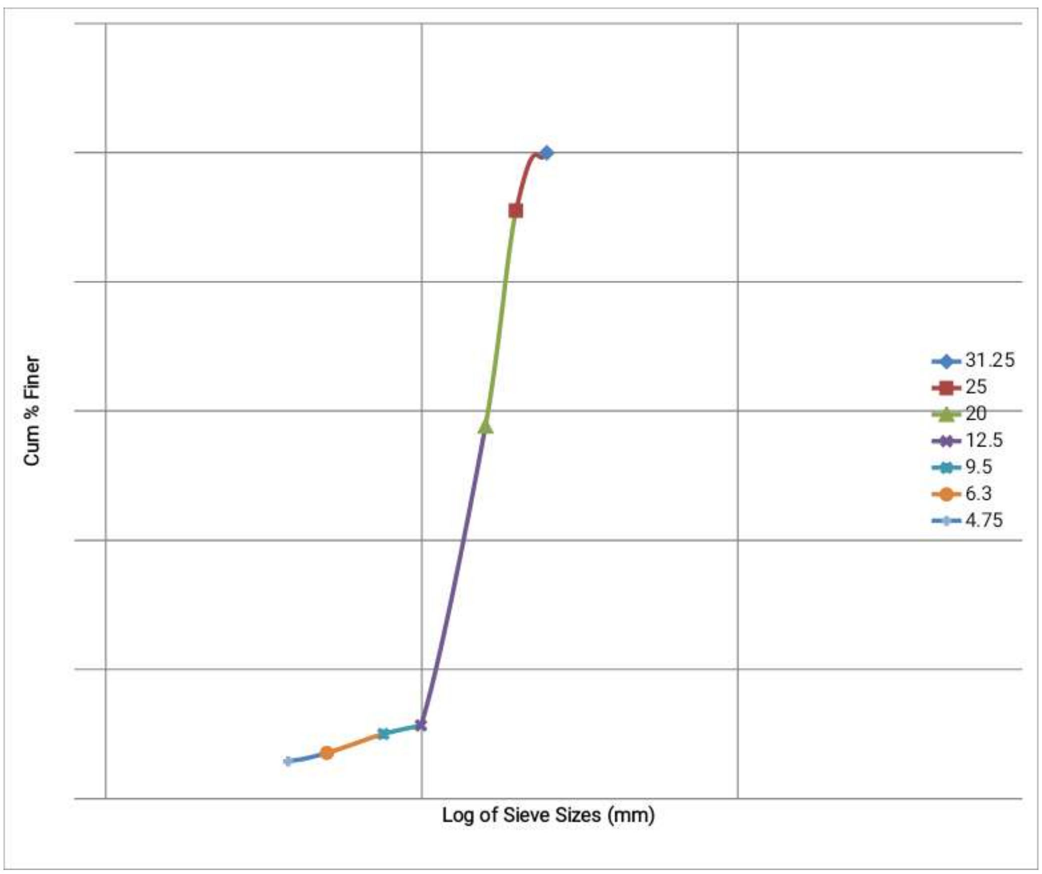

Figure E2: Particle Size Distribution Curve for Granite

Table E3: Sieve Analysis Test Result for Crushed Coconut Shell

Sieve Sizes	Mass Retained (g)	% Mass retained	Cum % Retained	Cum % finer
(mm)				
14	25	8.33	14.49	91.67
12.5	95	31.67	46.16	60.00
10	60	20.00	66.16	40.00
9.5	105	35.00	101.16	5.00
4.75	10	3.33	104.49	1.67
Tray	5	1.67	106.16	0.00
Total	300	37.50		

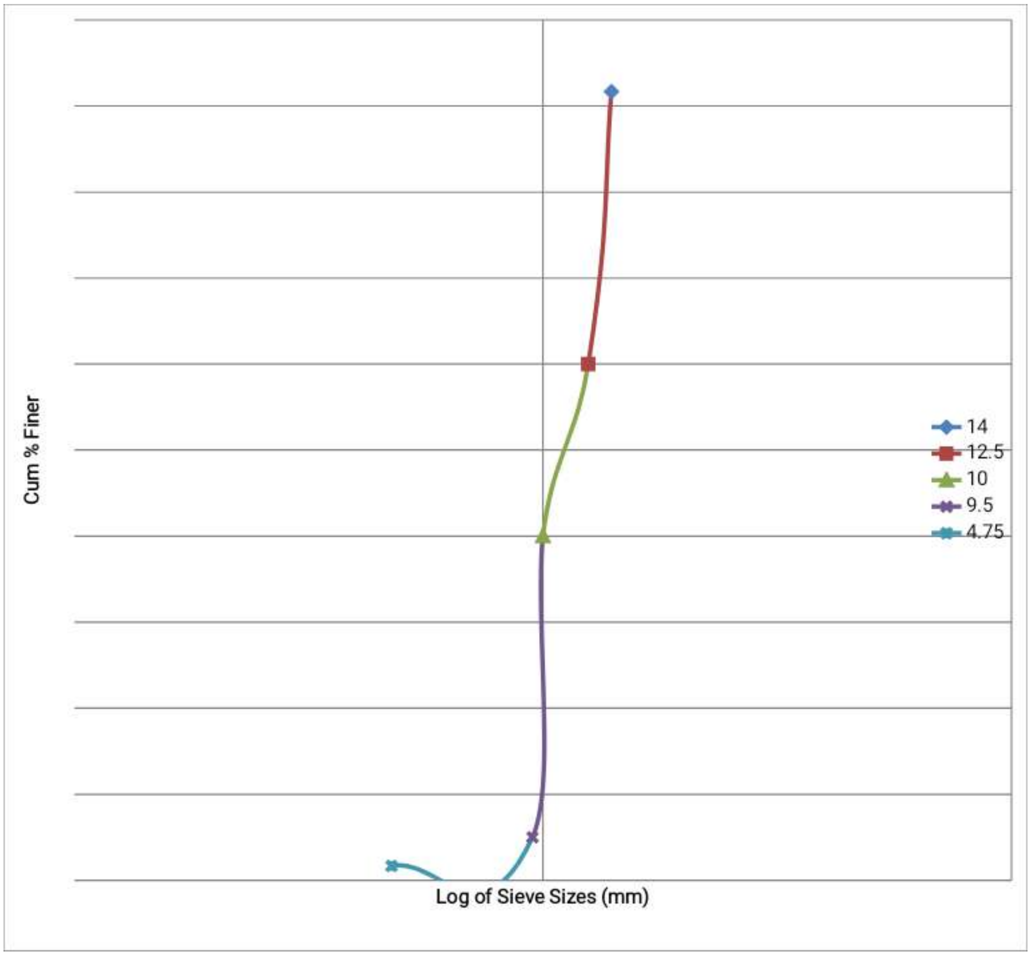

Figure E3: Particle Size Distribution Curve for CCS

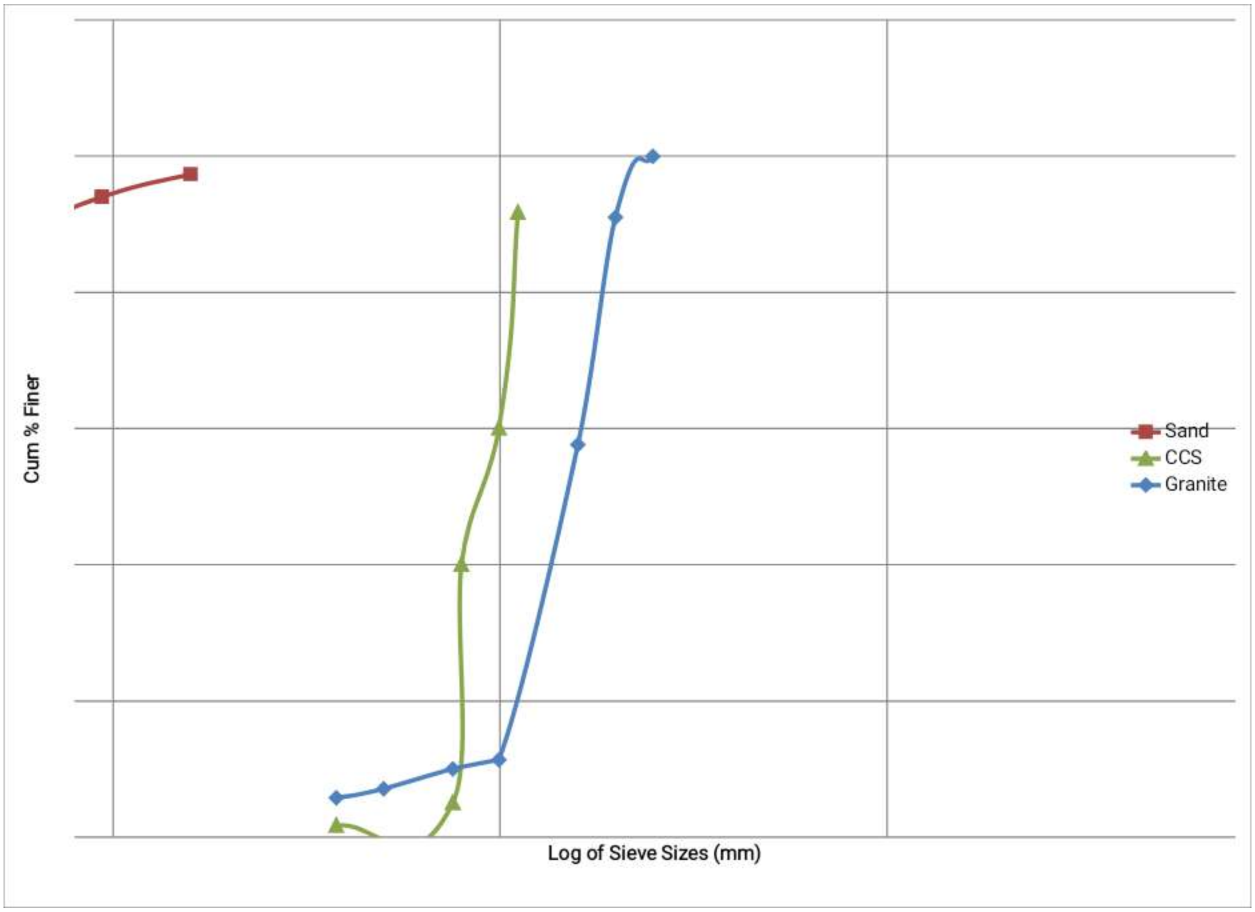

Figure E4: Particle Size Distribution Curve for Sand, Granite and Crushed Coconut Shell.

APPENDIX E

Specific Gravity Tests

Table F1: Specific Gravity Result for Crushed Granite.

Determinants	Trial 1	Trial 2	Trial 3
Wt of Saturated aggregate and basket in water W_1 (g).	458.72	460.68	462.46
Wt of basket in Water W_2 (g).	190.48	192.84	192.88
Wt of Saturated aggregate in air W_3 (g).	438.62	442.24	440.82
Wt of Oven-dried aggregate in air W_4 (g).	432.80	434.28	434.86

The Specific gravity of the sample is calculated as follows:

Apparent Specific Gravity for Crushed Granite.

$$\text{Trial 1 } (G_{S1}) = \frac{W4}{(W4 -(W1 -W2)} = \frac{432.80}{(432.80 -(458.72 -190.48)} = 2.63$$

$$\text{Trial 2 } (G_{S2}) = \frac{(W4}{(W4 -(W1 -W2)} = \frac{434.28}{(434.28 -(460.60 -192.84)} = 2.61$$

$$\text{Trial 3 } (G_{S3}) = \frac{W4}{(W4 - (W1 - W2)} = \frac{434.86}{(434.86 - (462.46 - 192.88)} = 2.60$$

$$\text{Apparent Specific Gravity} = \frac{(GS1 \ + GS2 \ + GS3)}{3} = \frac{(7.84)}{3} = 2.61$$

Bulk Specific Gravity for Crushed Granite.

$$\text{Trial 1 } (G_{S1}) = \frac{W4}{(W3 - (W1 - W2)} = \frac{432.80}{(438.62 - (458.7 - 190.48)} = 2.48$$

Table F2: Specific Gravity Result for Sand

Determinants	Trial 1	Trial 2	Trial 3
Wt of density bottle, W_1 (g).	24.50	25.32	25.12
Wt of bottle + dry soil, W_2 (g).	34.48	35.31	35.10
Wt of bottle + soil + water, W_3 (g).	84.43	86.39	85.03
Wt of bottle + water, W_4 (g).	78.35	80.32	78.93

The Specific gravity of the sample is calculated as follows:

Specific Gravity for Sand

$$\text{Trial 1 } (G_{S1}) = \frac{(W2 - W1)}{(W2 - W1) - (W3 - W4)} = \frac{(34.48 - 24.50)}{(34.48 - 24.50) - (84.43 - 78.35)} = 2.56$$

$$\text{Trial 2 } (G_{S2}) = \frac{(W2 - W1)}{(W2 - W1) - (W3 - W4)} = \frac{(35.31 - 25.32)}{(35.31 - 25.32) - (86.39 - 80.32)} = 2.55$$

$$\text{Trial 3 } (G_{S3}) = \frac{(W2 - W1)}{(W2 - W1) - (W3 - W4)} = \frac{(35.10 - 25.12)}{(35.10 - 25.12)(85.03 - 78.93)} = 2.53$$

$$\text{Specific Gravity} = \frac{(GS1 \;\; +GS2 \;\; +GS3)}{3} = \frac{(2.56 \;\; +2.55 \;\; +2.53)}{3} = 2.55$$

Table F3: Specific Gravity Result for Crushed Coconut Shell

Determinants	Trial 1	Trial 2	Trial 3
Wt of Saturated aggregate and basket in water W_1 (g).	268.5	254.8	230.4
Wt of basket in Water W_2 (g).	158.1	157	132.4
Wt of Saturated aggregate in air W_3 (g).	438.62	442.24	440.82
Wt of Oven-dried aggregate in air W_4 (g).	280.6	290.5	305.8

The Specific gravity of the sample is calculated as follows:

Apparent Specific Gravity for Crushed Coconut Shell

$$\text{Trial 1 } (G_{S1}) = \frac{W4}{(W4 - (W1 - W2)} = \frac{280.6}{(280.6 - (268.5 - 158.1)} = 1.65$$

$$\text{Trial 2 } (G_{S2}) = \frac{(W4}{(W4 - (W1 - W2)} = \frac{290.5}{(290.5 - (254.8 - 157)} = 1.51$$

$$\text{Trial 3 } (G_{S3}) = \frac{W4}{(W4 - (W1 - W2)} = \frac{305.8}{(305.8 - (230.4 - 132.4)} = 1.47$$

$$\text{Apparent Specific Gravity} = \frac{(GS1 + GS2 + GS3)}{3} = \frac{(4.63)}{3} = 1.54$$

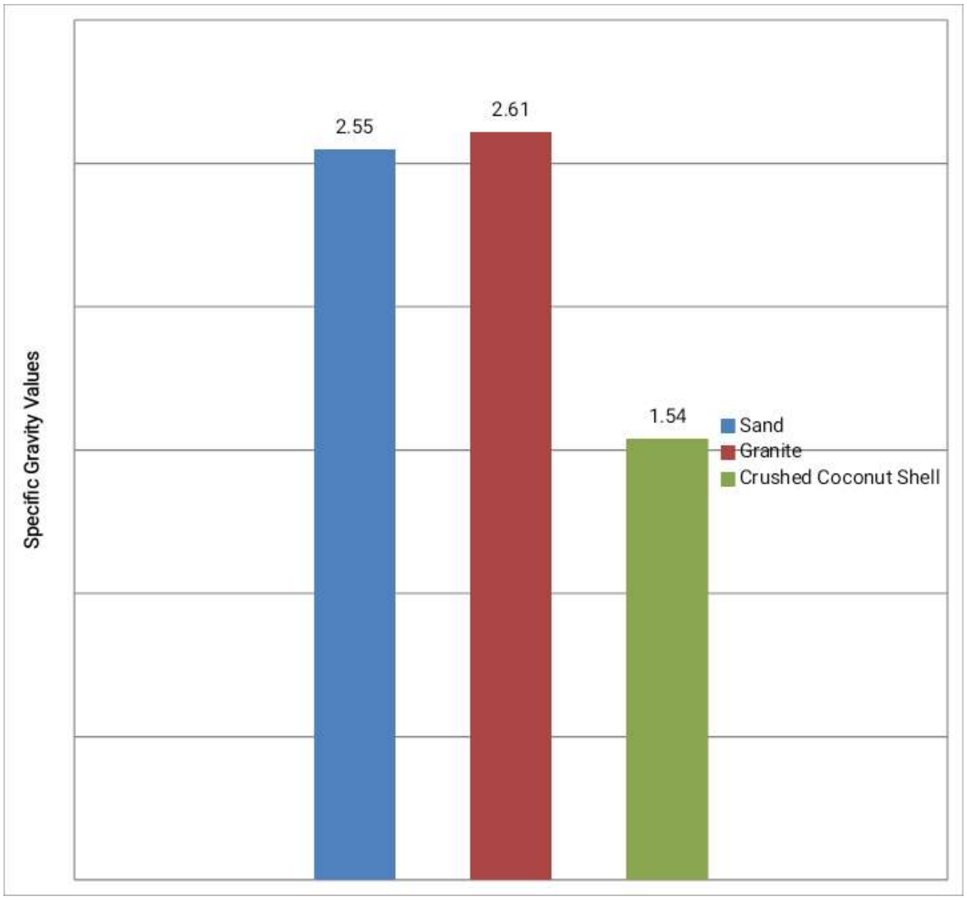

Figure F1: Specific Gravity of Aggregate and Crushed Coconut Shell