EFFECTS OF SELECTED BRANDS OF PORTLAND CEMENT ON COMPRESSIVE STRENGTH OF CONCRETE

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CERTIFICATION

This is to certify that this project topic titled "Effect of Selected Brands of Portland Cement on Compressive Strength of Concrete" was undertaken by Aniweteli John Nnabuneyi with registration number (NAU/2017224034) in the Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

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APPROVAL PAGE

This research work “Effect of Selected Brands of Portland Cement on Compressive Strength of Concrete” has been assessed and approved by department of civil engineering Nnamdi Azikiwe University.

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DEDICATION

This work is dedicated to Almighty God for the gift of life and also for guiding me through school. I also want to dedicate this work to my lovely mother Mrs Ateli Felicia who served as a real source of inspiration toward my academic pursuit.

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Special thanks go to Almighty God for giving me the strength to complete this work and also for His guidance and protection throughout my stay in Nnamdi Azikiwe University.

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ABSTRACT

The need to investigate the compressive strength of concrete produced with different brands of cement obtainable within south east Nigeria formed the basis for the study. The study was undertaken to assess the compressive strength of concrete produced with selected brands of Portland cement obtainable within south east Nigeria. Four different brands of Portland cement namely: Bua, Dangote 3x, Unicem and Lafarge were adopted for the study. The concrete components and the concrete were subjected to various laboratories testing which includes: sieve analysis test, specific gravity test, aggregate impact and crushing value test, slump test and compressive strength test. Sieve analysis test for the aggregate classified sand and granite as A-2-4 and A-1-b according to AASHTO Soil Classification System, SM (sand mixed with silt) and GC (gravel mixed with clay) according to Unified Soil Classification System, the specific gravity of sand and granite were 2.55 and 2.66, the aggregate impact and crushing value were 27.6% and 26.1% respectively, the initial and final setting time of Bua, Dangote 3x, Unicem and Lafarge ranged from 28min – 30min and 560min – 600min, the fineness of the four different brands of Portland cement ranged from 24.8% - 28.6%, the soundness of the cement ranged from 6.4% - 8.3%. The slump of the fresh concrete produced with different brands of Portland cement ranged from 40mm – 55mm. The hardened density and compressive strength of the concrete produced with Bua, Dangote 3x, Unicem and Lafarge were 2347kg/m^3, 2345kg/m^3, 2393kg/m^3 and 2361 kg/m^3 and 24.18N/mm^2, 24.81N/mm^2, 27.47N/mm^2, 27.15N/mm^2. It was observed that the highest dry density and compressive strength was recorded for concrete produced with Unicem while the lowest dry density and compressive strength was recorded for concrete produced with Dangote 3x cement. In the light of the findings, this study therefore recommends the use of Unicem cement for production of both structural and non structural concrete due to significant attainment in dry density and compressive strength.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATE

LIST OF SYMBOL & ABBREVIATION

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

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Concrete as the most widely used man-made construction materials is second only to water as the most utilized substance on the planet (Gambhir, 2005). It is obtained by mixing cementitious materials, water and aggregate (and sometimes admixtures) in required proportion. According to Bamigboye, et al., (2015), concrete is composed of aggregates embedded in a cement matrix which fill the space between the aggregates and bind them together. Concrete is a very strong building material and the use of concrete predates back before the Roman Empire. Concrete mixture when placed in form and allowed to cure hardens into rock-like mass known as concrete. In it harden state, concrete should have the following properties; strength, durability, impermeability, and it should have minimum dimensional changes. The strength, durability, and other characteristics of concrete depends upon the properties of its ingredients, proportion of mix, method of compaction and other controls during placing, compaction and curing (Gambhir, 2005).. Among the various properties of the concrete, its compressive strength is considered to be the most important and it is taken as an index of its overall quality.

Joseph and Raymond (2014) found that concrete develops an average of 26% of the 28 days strength in 1 day and 85% in 21 days and concluded that concrete develop strength rapidly at early age compared to later ages. Quality of concrete material can have positive or negative impact on a society. (Ayininuola and Olalusi 2004: Ede, 2010) have all identified the use of substandard materials, particularly concrete as the leading causes of building collapse in Nigeria. Deodhar (2009) reported that, the strength of concrete is mainly affected by the water to cement ratio; the workability is affected by aggregate to water ratio and the cost by the aggregate cement ratio. As the versatility of concrete continues to increase, the quality can hardly be certified because of many other factors such as aggregates, cement, mixing procedures and skill of operators, placement and consolidation. It varies according to so many variables such as quality of constituent materials (cement aggregates, water and admixtures), skill of the manufactures, management placement procedures and environmental issues (Zongjin, 2011; Ede et al., 2015).

Shetty (2005) reported that in concrete, aggregates and paste are the major factors that affect the strength of concrete. Abdullah, (2012) stated that the strength of the concrete at the interfacial ppzone essentially depends on the integrity of the cement paste and the nature of the coarse aggregate. The binding quality of Portland cement paste is due to the chemical reaction between the cement and water (Raheem and Bamigboye, 2013). The degree of cement hydration which is a function of water to cement ratio has a direct impact on the porosity and consequently on the strength. The richness of the mix is one of the factors that affect the rate of strength development in concrete mix and is a direct function of the quality and quantity of the cementitious material. This implies that cement is one of the most important ingredient influencing strength properties of concrete.

Moreover, there are various brands of Portland cement available in markets which are used in construction industries. There have been sentimental and unconfirmed analyses by various groups in the construction industry comparing between the available brands of cement on setting time, workability, fineness and compressive strength. It is then long overdue for a proper independent academic research to ascertain the properties of each of the brands of cement available.

In other to tackle the discrepancy in concrete compressive strength produced by different brands of Portland cement available in the market, this study will therefore evaluate the effect of selected brands of Portland cement on mechanical properties of concrete.

1.2 Statement of Problem

Quality of concrete material can have positive or negative impact on a society. (Ayininuola and Olalusi 2004: Ede, 2010) have all identified the use of substandard materials, particularly concrete as the leading causes of building collapse in Nigeria. Deodhar (2009) reported that, the strength of concrete is mainly affected by the water to cement ratio; the workability is affected by aggregate to water ratio and the cost by the aggregate cement ratio. Cement as one of the most important constituents influencing the strength of concrete ranges in different brands in Nigeria. There have been speculations by various groups in the construction industry that the mechanical properties of concrete especially the strength properties varies appreciably with the brand of cement used for the concrete production (Ige, 2013). These developments have necessitated the need for an independent research to ascertain the effect of different brands of cement obtainable in the market to be conducted.

In other to tackle the discrepancy in concrete compressive strength produced by different brands of Portland cement available in the market, this study will therefore evaluate the effect of selected brands of Portland cement on mechanical properties of concrete.

1.3 Aim and Objectives

The aim of the study is to assess the effect of selected brands of cement on mechanical properties of concrete while the objectives are as follows:

1. To determine the chemical composition of selected brands of Portland cement.
2. To determine certain properties of selected brands of Portland cement.
3. To determine the index properties of fine and coarse aggregate.
4. Study the effect of selected brands of Portland cement on workability and compressive strength of the concrete.
5. Draw conclusion and make recommendation on quality of selected brands of Portland cement based on findings.

1.4 Scope of Study

This study is centered at investigating the strength properties of selected brands of cement in south east Nigeria. Concrete grade 20 (1:2:4) will be used for the experimental study. Four cement brands namely: Bua, Dangote 3x, Unicem and Lafarge will be adopted for the study. The four different brands of cement will be subjected to consistency limit test ranging from Setting time, Soundness and Fineness test. The aggregates and concrete produced from the selected brands of cement will be subjected to Particle size distribution test, Specific gravity test, Aggregate impact value (AIV), Aggregate crushing value test (ACV), Workability (Slump) test and Compressive strength test of the hardened concrete. Recommendation on quality of selected brands of Portland cement will be made.

1.5 Significance of Study

The findings obtained from the study of strength properties of selected brands of Portland cement in south east Nigeria will be significant in the following ways:

1. Bridge knowledge gap on sentiment and unconfirmed analyses by various groups in the construction industry comparing between the effect of available brands of cement on mechanical properties of fresh and hardened concrete
2. Tackle discrepancy in concrete mechanical properties produced using different brands of cement.
3. Valuable in assisting government at all levels in addressing issue related to cement quality and use.
4. Make recommendation on cement brands appropriate for a particular construction work.
5. Valuable as reference for further studies and field work.

CHAPTER TWO

2.0 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. 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. Concrete may be defined as a composite material consisting of a binding material, water, fine and coarse aggregates, and in some instances, the incorporation of admixtures all in definite proportions to achieve a desired property. The binding material in most instances is the Ordinary Portland Cement (OPC) although other binding materials are also in used. Concrete is an artificial material comparable in appearance and properties to some natural lime stone rock. It is a man-made composite, the major constituent being natural aggregate such as gravel, or crushed rock, sand and fine particles of cement powder all mixed with water. The concrete as time goes on through a process of hydration of the cement paste, producing a required strength to endure the load (Maninder and Manpreet, 2012).

Concrete is a widely used construction material in civil engineering projects throughout the world for the following reasons: It has great resistance to water, structural concrete elements can be formed into a variety of shapes and sizes and it is usually the cheapest and most readily available material for the job (Olanipekun, 2006).

The compressive strength of concrete is one of the most useful properties of concrete. In most structural applications, concrete is employed primarily to resist compressive strength stresses. In case where strength in tension or in shear is of primary importance, the compressive strength is frequently used as a measure of these properties. Therefore the concrete making properties of various ingredients of mix are usually measured in terms of the compressive strength. Compressive strength is also used in a qualitative measure for other properties of a hardened concrete. The compressive strength is determined by testing cubes or cylinders in the laboratory. The strength of a concrete is it resistance to rupture. It can be measured in a number of ways: strength compression in tension, in shear or in flexures. The cohesion and internal friction developed by concrete in resisting failure is related to the water-cement ratio, the design constituents, the mixing, placement and curing methods employed. There are speculations shared by various groups in the construction industry that the compressive strength of concrete varies appreciably with the brands of concrete. This study will investigate the compressive strength of concrete produced by different brands of Portland cement.

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. Pozzolanic 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.

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. 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. 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:

$$\frac{\mathbf{CaO-0.7SO3}}{\mathbf{SiO2+1.2AL2O3\ 0.65\ Fe2O3}}$$

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 (SO3) 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 (SiO2), alumina (Al2O3) and iron oxide (Fe2O3). The four compounds are usually regarded as the major constituents of cement. They are described in abbreviated form by cement chemists as follows: CaO = C; SiO2 = S; Al2O3 = A; and Fe2O3 = F. Likewise, H2O in hydrated cement is denoted by H, and SO3 by S. In addition to the main compounds listed above, there exist minor compounds, such as MgO, TiO2, Mn2O3, K2O and Na2O; they usually amount to not more than a few per cent of the mass of cement. Two of the minor compounds are of particular interest: the oxides of sodium and potassium, 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 Quality of Concrete

Quality means excellence. It is thus a philosophy rather than a mere feature. The difference between two objects is judged by their qualities. We set some standards those can determine the level of acceptability. In most industries especially in manufacturing and processing, the concept of quality control is old and used extensively.

Nowadays, application of quality control is not only becoming popular but also mandatory in construction industry. Just knowing some quality control methods or procedures will not do any good. We must have to adopt and implement the quality control methods and tools that are available to us. The concept and its practice must be tuned in harmoniously. Quality control in construction activities guides the implementation of correct structural design, specifications and proper materials ensuring that the quality of workmanship by the contractor /sub-contractor is achieved.

2.5.1 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.

2.5.1.1 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.

2.5.1.2 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.

2.5.1.3 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.

2.5.1.4 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.

2.5.1.5 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.

2.5.1.6 Equipments

The equipment used for batching, mixing and vibration shall be of the right capacity. Weigh-batchers shall be frequently checked for their accuracy.

2.5.1.7 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.

2.5.1.8 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.

2.5.1.8 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.

2.6 Review of Past Works

Yahaya, et al., (2014) carried out a comparison of the compressive strength of concrete made with different brands of ordinary portland cement. The Ordinary Portland cement (OPC) used is Eagle cement, Ibeto Cement, Unicem and Dangote Cement. The concrete mix design of 1:2:4 with water/cement ratio of 0.5 was used. 150mm×150mm×150mm metal moulds was used for casting the concrete specimen after obtaining a uniform and consistent mixture for each brand of Cement. The average compressive strength of concrete made with Eagle cement, Unicem, Dangote and Ibeto cement were found to be 48.74N/mm2, 46.34N/mm2, 44.35N/mm2 and 44.96N/mm2 respectively after 28 days curing. Compressive strength of 30N/mm2 was targeted for the cubes. It was observed that there is a slight difference between the compressive strengths of the concrete cubes made with four brands of OPC used. This can be due to the difference in quality of the cement produced by these companies. Results obtained clearly show that Eagle cement has the highest compressive strength.

Bamigboye, et al., (2015) investigated the compressive strength of concrete produced from different brands of portland cement. Different brands of Portland cement were used to produce concrete varying with1:2:4 and 1:3:6 mix ratio respectively with a curing date of 3, 7, 14, 21, and 28 days respectively. No additive was used in any of the mix. The tests carried out include slump test at its fresh state while compressive strength was carried out for the hardened concrete, also the vicat test was carried out on the cement brands to determine the setting time. Compressive strength at 28 days showed that Dangote 3X cement produced 25.27N/mm2, Ibeto cement 38.89 N/mm2, Purechem cement 24.58 N/mm2, Unichem cement 21.16 N/mm2 and Elephant cement 27.9 N/mm2 for 1:2:4 mix ratio respectively. For 1:3:6 mix ratio at 28 days Dangote cement produced 18.89 N/mm2, Ibeto cement 22.07 N/mm2, Purechem cement 11.63 N/mm2,Unichem cement 15.86 N/mm2 and Elephant cement16.71 N/mm2 respectively. The study concluded that Ibeto cement has the highest strength at 28 days for 1:2:4 and 1:3:6 mix ratios respectively.

Gana, et al., (2020) conducted an experimental study on Effect of different brands of Nigerian cement on the properties of pervious concrete. Four different brands of Portland cement; Dangote Falcon (grade 32.5), Elephant Supaset (grade 42.5), Elephant Lafarge (grade 32.5) and Dangote 3x (grade 42.5) were used to produce pervious concrete of mix ratio 1:2:4 and tests such as compressive strength, permeability and density were tested; the void content was also analyzed.

The densities of pervious concrete produced were between 2000kg/m^3--1948kg/m^3 with Elephant Supaset being the densest. All brands produced Portland cement of compressive strength higher than 6N/mm^2 which is the minimum strength requirement in BS 5224 Dangote Falcon cement had the highest compressive strength followed by Elephant Supaset, Elephant

Lafarge and Dangote 3x cement in that order after a 21 day curing period with values 16.39N/mm^2, 13.97N/mm^2, and 13.54N/mm^2 and 13.116N/mm^2 respectively. Elephant cement was most permeable with a 10.1mm/sec value, followed by Dangote 3x cement with 9.98mm/sec then Dangote and Elephant S had 9.89 and 8.46mm/sec respectively. Density is inversely proportional to porosity and permeability. Elephant Lafarge cement had the highest void content with 20.43% followed by 20.13%, 19.52%, 18.31% respectively for Dangote 3x cement, Dangote Falcon, Elephant Supaset cement.

In another study, Okonkwor, et al., (2019) carried out comparative analysis of concrete strength made from selected brands of cement in Anambra State, Nigeria. Samples of the selected brands of cement were collected and are used in mixing concrete. The fine aggregates used was obtained from River Sand (Onitsha), coarse aggregate is 12 mm quarried granite and water used for the concrete mixing is fit for drinking. These samples of concrete are tested in the laboratory (Anambra State Material Testing Laboratory) for workability and compressive strength and the result obtained were presented in simple tables The study found out that the compressive strength of Bua, Supaset, Dangote and Unicem cements were 30.5, 31.70, 29.66 and 29.08 N/mm2, respectively at 28 days of curing. Also, the result of the slump value ranges from 70–140 (indicating that the concrete mix is workable) for all the four samples. The results indicate that Supaset yielded the highest compressive strength while Unicem yielded the lowest compressive strength (28th day). The study was concluded by recommending that all the selected brands of cement within the study area met with the required standard.

Ige, (2013) investigated the comparative strength of Portland cements In Nigeria. Five brands of Portland cement commonly available in Nigeria were investigated through series of tests conducted to determine their strength characteristics, setting time, soundness, workability and fineness among others and examined if they meet the minimum standard as stipulated by the British Standard Institute. The five brands of cement considered were Dangote, Elephant, Burham, Diamond and Purechem. The results show that all the brands examined meet the British Standard requirements. Burham cement was fastest with initial setting time of 100 minutes ahead of other, while Dangote cement was the least with initial setting time of 180 minutes. The strengths characteristics of the five brands are similar with slight difference recorded. Dangote cement had the highest strength at 28 days of curing with a crushing load of 474KN while the least strength was recorded Purechem with a crushing load of 370.6 KN.

CHAPTER THREE

3.0 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, Aggregate impact value (AIV) and Aggregate crushing value test (ACV), setting time, soundness and fineness test of cement, slump or workability test of fresh concrete and compressive strength of hardened concrete were carried out at Nnamdi Azikiwe University Civil Engineering Laboratory located inside the school campus.

3.1 Collection and Preparation of Materials

3.1.1 Cement

Four brands of Portland cement namely: Dangote 3x cement designated as DT, Bua cement designated as BU and Larfarge cement designated as LF and Unicem designated as UC were used for the experimental study. This respective 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. Relevant laboratory test performed on the cement was setting time, soundness and fineness test.

Plate 3.1: Samples of Larfarge and Unicem used for the Study

3.1.2 Water

The water sample used for this experiment 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.

3.1.3 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 was determined prior to it incorporation into the concrete.

3.1.4 Coarse Aggregate (Granite)

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

3.2 Sampling Locality

The three different brands of Portland cement (Dangote, Bua and Lafarge), sand and water samples used for the production of concrete were collected at Onitsha and Nnamdi Azikiwe University campus Awka Anambra State. Anambra is located within the south eastern region and lies within longitude 6°45lE to 7°30lE and latitude 6°00lN to 6°30lN. The granite samples were collected from Infrastructure development Company (Popularly known as IDC) located along –Onitsha express way. Enugu state is located within south east Nigeria and lies within a within longitude 6°65lE to 7°30lE and latitude 6°10lN to 6°30lN.

3.3 Laboratory Investigation

This section presents the experimental procedure and laboratory tests that were adopted for the project work. The tests conducted was conducted for all the constituents of concrete and this include: sieve analysis test for fine, coarse aggregate, specific gravity of fine and coarse aggregate, setting time, soundness and fineness test of cement, slump or workability test of fresh concrete and compressive strength of hardened concrete were carried out at Nnamdi Azikiwe University Civil Engineering Laboratory located inside the school campus. Below is a description of test procedures and apparatus:

3.3.1 Specific Gravity of Fine Aggregate

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

The apparatus employed for this experiment includes:

1. Density bottle of 50ml capacity and a stopper.
2. Desiccator containing anhydrous silica gel.
3. Thermostatically controlled oven with temperature of about 80-110^{O}C.
4. Weighing balance of 0.01g sensitivity.
5. Mantle heater.
6. Plastic wash bottle.
7. Distilled water.

8 Funnel

9 Thin glass rod for stirring.

10 425um Sieve.

11 Dry piece of cloth for cleaning.

12 Masking tape for identification of sample.

13 Exercise book and pen for recording of results.

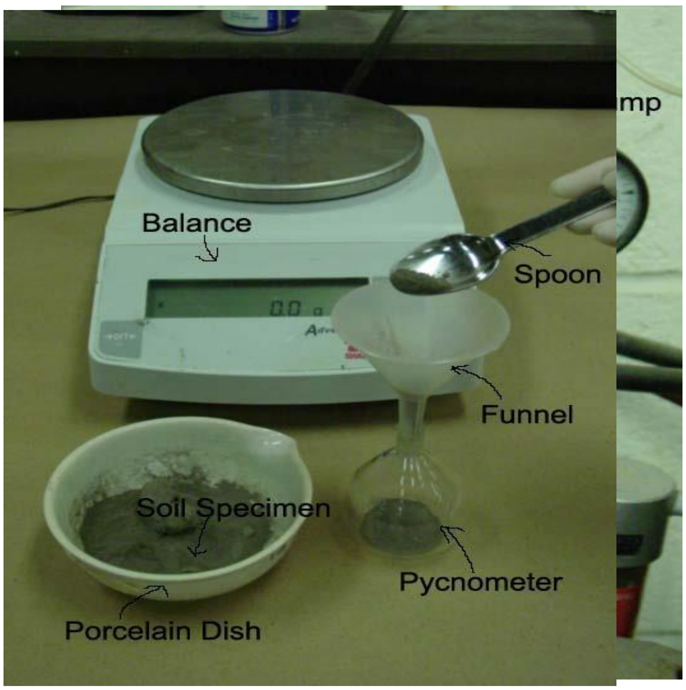

Plate 3.2 Apparatus used for Specific Gravity Test (Source: Braja, 2006)

Test Procedure

1 The density bottle properly cleaned and rinsed with distilled water, thereafter oven- dried and then cooled it in a desiccator so as to remove any moisture present.

2 The empty clean and dry density bottle was weighed and recorded as (M_1).

3 About 10-15g of soil passing through 425um sieve was placed inside the density bottle, weigh and the weight of density bottle +dry soil + stopper was recorded as (M_2).

4 Distilled water was added to fill about half to three-fourth of the density bottle, and then the sample was soaked for 24hrs (The time stated is to enable complete settlement of the soil particle which is evident when clear water appears above the submerged soil).

5 The density bottle was gently stirred using thin glass rod and thereafter connected to a mantle heater to de-air the sample, the sample was not allowed to boil over.

6 After agitation, the sample was allowed to cool at room temperature and then filled with distilled water up to the specified mark (at lower meniscus level), the exterior surface of the density bottle was cleaned with a clean dry cloth and the weight of the density bottle + stopper +soil filled with water was determined and recorded as (M_3).

7 The density bottle was emptied, cleaned and rinsed with distilled water, then filled with distilled water up to the same mark. The exterior surface of the density bottle was cleaned with a clean dry cloth and the weight of the density bottle filled with distilled water + stopper was determined and recorded as (M_4).

8 The test procedure was repeated for two more trials and the average specific gravity value was obtained from the total no of trial, the variation in the specific gravity result obtained for each trial must not exceed 2%, otherwise repeat the experiment.

The Procedure for Computation of result obtained are as follows:

Specific gravity (G_S) = $\frac{(M2-M1)}{(M2-M1)-(M3-M4)}$

Where M_1= weight of density bottle + stopper

M_2= Weight of density bottle + air-dried soil + stopper.

3.3.2 Specific Gravity of Coarse Aggregate

The specific gravity of aggregate is defined as the ratio of aggregate to the weight of equal volume of water (Braja, 2006). The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Aggregate having low specific gravity are generally weaker than those with high specific gravity (Braja, 2006). This property helps in general identification of aggregate.

Apparatus Employed

1 Wires mesh Bucket or perforated container of convenient sizes with thin wire hangers for suspending it from a balance.
2 Pycnometer of 1000ml.
3 Set up consisting of container for filling water and suspending the wire basket in it and airtight container of capacity similar to that of a bucket, a shallow tray, two dry absorbent clothes.

Test Procedure

1. About 2 kg of aggregate sample is taken, washed to remove fines and then placed in the wire basket. The wire basket is then immersed in water, which is at a temperature of 22^0C to 32^0C.
2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket 2mm above the base of the tank and allowing it to drop, 25 times at a rate of about one drop per second.
3. The basket, with aggregate are kept completely immersed in water for a period of 24 ± 0.5 hour.
4. The basket and aggregate are weighed while suspended in water, which is at a temperature of 22^0C to 32^0C.
5. The basket and aggregates are removed from water and dried with dry absorbent cloth.
6. The surface dried aggregates are also weighed.
7. The aggregate is placed in a shallow tray and heated to about 110^0C in the oven for 24 hours. Later, it is cooled in an airtight container and weighed.

3.3.3 Aggregate Impact Value Test (AIV)

The property of a material to resist impact is referred to as toughness (TELM, 2013). Due to movement of vehicles to the road, the aggregate are subjected to impact resulting in their breaking down into small pieces (TELM, 2013). The aggregate should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test.

The aggregate impact value test is a measure of its resistance to sudden impact or shock which may differ from it resistance to gradually applied compressive load.

Test Apparatus

1 A cylindrical steel cup of internal diameter 102mm, depth 50mm and minimum thickness 6.3mm.

2 A metal hammer weighing 13.5 to 14kg with the lower end cylindrical in shape and 50mm long, 100mm in diameter with a 2mm chamfer at the lower edge and case hardened. The hammer should slide freely between vertical guides and be concentric with the cup.

3 A cylindrical metal mould having an internal diameter of 75mm and depth 50mm for measuring aggregates.

4 Tamping rod 10mm in diameter and 230mm long and rounded at one end.

5 A weighing balance of capacity not less than 500g, readable and accurate up to 0.1g.

6 A testing weighing machine 45 to 60kg, having a metal base with a plane lower surface not less than 30cm in diameter. It is supported on level and plane concrete floor of minimum 45mm thickness. The machine should have provision for fixing it base.

Plate 3.3: Apparatus Used for Aggregate Impact Value Test

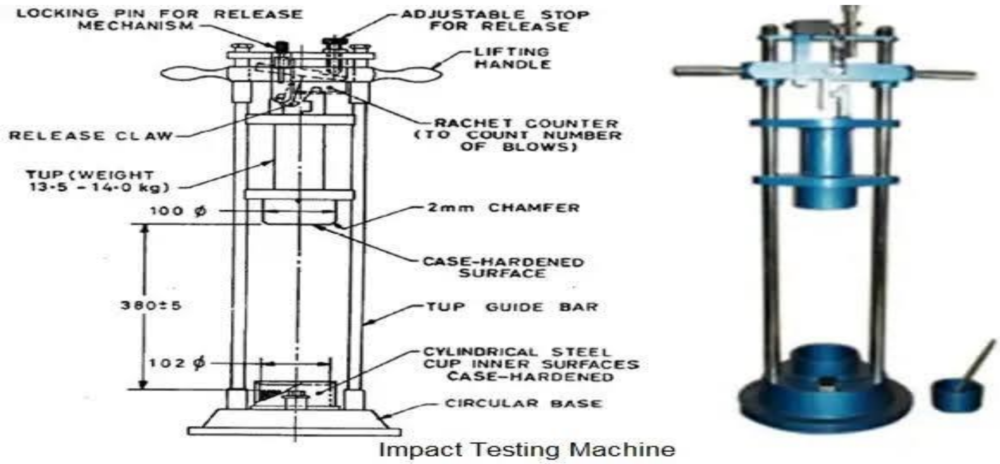

Plate 3.3.1: Apparatus Used for Aggregate Impact Value Test.

Test Procedure

1. The aggregate used for the experimental study was dried by heating at 100^0C-110^0C for a period of 4 hours and then allowed to cool.
2. The material was sieved through 12.5mm and 10mm sieve. The aggregate passing through 12.5mm and retained on 10mm sieve comprises the test material.
3. The aggregate passing through the 10mm sieve referred to as the test material was poured in a cylindrical metal mould about one- third the volume of the mould.
4. The aggregate was compacted evenly by giving 25 no of blows with the aid of the tamping rod.
5. The remaining layers of the test aggregate were added into the mould until full and compacted evenly with 25 no of blows.
6. The surplus aggregate was strike off using a spatula or straight edge.
7. The net weight of the aggregate was determined to the nearest gram.
8. The impact machine was brought to rest without wedging so that it is rigid and the column guides are vertical.
9. The cup was fixed firmly to the base of the machine; the test sample was placed and compacted evenly by giving 25 gentle strokes with the aid of a tamping rod.
10. The hammer was raised until its lower face is 380mm above the surface of the aggregate sample in the cup and allowed to fall freely on the aggregate sample. The aggregate sample was given 15 blows at an interval not less than one second between successive blows.

11 The crushed aggregate was removed from the cup and sieved through 2.36mm sieve until no further significant amount passes in one minute. The fraction passing through the sieve was weighed to an accuracy of 1gm and the fraction retained on the sieve was also weighed.

12 The test observation was noted down and the aggregate impact value was computed.

3.3.4 Aggregate Crushing Value Test

The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under gradually applied compressive load (TELM, 2013). Crushing value is a measure of the strength of the aggregate, aggregate with higher strength should have a minimum crushing value.

Apparatus Used

1 A weighing balance readable to an accuracy of 1gm

2 IS Sieve sizes of 2.36mm, 10mm and 12.5mm.

3 A compression testing machine capable of applying a load of 40 tonnes and which can be operated to give a uniform rate of loading so that the maximum load is reached in 10 minute.

4 Cylindrical metal mould of sufficient rigidity to retain its form under rough usage having an internal diameter of 11.5cm and height of 18cm.

5 A tamping rod.

Plate 3.4: Apparatus Used for Aggregate Crushing Value Test.

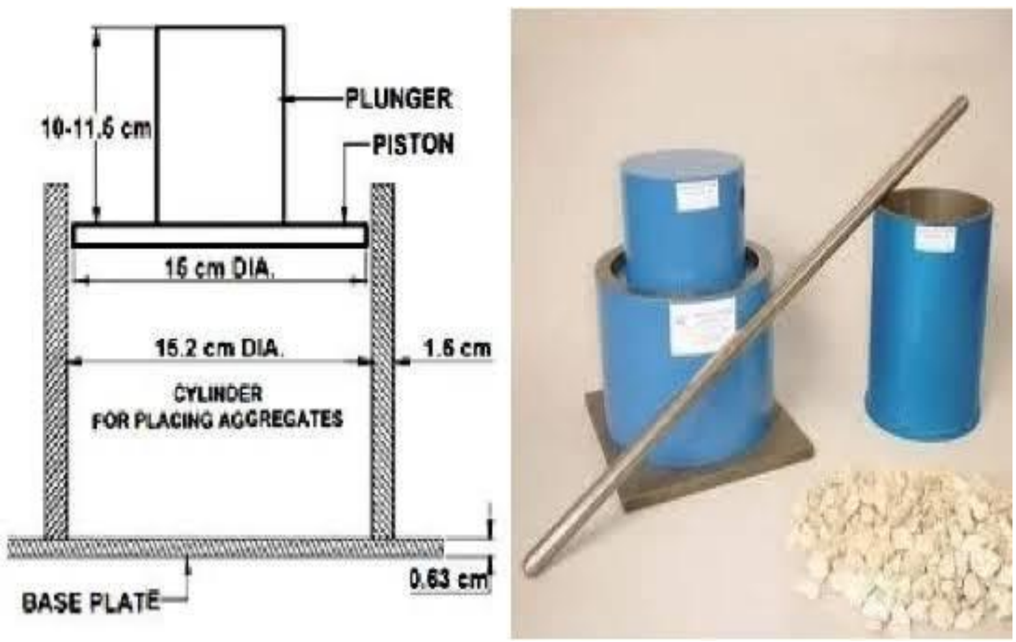

Plate 3.4.1: Apparatus Used for Aggregate Crushing Value Test.

Test Procedure

1 The aggregate used for the experimental study was dried by heating at 100^0C-110^0C for a period of 4 hours and then allowed to cool.

2. The material was sieved through 12.5mm and 10mm sieve. The aggregate passing through 12.5mm and retained on 10mm sieve comprises the test material.
3. The cylindrical mould was assembled into position and the test sample was added to about one-third the volume of the mould.
4. The test aggregate was subjected to compaction by giving 25 no of blows with the aid of tamping rod.
5. The other layers was added and compacted evenly with the surface of the aggregate leveled to flush with the top surface of the mould using a straight edge.
6. The plunger was inserted so that it rest horizontally on the surface of the test aggregate, care was exercised to ensure that there was no collision between the plunger and the cylinder.
7. The apparatus with the test sample with the plunger in position was placed between the plates of the testing machine.
8. The load was applied at a uniform rate as possible so that the total load is reached in 10 minutes.
9. The load was released and the whole of the material is removed from the cylinder and sieved on 2.36mm IS sieve.
10. The fraction passing through the sieve was weighed and recorded.
11. The test observation was noted down and the aggregate crushing value was computed.

3.3.5 Particle Size Distribution Test

Sieve analysis is a procedure used to assess the particle size distribution of a granular material Atkinson (2000). 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.

Soil possesses a number of physical characteristics which can be used as aid to identify it sizes in the field. A handful of soil rubbed through the finger can yield the following:

1. Sand and other coarser particle are visible to the naked eye.
2. Silt particle becomes dusty and are easily brushed off.
3. Clay particle are greasy and sticky when wet and hard when dry and have to be scrapped or washed off hand and boot

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

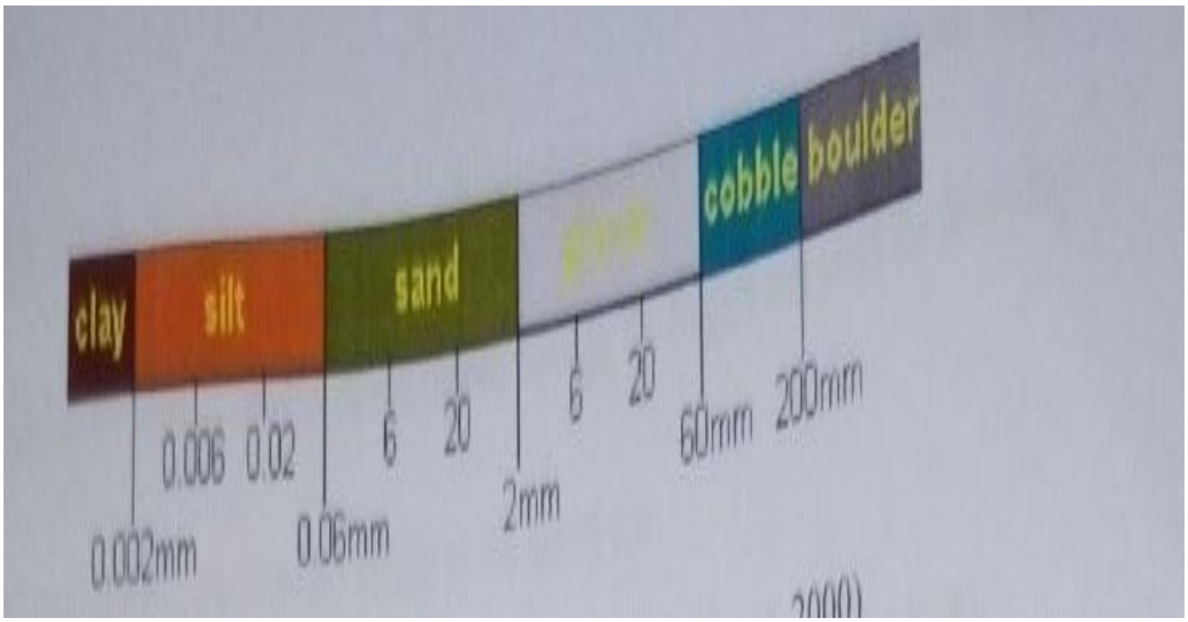

Fig 3.0 Ranges for grain Sizes of different Soil type (Atkinson, 2000).

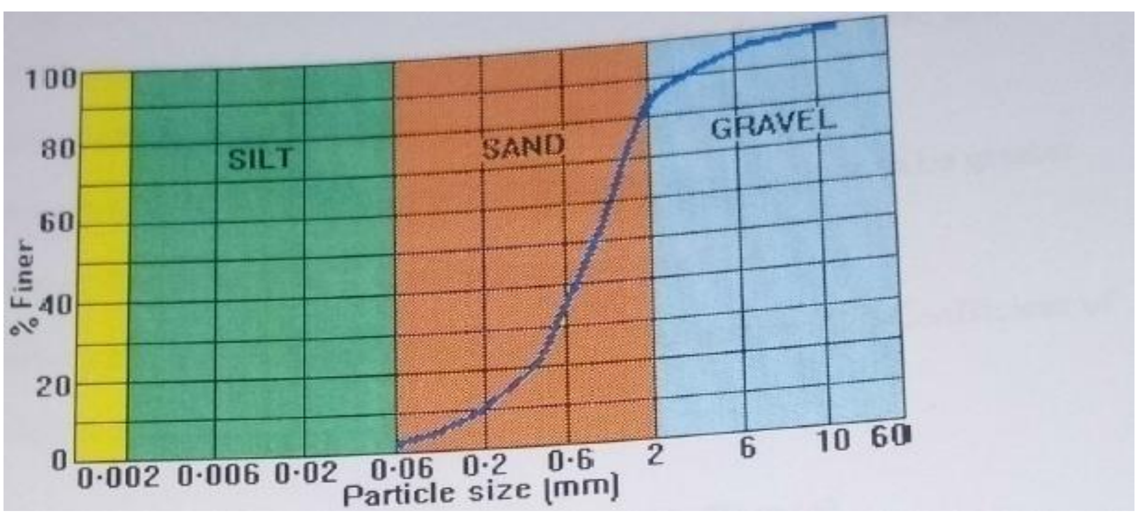

Figure 3.1 Grading Curve Ranges for Different Soil Types (Atkinson, 2000).

The apparatus needed for this experiment is listed below:

1. Stack of sieves including pan and cover.
2. Mechanical sieve shaker.
3. Weighing balance of 0.01g sensitivity.
4. Hand brush
5. Mortar and pestle (Used for crushing if the sample is conglomerated or lumped)
6. Thermostatically controlled Oven (With temperature of about $80^{O}C$-$110^{O}C$).
7. Masking tape for identification of sample.
8. Exercise book and pen for recording of result.
9. The calculation for attaining Coefficient of uniformity and Coefficient of curvature are outlined below.

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

Cumulative percentage retained = $\sum Percentage retained$ (%)

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

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

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

Where

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

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

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

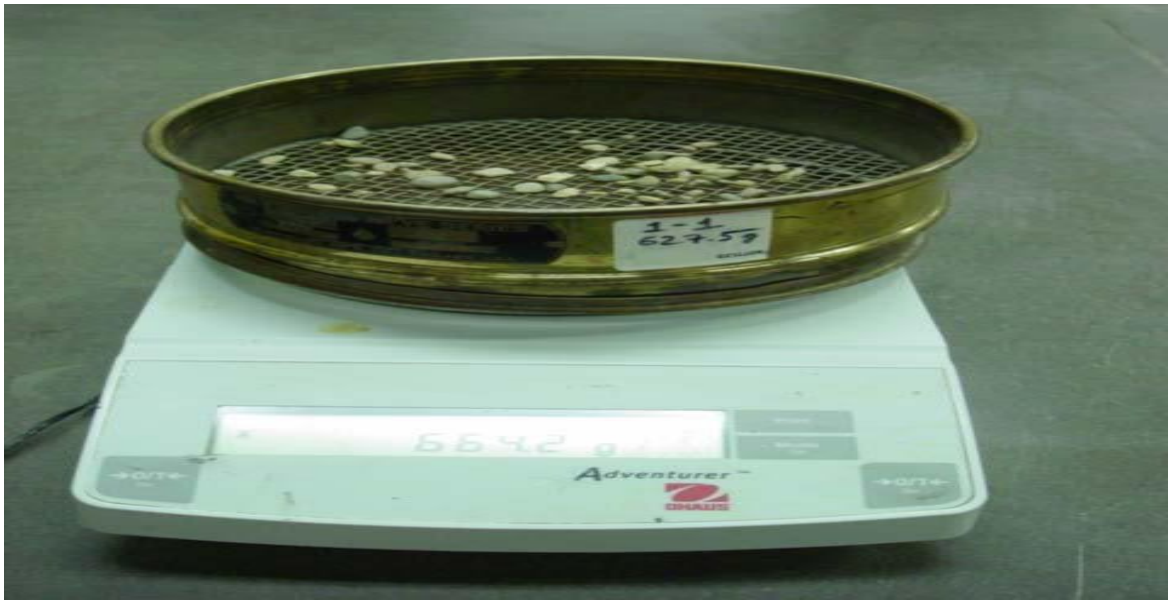

Plate 3.5: Apparatus for Particle Size Distribution Test (Source: Braja, 2006).

Plate 3.5.1: Apparatus for Particle Size Distribution Test (Source: Braja, 2006).

Test Procedure

1 The stack of sieves to be used for the experiment was properly cleaned using hand brush.

2 About 500g of air-dried soil sample was weighed with the aid of a weighing balance.

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

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

5 The sample was removed from the oven and the weight was determine (net weight) by deducting the weight of plate from the weight of plate and soil.

6 The stacks of sieve was arranged in the ascending order, placed in a mechanical sieve shaker, and thereafter the sample was poured and connected to the shaker for about 10-15 minute.

7 The sieve shaker was disconnected and the mass retained on each of the sieve sizes was determined.

8 The percentage retained, Cumulative percentage retained and Cumulative percentage finer was determined.

9 The graph of sieve Cumulative percentage finer against sieve sizes was plotted.

10 D10, D30 and D60 were determined from the plotted graph.

11 The Coefficient of Curvature and Coefficient of Uniformity was determined and used to classify the soil adopting the American Association of State Highway and Transportation Official (AASHTO) and Unified Soil Classification System (USCS) respectively.

3.3.6 Fineness Test of Cement

This test is carried out to check the proper grinding of cement. Fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also rate of evolution of heat. Finer cement offers greater surface area for hydration and hence faster the development of strength. Different cements are ground to different fineness. The disadvantage of fine grinding is that it is susceptible to air set and early deterioration. Maximum number of particles in a sample of cement should have a size less than 100 microns. The smallest size should have a size about 1.5 microns.

The apparatus employed for fineness test include:

1. IS-Sieve no: 9 (90 microns confirming to IS 460-1962)
2. Weighing balance with 100gm weighing capacity
3. Tray and a brush.

Test Procedure

1. Weigh 100 grams of cement and placed in an IS-Sieve no 9

2. Breaking down any air set lumps by fingers.

3. Holding the sieve with both the hands, sieve it continuously for 5-10 minutes until all the fine material is passing through.

4. While sieving rotate the continuously taking care that the cement does not spill out.

5. Collect the residue on the sieve and weigh it.

The Fineness is computed as follows:

Weight of cement taken W1 =

Weight of residue after sieving W2 =

Percentage of fineness of cement = Weight of residue retained weight of cement×100

3.3.7 Soundness Test 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.

The apparatus employed for Soundness test include:

1. Le- Chatlier test apparatus conform to IS: 5514-1969
2. Weighing Balance
3. Gauging Trowel
4. Water Bath

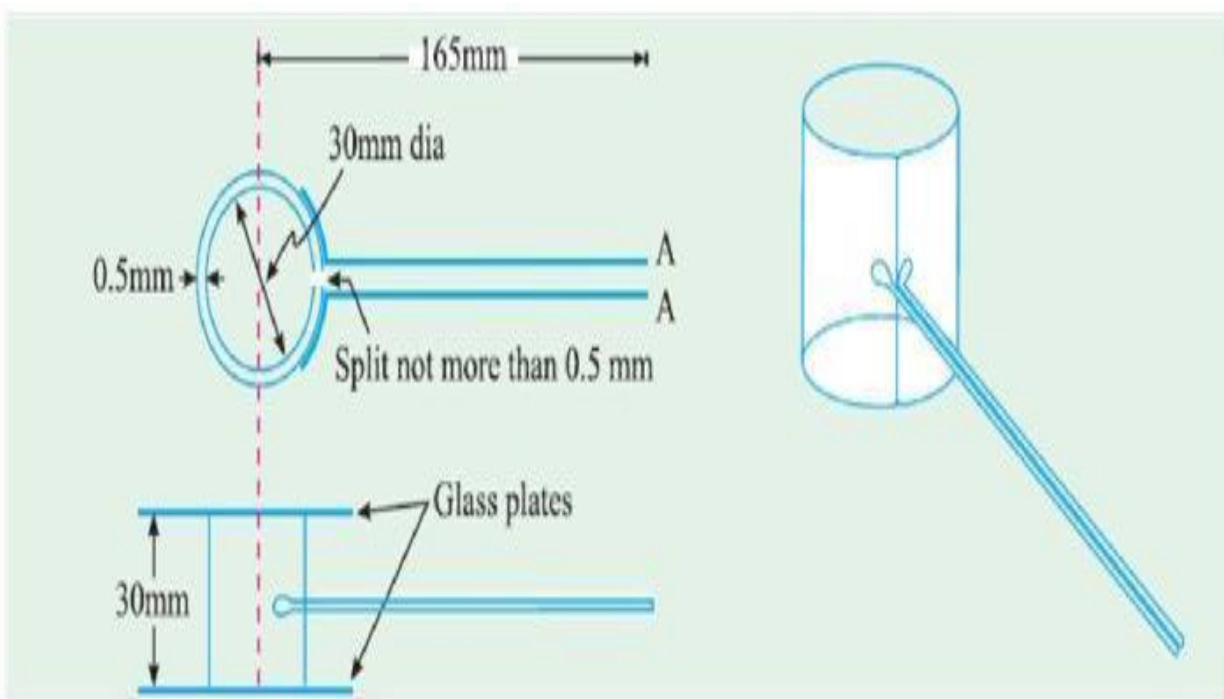

Plate 3.6: Apparatus used for Soundness Test

Test Procedure

1. Place the lightly oiled mould on a lightly oiled glass sheet and fill it with cement paste formed by gauging cement with 0.78 times the water required to give a paste of standard consistency
2. The paste shall be gauged in the manner and under the conditions prescribed in experiment No.1, taking care to keep the edges of the mould gently together while this operation is being performed.
3. Cover the mould with another piece of lightly oiled glass sheet, place a small weight on this covering glass sheet and immediately submerge the whole assembly in water at a temperature of 27 ± 2°C and keep there for 24 hours.
4. Measure the distance separating the indicator points to the nearest 0.5 mm Submerge the mould again in water at the temperature prescribed above.

5. Bring the water to boiling, with the mould kept submerged, in 25 to 30 minutes, and keep it boiling for three hours. Remove the mould from the water, allow it to cool and measure the distance between the indicator points.

6. The difference between these two measurements indicates the expansion of the cement. This must not exceed 10 mm for ordinary, rapid hardening and low heat Portland cements. If in case the expansion is more than 10mm as tested above, the cement is said to be unsound.

3.3.8 Setting Time Test of Cement

Initial setting time is regarded as the time elapsed between the moments that the water is added to the cement to the time that the paste starts losing its plasticity (IS, 4031, 1988). The final setting time is the time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite Pressure. The temperature of moulding room, dry materials and water shall be maintained at 27 ± 2°C. The relative humidity of the laboratory shall be 65 ± 5 percent.

The apparatus used for setting time test includes:

1. Weighing balance
2. Vicat apparatus set up
3. Stop watch
4. Gauging trowel
5. Non porous plate

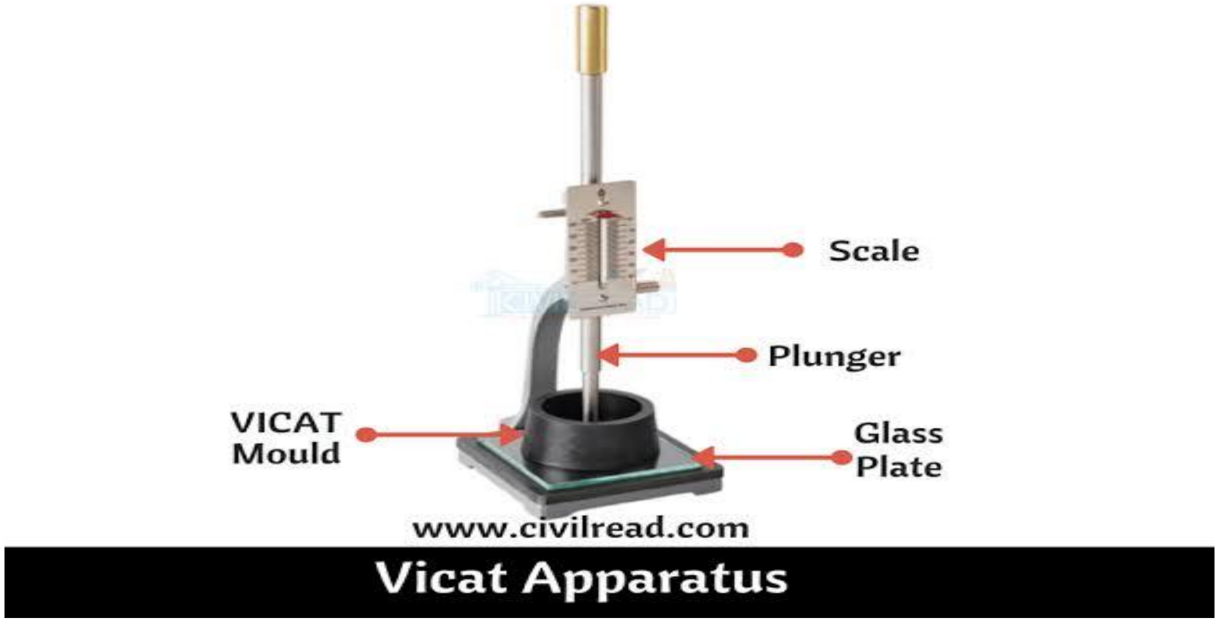

Plate 3.7: Vicat Apparatus Set up used for Setting Time Test

Plate 3.7.1 Gauging Trowel used for Setting Time Test

Plate 3.7.2 Stop Watch used for Setting Time Test

Plate 3.7.3 Weighing Balance used for Setting Time Test

Test Procedure

1 The cement paste was prepared by gauging the cement with 0.65 times the water required to give a paste of standard consistency. Distilled water was used in preparing the cement paste.
2 The stop watch was started at the instance water was added to the cement.
3 The vicat mould was filled with the cement paste using the gauging trowel with the mould resting on a non porous plate.
4 The surface of the cement paste was leveled with the top of the mould using the gauging trowel
5 The cement block confined in the mould was kept in a moist room for determination of setting time.

Determination of Initial Setting Time

1 The cement block confined in the mould resting on a non porous plate was placed in a Vicat apparatus set up.
2 The needle in the Vicat apparatus set up was lowered until it comes in contact with the surface of the test block thereafter; the needle was released allowing it to penetrate into the test block.
3 The procedure was repeated until the needle pierced the cement block confined in the mould beyond 5.5mm measured from the bottom of the mould.
4 The period elapsing between the time water is added to the cement and the time the needle fails to pierce the test block to a point beyond 5.5mm measured from the bottom of the mould is regarded as the initial setting time of the cement.

Determination of Final Setting Time

1 The needle in the Vicat apparatus was replaced by the needle with an annular attachment.
2 The cement was considered to have finally set when upon applying the needle gently to the surface of the test block, the needle made an impression while the attachment fails to do so.

3. The period elapsing between the time water is added to the cement and the time at which the needle makes an impression on the surface of the test block while the attachment fails to do so shall be regarded as the final setting time of the cement.
4. In the event of scum forming on the surface of the test block, the bottom of the test block was used for the determination.

3.3.9 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:

1. Clean the internal surface of the mold and apply oil.
2. Place the mold on a smooth horizontal non- porous base plate.
3. Fill the mold with the prepared concrete mix in 4 approximately equal layers.
4. 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.
5. Remove the excess concrete and level the surface with a trowel.
6. Clean away the mortar or water leaked out between the mold and the base plate.
7. Raise the mold from the concrete immediately and slowly in vertical direction.
8. 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.

a) **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.
b) **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.

c) **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.

d) **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.

Plate 3.8: Apparatus for Slump Test

3.3.10 Compressive Strength Test of Hardened Concrete

This is aimed at determining the compressive strength of concrete made from different brands of cement. It consists of applying a compressive axial load to molded cubes at a rate which is within a prescribed range until failure occurs.

The Apparatus Used includes:

1. **Testing Machine -** The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified in 5.5. The permissible error shall be not greater than ± 2 percent of the maximum load.
2. **Cube Moulds -** The mould shall be of 150 mm size conforming to IS: 10086-1982.
3. Weights and weighing device
4. Tools and containers for mixing,
5. Tamper (square in cross section)

Preparation of Samples

For this research concrete mix design of 1:2:4 with water/cement ratio of 0.55 was used. The materials used were batched by weight and mixing was carried out manually and separately for each of the Ordinary Portland Cement (OPC) under laboratory conditions. 150mm×150mm×150mm metallic moulds with oil smeared on the inside of the mould to avoiding sticking was used for casting the concrete specimen after obtaining a uniform and consistent mixture. Vibration to remove entrapped voids was done manually and the concrete specimens were left in the mould for 24hours after casting before they were removed from the mould.

Test Procedure

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

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

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

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

5. Mould - Test specimens cubical in shape shall be 15 × 15 × 15 cm. If the largest nominal size of the aggregate does not exceed 2 cm, 10 cm cubes may be used as an alternative. Cylindrical test specimens shall have a length equal to twice the diameter.

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

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

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

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

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

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

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

The compressive strength of concrete cube is computed as follows:

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

Where applied load (N) = Force

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

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

For 220kN = 220× 1000 = 220,000N

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

Compressive Strength = $\frac{220,000N}{22,500mm2}$ = 9.78N/mm^2

Plate 3.9: Universal Testing Machine for Compressive Strength Test

CHAPTER FOUR

RESULTS AND DISCUSSION

During the course of the experimental study, certain results were obtained which was valuable in evaluating the effect of different brands of Portland cement on compressive strength 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

Properties	Granite	Sand	Bua	Dangote 3x	Unicem	Lafarge
Specific Gravity	2.61	2.55	-----	-----	----	-----
Coefficient of Uniformity (Cu)	1.42	-----------	-----	-----	-----	-----
Coefficient of Curvature (Cc)	0.8	-------	-----	-----	----	----
Percentage Passing Sieve Size 0.075mm	------------	22.36	-----	-----	-----	-----
Percentage Passing Sieve Size 4.75mm	1.63	----------	-----	-----	-----	-----
AASHTO Classification System	A-1-b	A-2-4	-----	------	-------	------
Unified Soil Classification System	GC	SM	------	------	------	-----
Aggregate Impact Value (%)	27.6	--------	---------	---------	-------	-------

Aggregate Crushing Value (%)	**26.1**	**-------**	**---------**	**------**	**------**	**-------**
Initial Setting Time (min)	**----**	**-----**	**30**	**30**	**28**	**28**
Final Setting Time (min)	**------**	**------**	**600**	**580**	**560**	**600**
Fineness (%)	**-----**	**-----**	**24.8**	**26.4**	**28.6**	**27.6**
Soundness (mm)	**-------**	**--------**	**8.3**	**6.7**	**6.4**	**8.3**

Table 4.2: Slump Test Result for the Fresh concrete at 1: 2: 4 and w/c ratio of 0.5

Portland cement Type	Height of Cone (mm)	Height of Collapse (mm)	Slump (mm)	Slump Type
Bua	**300**	**260**	**40**	**True Slump**
Dangote 3x	**300**	**260**	**40**	**True Slump**
Unicem	**300**	**245**	**55**	**Shear Slump**
Lafarge	**300**	**250**	**50**	**Shear Slump**

Table 4.3: Density Test Results for Bua cement

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
7 days	**7.45**		**2207**	
	7.52	**7.52**	**2228**	**2229**
	7.6		**2252**	
14 days	**7.75**		**2296**	
	7.82	**7.79**	**2317**	**2309**
	7.8		**2311**	
21 days	**8.14**		**2412**	
	8.20	**8.15**	**2430**	**2414**
	8.11		**2400**	

28 days	**8.24**	**8.22**	**2441**	**2436**
	8.15		**2415**	
	8.28		**2453**	

Table 4.4: Density Test Results for Dangote 3x cement

Curing days (Age)	**Weight (kg)**	**Average Weight (kg)**	**Density (kg/m^3)**	**Average Density (kg/m^3)**
7 days	**7.58**	**7.62**	**2246**	**2257**
	7.65		**2267**	
	7.62		**2258**	
14 days	**7.85**	**7.82**	**2326**	**2318**
	7.82		**2317**	
	7.80		**2311**	
21 days	**7.9**	**7.91**	**2341**	**2343**
	7.94		**2353**	
	7.88		**2335**	
28 days	**8.25**	**8.31**	**2444**	**2463**
	8.31		**2462**	
	8.38		**2483**	

Table 4.5: Density Test Results for Lafarge cement

Curing days (Age)	**Weight (kg)**	**Average Weight (kg)**	**Density (kg/m^3)**	**Average Density (kg/m^3)**
7 days	**7.68**	**7.73**	**2276**	**2291**
	7.72		**2287**	
	7.78		**2309**	
14 days	**7.8**	**7.83**	**2311**	**2321**
	7.82		**2317**	
	7.88		**2335**	
21 days	**8.01**	**8.05**	**2373**	**2384**
	7.98		**2364**	
	8.15		**2415**	

28 days	**8.28**	**8.27**	**2453**	**2449**
	8.18		**2424**	
	8.34		**2471**	

Table 4.6: Density Test Results for Unicem cement

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
7 days	**7.78**	**7.81**	**2305**	**2315**
	7.81		**2314**	
	7.85		**2326**	
14 days	**7.84**	**7.90**	**2323**	**2341**
	7.91		**2344**	
	7.95		**2356**	
21 days	**8.18**	**8.24**	**2424**	**2440**
	8.25		**2444**	
	8.28		**2453**	
28 days	**8.34**	**8.35**	**2471**	**2475**
	8.42		**2495**	
	8.31		**2459**	

Table 4.7: Compressive Strength Test Result for Bua cement

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**	**520.5**	**23.13**	**23.24**
		525.6	**23.36**	
		522.4	**23.22**	
14 days	**1: 2: 4**	**538.5**	**23.93**	**24.02**
		540.4	**24.02**	
		542.5	**24.11**	
21 days	**1: 2:4**	**548.5**	**24.38**	**24.54**
		553.3	**24.59**	
		554.8	**24.66**	

28 days	**1: 2: 4**	**558.5**	**24.82**	**24.91**
		560.2	**24.90**	
		562.5	**25.00**	

Table 4.8: Compressive Strength Test Result for Dangote 3x cement

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**	**540.5**	**24.02**	**24.11**
		544.3	**24.19**	
		542.8	**24.12**	
14 days	**1: 2: 4**	**553.8**	**24.61**	**24.69**
		555.2	**24.68**	
		557.8	**24.79**	
21 days	**1: 2:4**	**564.3**	**25.08**	**25.07**
		562.8	**25.01**	
		565.5	**25.13**	
28 days	**1: 2: 4**	**571.2**	**25.39**	**25.38**
		568.8	**25.28**	
		573.4	**25.48**	

Table 4.9: Compressive Strength Test Result for Lafarge cement

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**	**590.5**	**26.24**	**26.33**
		598.6	**26.60**	
		588.4	**26.15**	
14 days	**1: 2: 4**	**598.5**	**26.6**	**27.11**
		602.4	**27.7**	
		608.5	**27.04**	

21 days	**1: 2:4**	**612.4**	**27.22**	**27.26**
		609.2	**27.08**	
		618.5	**27.49**	
28 days	**1: 2: 4**	**624.8**	**27.77**	**27.90**
		628.4	**27.93**	
		630.2	**28.01**	

Table 4.10: Compressive Strength Test Result for Unicem cement

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**	**608.5**	**27.04**	**26.74**
		594.5	**26.42**	
		602.3	**26.77**	
14 days	**1: 2: 4**	**611.8**	**27.19**	**27.21**
		614.5	**27.31**	
		610.2	**27.12**	
21 days	**1: 2:4**	**620.8**	**27.59**	**27.69**
		622.7	**27.68**	
		625.6	**27.80**	
28 days	**1: 2: 4**	**632.4**	**28.11**	**28.25**
		633.5	**28.16**	
		640.8	**28.48**	

4.2 Analysis of Experimental Results

4.2.1 Sieve Analysis

Figure 4.0 is a semi logarithmic plot of the particle size distribution of granite and sand sample respectively. Results obtained revealed that the percentage passing through sieve size 4.75mm for granite was 0.16, coefficient of uniformity and curvature were 1.42 and 0.82 and according to AASHTO classification system, the granite sample was classified as A-1-b and Clayey gravel (SC) according to unified soil classification system. The percentage passing through sieve size 0.075mm for sand was 43.56 and as a result, the sand sample was classified as A-2-4 according to AASHTO

Classification System and Silty sand (SM) according to unified soil classification system. The shape parameters (coefficient of uniformity and coefficient of curvature) for sand sample cannot be obtained from the graph and as a result gradation of the sample cannot be ascertained.

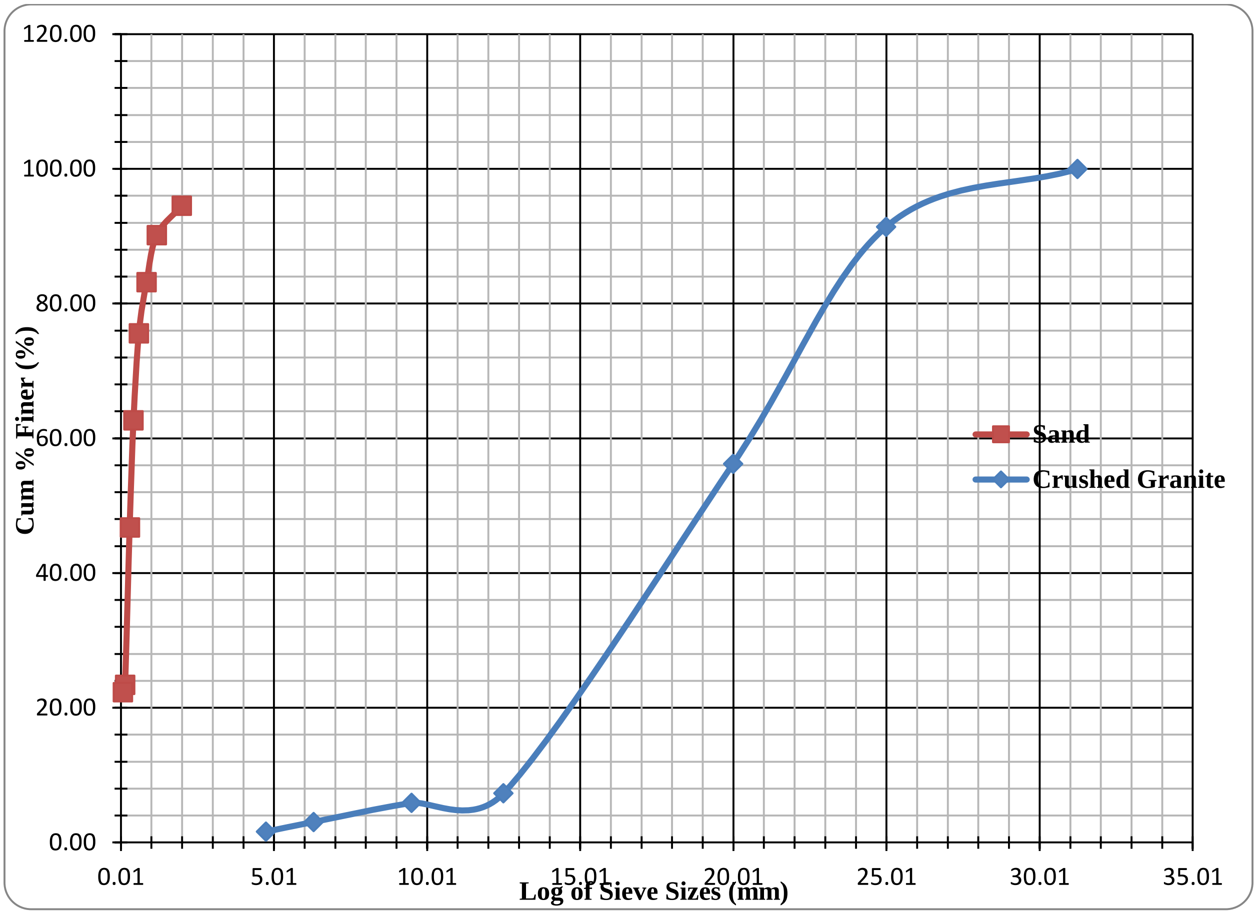

Figure 4.0: Particle Size Distribution Curve for Sand and Granite

4.2.2 Specific Gravity

Figure 4.1 shows the specific gravity values obtained for granite and sand sample respectively. Comparative deduction revealed that granite sample with a specific gravity of 2.61 recorded the highest specific gravity value. The specific gravity of the aggregate sample tested was greater than 2.4 and as a result, they are classified as normal weight aggregate. The classification was done in accordance with the specification given by Popovics, (2014) on weight classification of aggregate based on their respective specific gravity values. Popovics, (2014) stated that aggregate with specific gravity value less than 2.4 are classified as light weight aggregate while aggregate with specific gravity value exceeding 2.4 are classified as normal weight aggregate which correlate with the result obtained by the study. The range of specific gravity values (2.55 -2.61) obtained by the study for sand and granite satisfied ASTM D854-14 requirements which state that the specific gravity of aggregate used for concrete production should lie between 2.55 to 2.9 and therefore, the result obtained justifies the use of this aggregates for the study. This finding is consistent with the works of Apeh and Ogunbode, (2012).

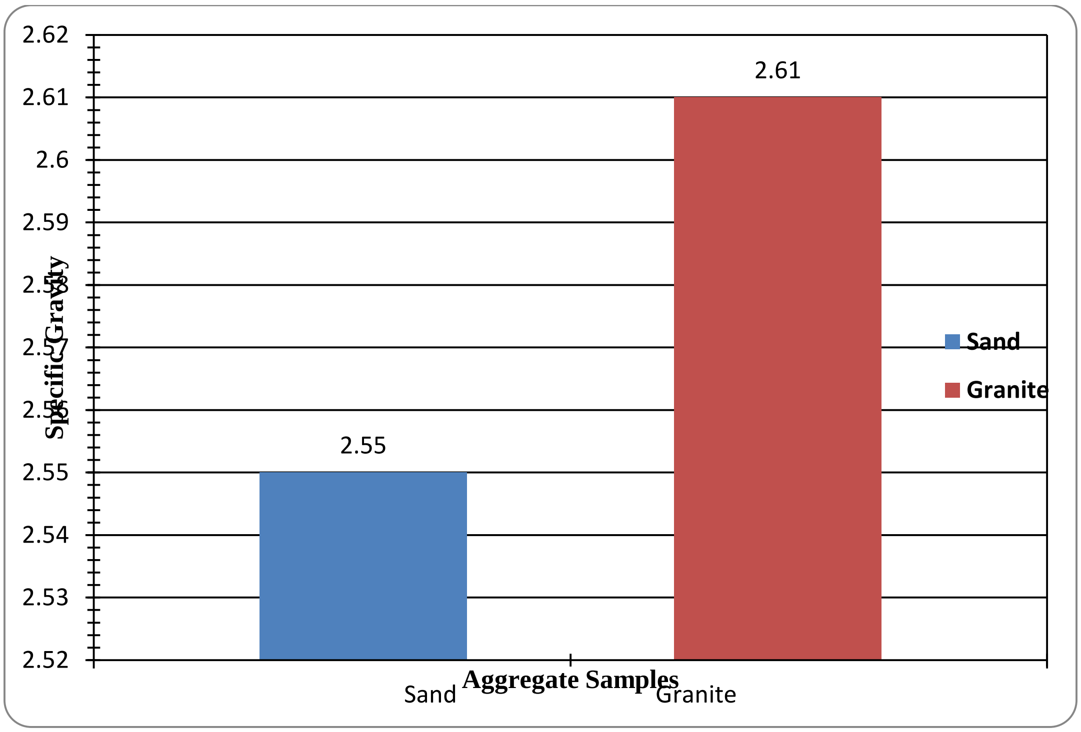

Figure 4.1: Chart Showing the Specific Gravity Values of Sand and Granite

4.2.3 Fineness of Portland cement

The fineness of cement is the property of cement which regulates the level of grinding of cement clinker with gypsum in a milling machine (Ehikhuenmen, et al., 2019). Change in cement fineness has a direct impact to some key properties of cement and concrete ranging from setting time, consistency, workability, tensile, flexural and compressive strength (Liaqat and saeed, 2011). Fineness test results obtained for the selected brands of Portland cement used in the study revealed that the fineness of the different brands of Portland cement ranged from 12.4 – 14.3% with Unicem cement produced the highest value of fineness. The relatively high value of fineness obtained for

Unicem and Larfarge cement is a confirmation to the quick setting time of the cement as fineness increases the setting time of the cement due to large surface area provided for hydration action of the cement with water.

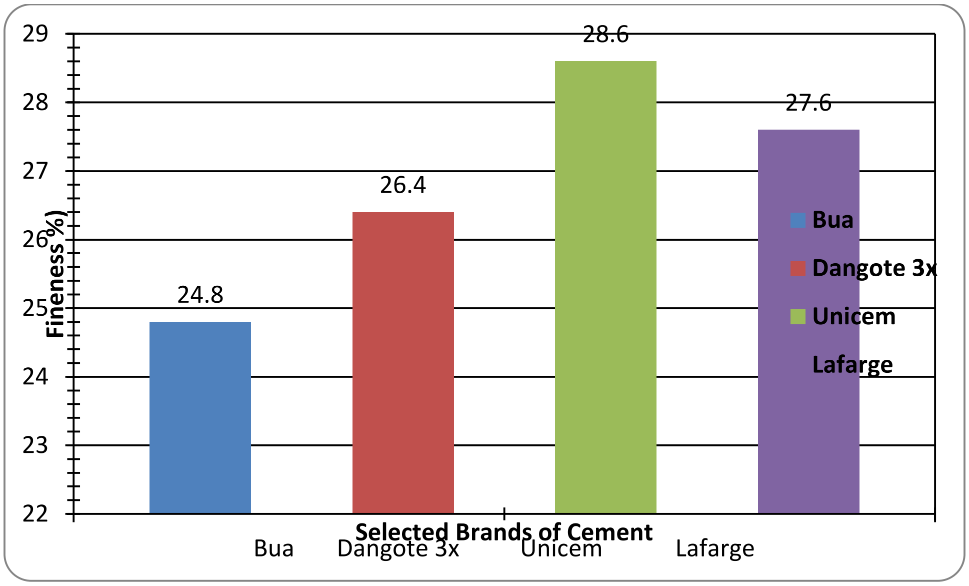

Figure 4.2: Fineness Property of Selected Brands of Portland cement.

4.2.4 Setting Time of Portland cement

Setting time test results obtained from the test conducted for the different brands of Portland cement revealed that the minimum initial setting time of Bua, Dangote 3x, Unicem and Lafarge were 30 and 28 minute while the final setting time varied from 560 minute to 600 minute. Comparative deduction of the initial setting time obtained for the different brands of Portland cement tested shows that Unicem and Lafarge sets relatively faster than Bua and Dangote 3x and as a result, this may pose problem to transportation, placement and compaction of the finished concrete if sufficient care especially regarding timing is not taken into cognizance during the concreting process. The quick initial setting time value obtained for Unicem and Lafarge could be attributable to the fineness property of the cement brand. Comparison of the initial and final setting time values obtained for the different brands of Portland cement with relevant standard revealed that the setting time values obtained satisfied the specification given by BS 4550 part 3: (1978) which state that the initial and final setting time of Portland cement should not exceed 30 minute and 600 minute (10 hours) respectively Past works indicative of this findings are the work of Bamigboye, et al., (2015).

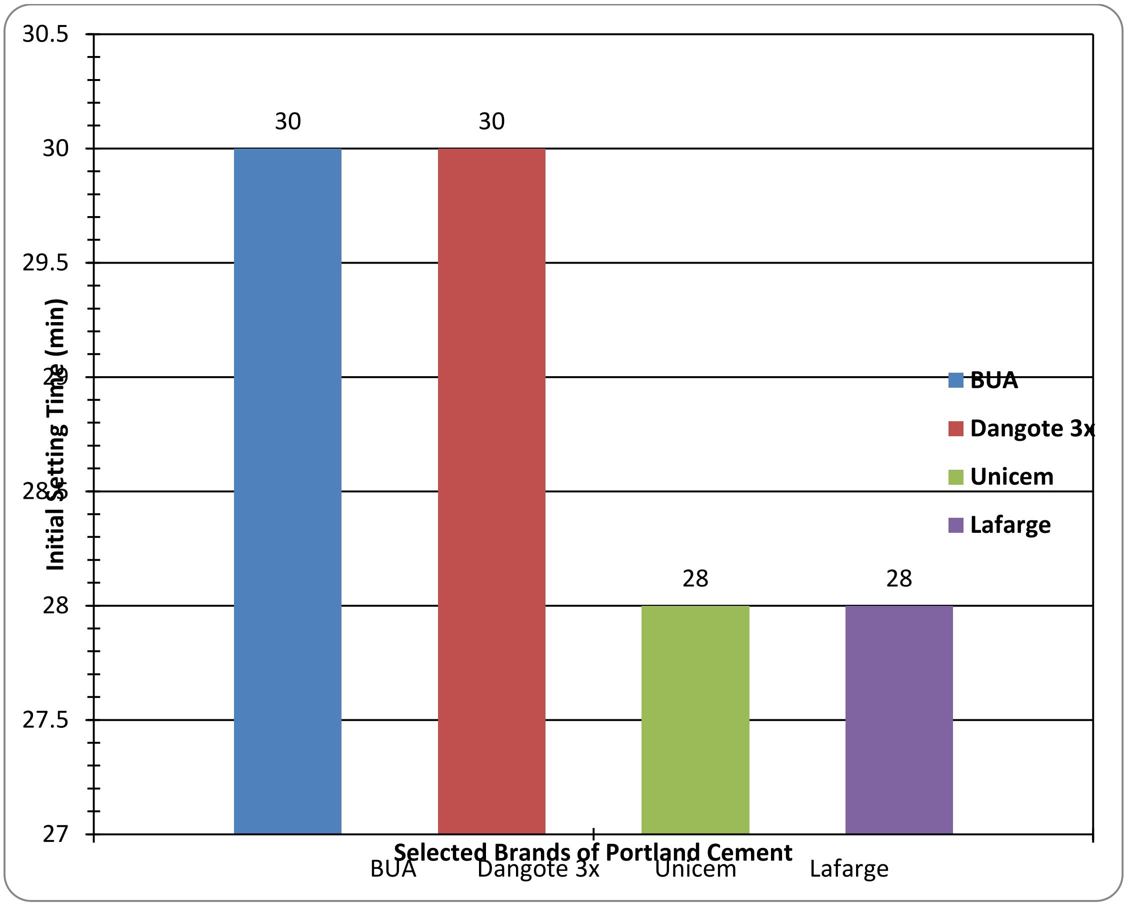

Figure 4.3: Charts Showing the Initial Setting Time of Selected Brands of Portland cement

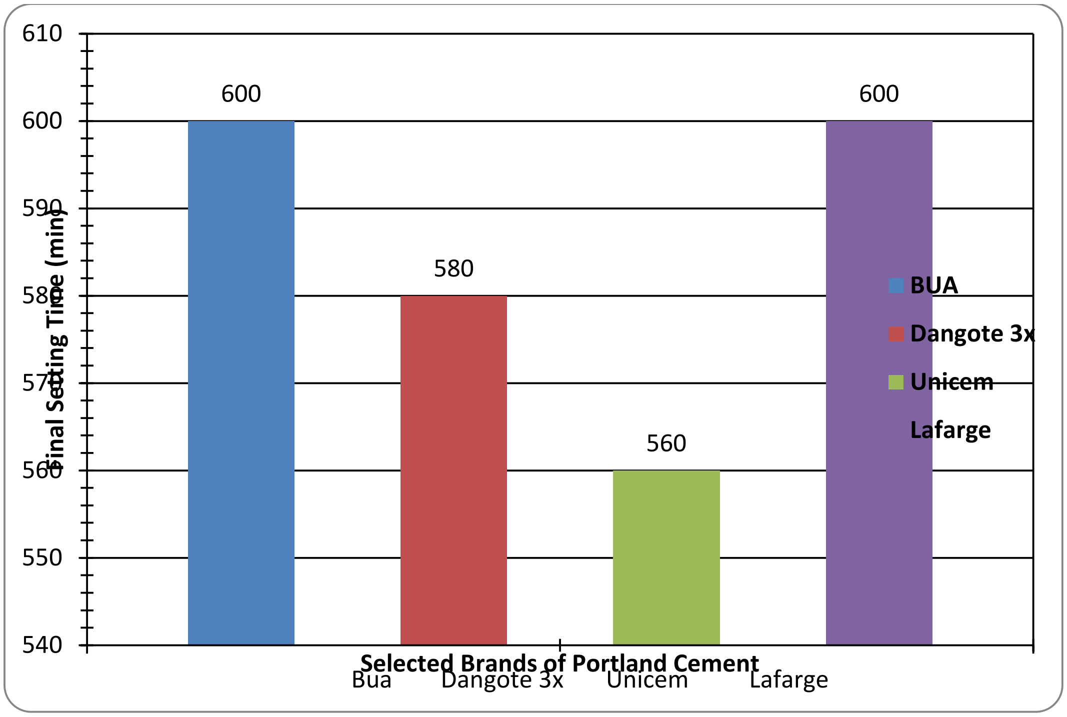

Figure 4.3.1: Charts Showing the Final Setting Time of Selected Brands of Portland cement

4.2.4 Soundness of Portland cement

Soundness of cement refers to the ability of cement to retain its volume after hardening (Usman, et al., 2018). The aim of soundness test of cement is to observe and evaluate the expansion characteristics of cement that is, the ability of cement to retain its volume after setting (Usman, et al., 2018). Tests results revealed that Bua cement produced the highest value of soundness while Lafarge cement produced the lowest value of soundness. The lowest value of soundness produced by Lafarge cement could be attributable to the significant amount of fines present in the cement sample which resulted to uncontrolled expansion when mixed with water. It was also observed that the value of soundness obtained for the different brands of Portland cement employed in the experimental study falls within acceptable limit specified by BSEN, (1995) which state that at the end of the test, the indicator of Lechatelier mold should not expand more than 10mm once the concrete has hardened.

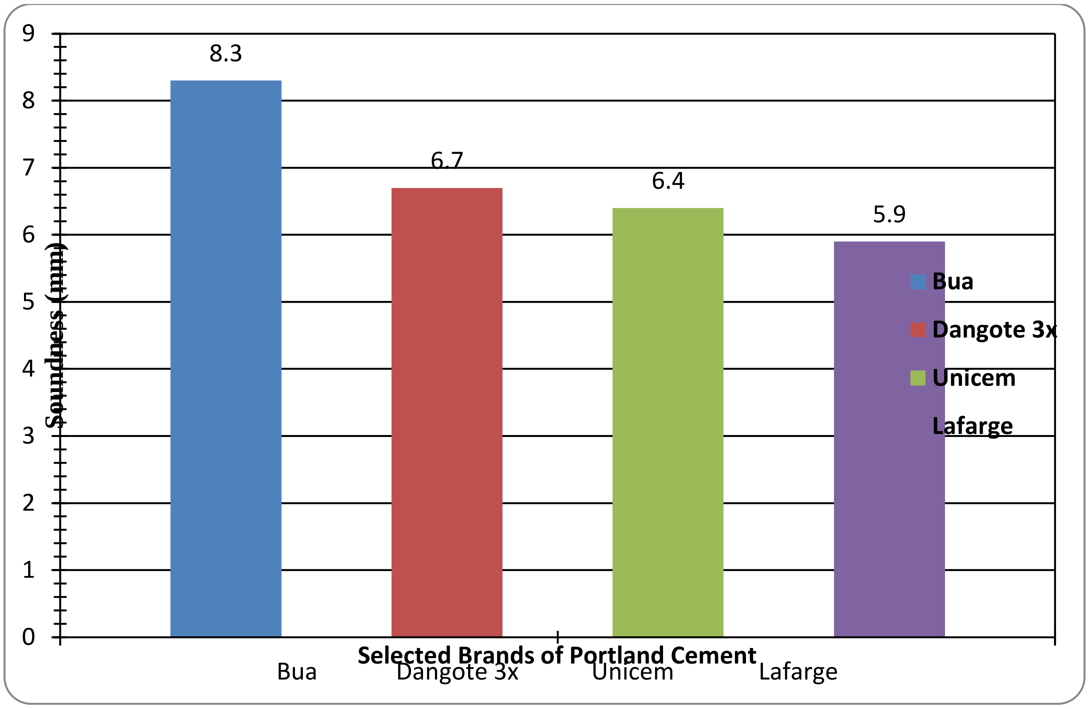

Figure 4.4: Charts Showing the Soundness Values of Selected Brands of Portland cement

4.2.6 Aggregate Impact and Crushing Value

The aggregate crushing test was performed to determine resistance of the aggregate crushing under imposed load. It is a measure of the strength of aggregate which invariably determines the strength of the finished concrete. The aggregate impact test was performed to ascertain the resistance of aggregate to shock. Results obtained from the aggregate crushing and impact test suggest that the impact value and crushing value of aggregates tested were 27.6 and 26.1% respectively. The impact and crushing values obtained for aggregate samples fairly satisfied the specification set by Federal Ministry of Works and Hosing (2007) which stated that the impact and crushing value of aggregates used for concrete production should not exceed 30%. The impact and crushing value obtained suggest that the aggregate is satisfactory for production of concrete using selected brands of Portland cement. The impact and crushing value obtained for the coarse aggregate also met ASTM requirement for normal weight concrete which state that the impact and crushing value of normal weight aggregate must not exceed 45%.

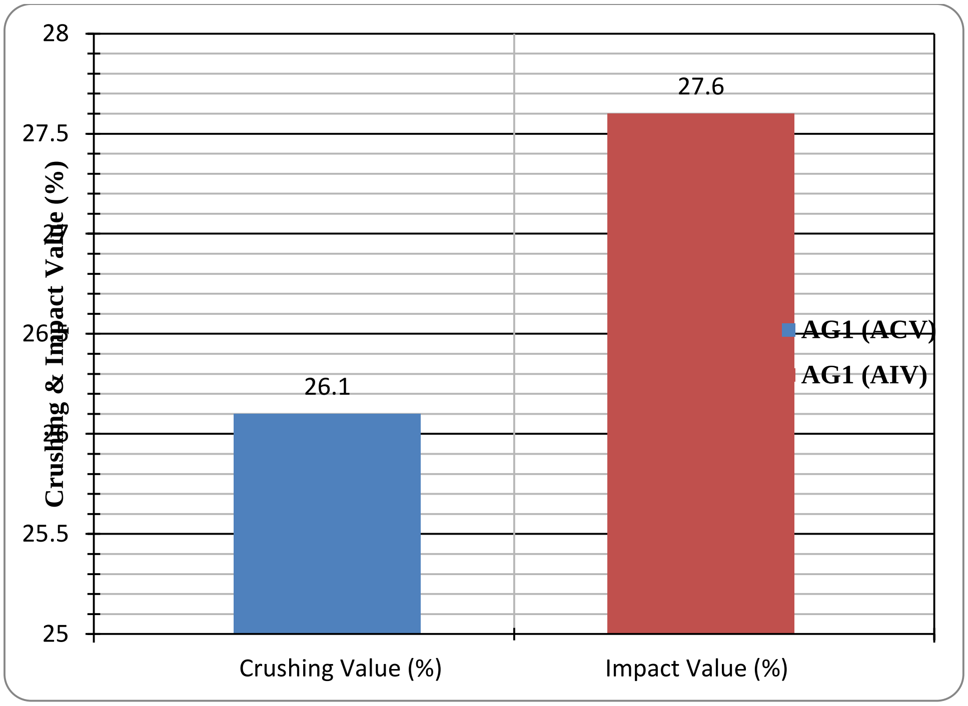

Figure 4.5: Charts Showing the Impact and Crushing Values of Aggregates

4.2.7 Slump (Workability) of Fresh Concrete

Table 4.2 shows the slump value for different brands of Portland cement employed in the study. Results obtained revealed that concrete produced with Unicem cement having a slump value of 55mm recorded the highest slump value while concrete produced with Bua and Dangote 3x having slump of 40mm recorded the lowest slump value. The slump of Bua and Dangote 3x concrete were relatively the same. The high slump recorded concrete produced using Unicem and Lafarge could be attributable to the significant amount of fines present in the cement samples which offers high surface area for hydration of the cement paste. The results therefore suggest that Bua and Dangote 3x cement produced a workable (flow-able) concrete than Unicem and Lafarge cement due to the fact that the slump type formed were true slump as opposed to shear slump formed by concrete produced using Unicem and Lafarge cement brands. Past findings correlative to this study were the works of Bamiboye, et al., (2015) and Yahaya, et al., (2014).

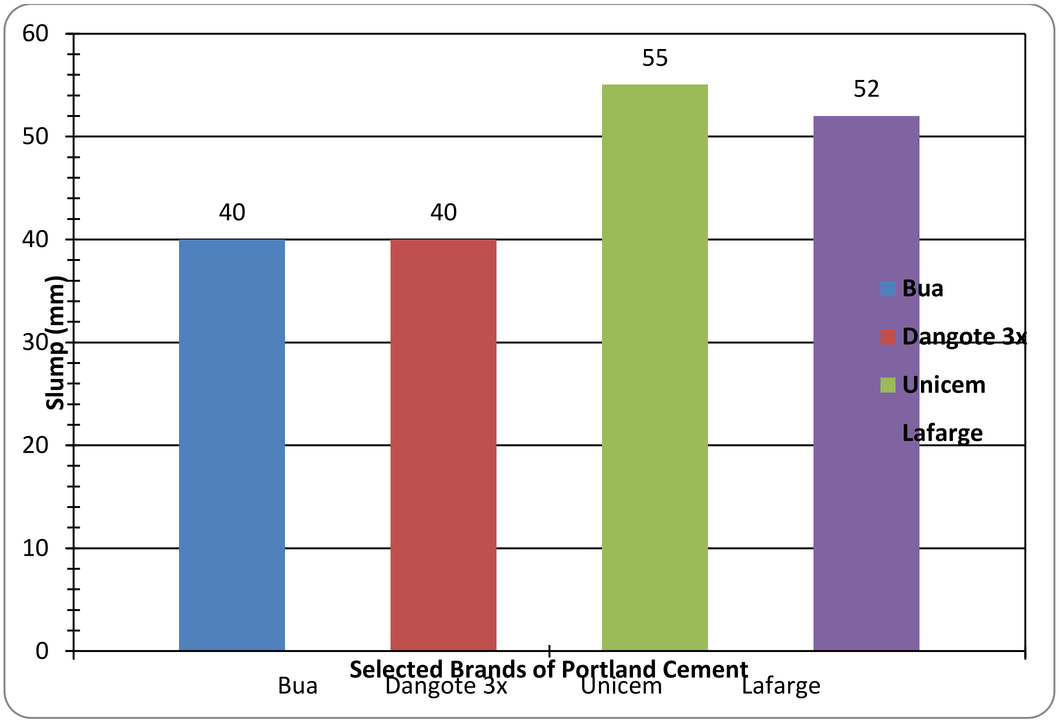

Figure 4.6: Charts Showing the Slump of Fresh Concrete Produced Using Selected Brands of Portland cement.

4.2.7 Compressive Strength and Density of Hardened Concrete

Figure 4.7 and 4.8 displays the results of compressive strength and density of the selected brands of Portland cement used for the experimental study. It was observed that the compressive strength and density increased with curing days which agrees with findings obtained by Neville, (2012) where it was stated that concrete gains 60% of its compressive strength at 28 days of curing. Comparative analysis of strength and density of the selected brands of Portland cement shows that Unicem cement produced concrete with the highest density and compressive strength while the lowest density and compressive strength was recorded by concrete produced with Dangote 3x cement. The highest compressive strength recorded by Unicem could be attributed to the fineness property of the cement as fineness of cement improves the compressive strength of concrete. This can be explained by increase of the fast kinetics of hydration of the mineral C3S (tricalcium silicate) and C2S (dicalcium silicate). These two phases are two principal minerals which ensure the development of strength in concrete. Thus it can be concluded that the fineness of cement is a significant factor during hydration of the mix as the more the fineness of particles, the more the cement surface in contact with water and the faster the rate of hydration and ultimately the higher the compressive strength. It was also deduced that the density of the hardened concrete produced with different brands of Portland cement shares a direct relationship with the compressive strength as Unicem cement which produced concrete with the highest density also recorded the highest compressive strength. This finding correlates with the works of Bamiboye, et al., (2015) and Yahaya, et al., (2014).

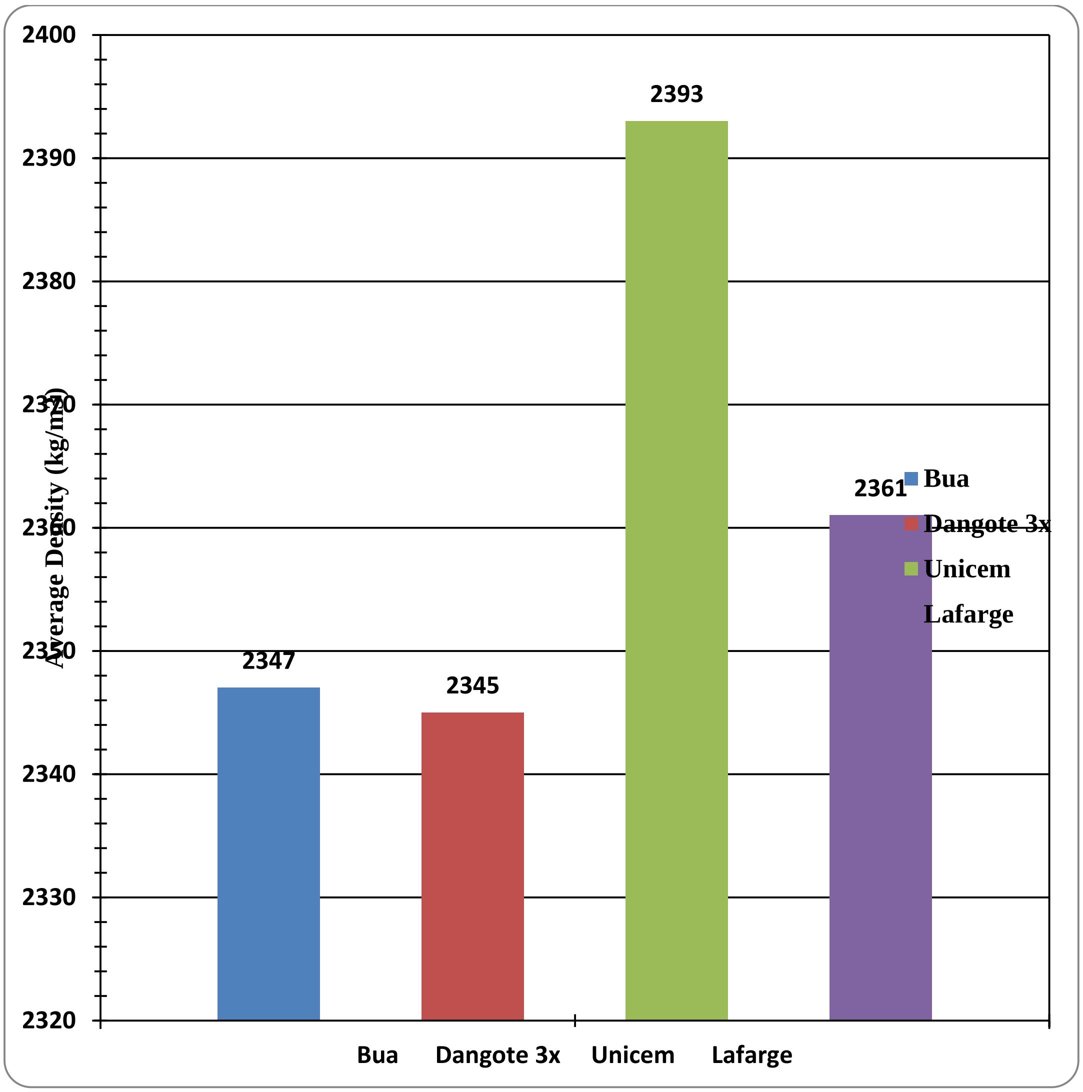

Figure 4.7: Charts Showing the Average Densities of Selected Brands of Portland cement

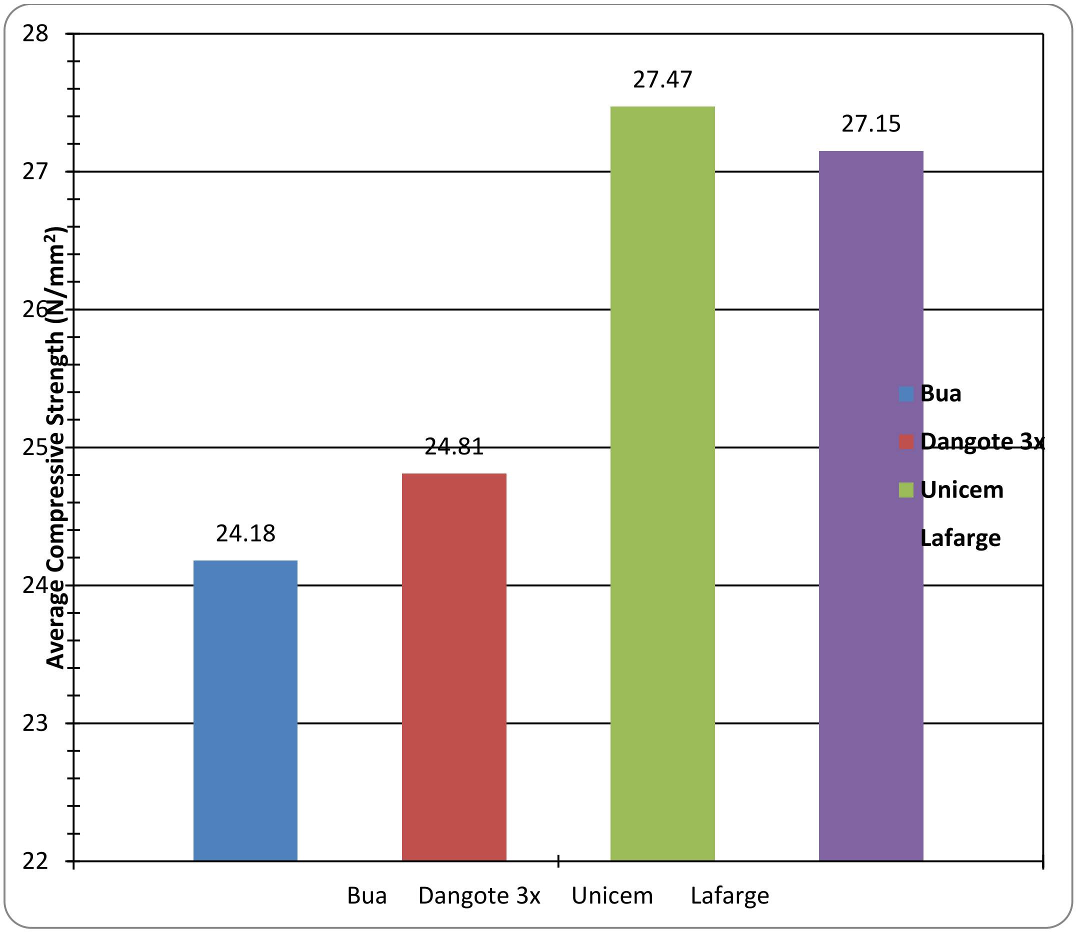

Figure 4.8: Charts Showing the Average comprehensive strenght of Selected Brands of Portland cement

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the findings obtained on effect of selected brands of cement on compressive strength of concrete, the following conclusion can be drawn:

1 The sand and granite samples employed in the research were classified as A-2-4 and A-1-b according to AASHTO soil classification system, SC (clayey sand) and SM (silty sand) according to Unified soil classification system.

2 The specific gravity of sand and granite were greater than 2.4 and as a result, they are classified as normal weight aggregate.

3 Lafarge and Unicem exhibited quick initial setting time while Dangote 3x and Unicem exhibited quick final setting time with the final setting time of Bua and Lafarge been relatively the same.

4 The fineness of Unicem cement was higher than Bua, Dangote 3x and Lafarge conversely, the soundness of Unicem cement was relatively lower than other cement brands.

5 The impact and crushing value of aggregates used for production of concrete satisfied the specification set by Federal Ministry of Works which state that the impact and crushing value of aggregate samples used for concrete production must not exceed 30%.

6 Slump test results revealed that concrete produced using Bua and Dangote 3x cement were more workable than concrete produced using Unicem and Lafarge cement.

7 Compressive strength test results revealed that Unicem cement produced concrete with the highest density and compressive strength. The lowest density and compressive strength was recorded for concrete produced with Dangote 3x cement. The early development in compressive strength and density of concrete produced with Unicem cement could be attributable to the greater surface area for hydration provided by the Portland cement.

8 Unicem cement is therefore adjudged as most effective chemical binder for concrete production due to relatively high attainment in density and compressive strength at similar curing days.

5.2 Recommendation

Recommendations from the study on effect of selected brands of Portland cement on compressive strength of concrete are as follows:

1. The study recommends the use of Unicem cement for production of structural and non structural concrete due to early gain in density and compressive strength of the hardened concrete.
2. Painstaking attention must be given to the setting time of the selected brands of Portland cement so as to avoid problems associated with transportation, placement and compaction of the concrete.

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APPENDICES

APPENDIX A

Specific Gravity Test

Table A1: 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.

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

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

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

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

Table A2: 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.

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

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

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

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

Bulk Specific Gravity for Crushed Granite.

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

Trial 2 (G_{S2}) = $\frac{W4}{(W3-(W1-W2)}$ = $\frac{434.28}{(442.24-(460.60-192.84)}$ = 2.49

Trial 3 (G_{S3}) = $\frac{W4}{(W3-(W1-W2)}$ = $\frac{434.86}{(440.82-(462.46-192.88)}$ =2.54

Bulk Specific Gravity = $\frac{(GS1+GS2+GS3)}{3}$ = $\frac{(2.48+2.49+2.54)}{3}$ = 2.50

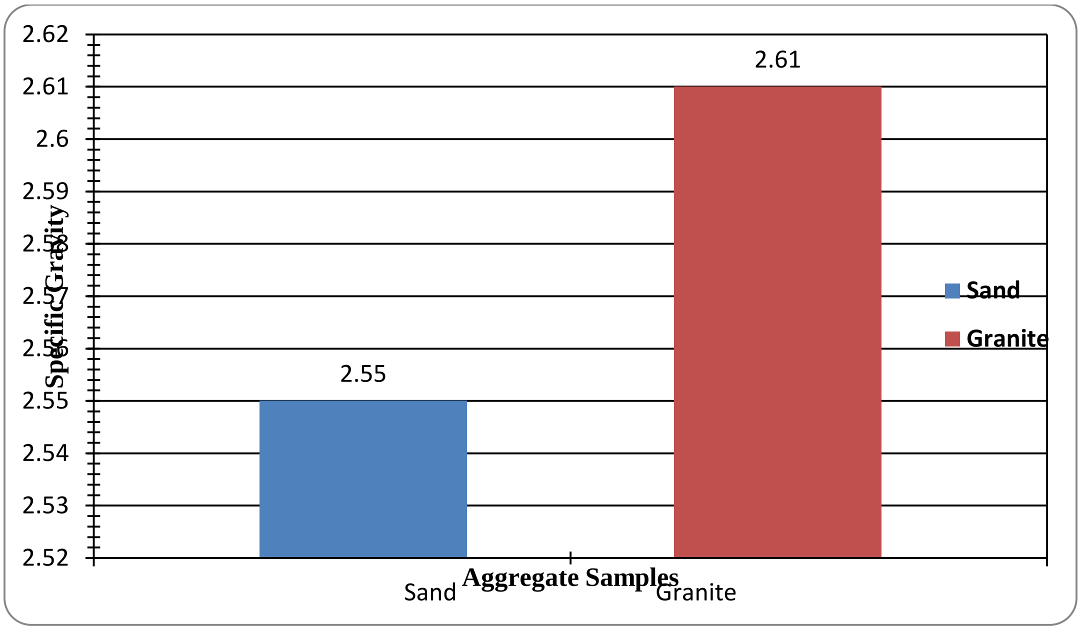

Figure A1: Specific Gravity Charts for Sand and Granite

APPENDIX B

Sieve Analysis Result

Table B1: Sieve Analysis Result for Sand

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

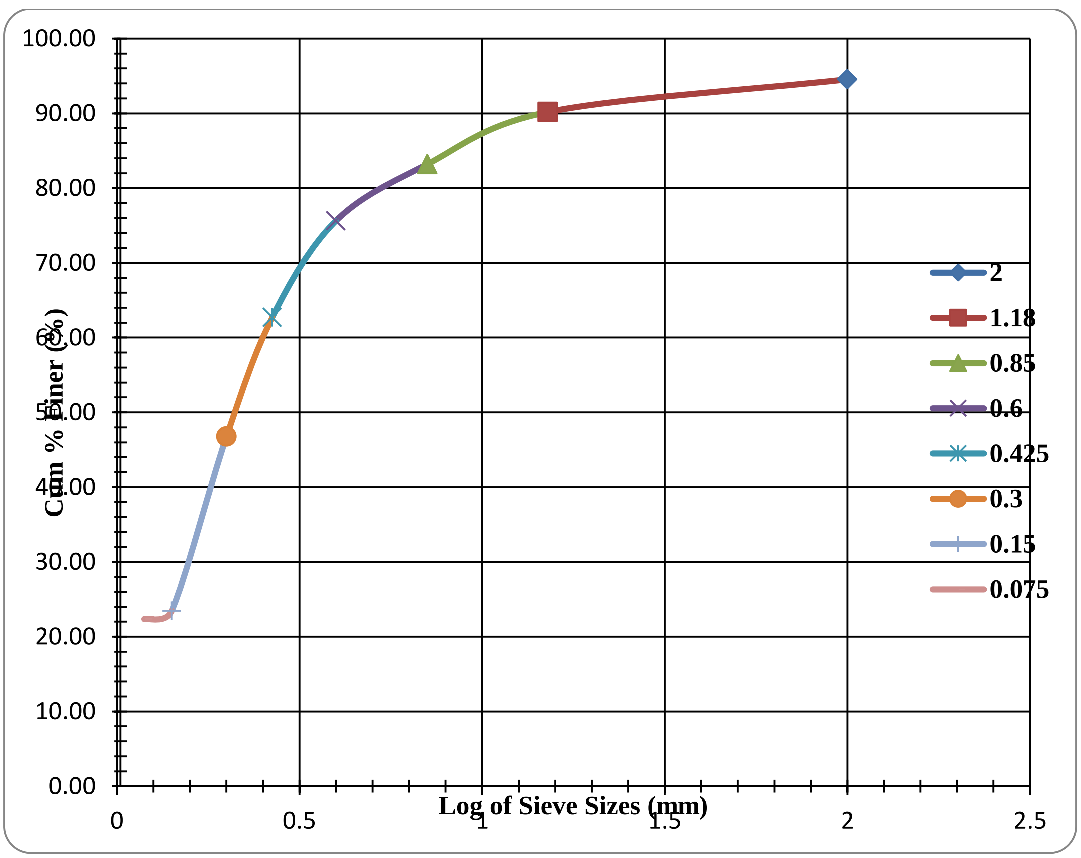

Figure B1: Particle Size Distribution Curve for Sand

Table B2: Sieve Analysis Result for Granite

Sieve Sizes (mm)	Mass Retained (g)	% Mass Retained	Cum % Retained	Cum % Finer
31.25	0.14	0.01	0.01	99.99
25	88.5	8.63	8.644146341	91.36
20	362.11	35.33	35.33780488	64.66
12.5	504	49.17	49.18073171	50.82
9.5	14.61	1.43	1.435365854	98.56
6.3	29.02	2.83	2.841219512	97.16
4.75	14.83	1.45	1.456829268	98.54
Tray	12.44	1.21	1.223658537	98.78

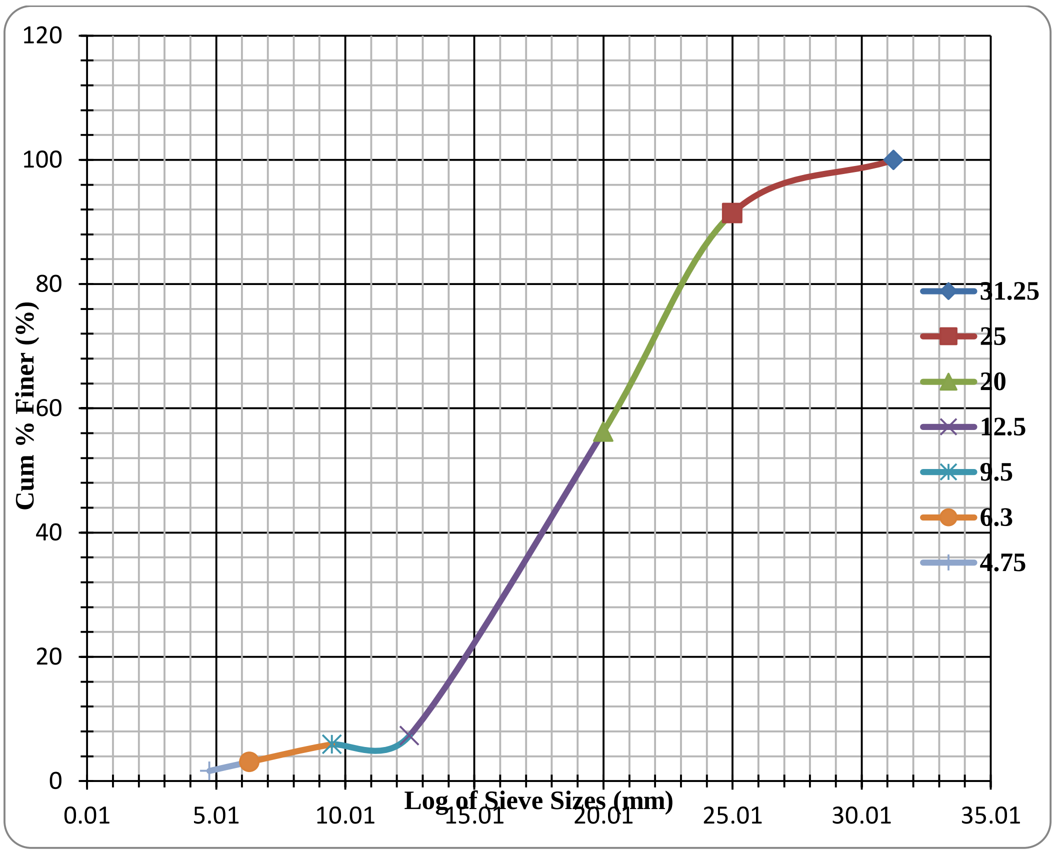

Figure B2: Graph Showing the Particle Size Distribution Curve for Granite

APPENDIX C

Slump (Workability) Test

Table C1: Slump Test Result for the Fresh concrete at 1: 2: 4 and w/c ratio of 0.5

Portland cement Type	Height of Cone (mm)	Height of Collapse (mm)	Slump (mm)	Slump Type
Bua	300	260	40	True Slump
Dangote 3x	300	260	40	True Slump
Unicem	300	245	55	Shear Slump
Lafarge	300	250	50	Shear Slump

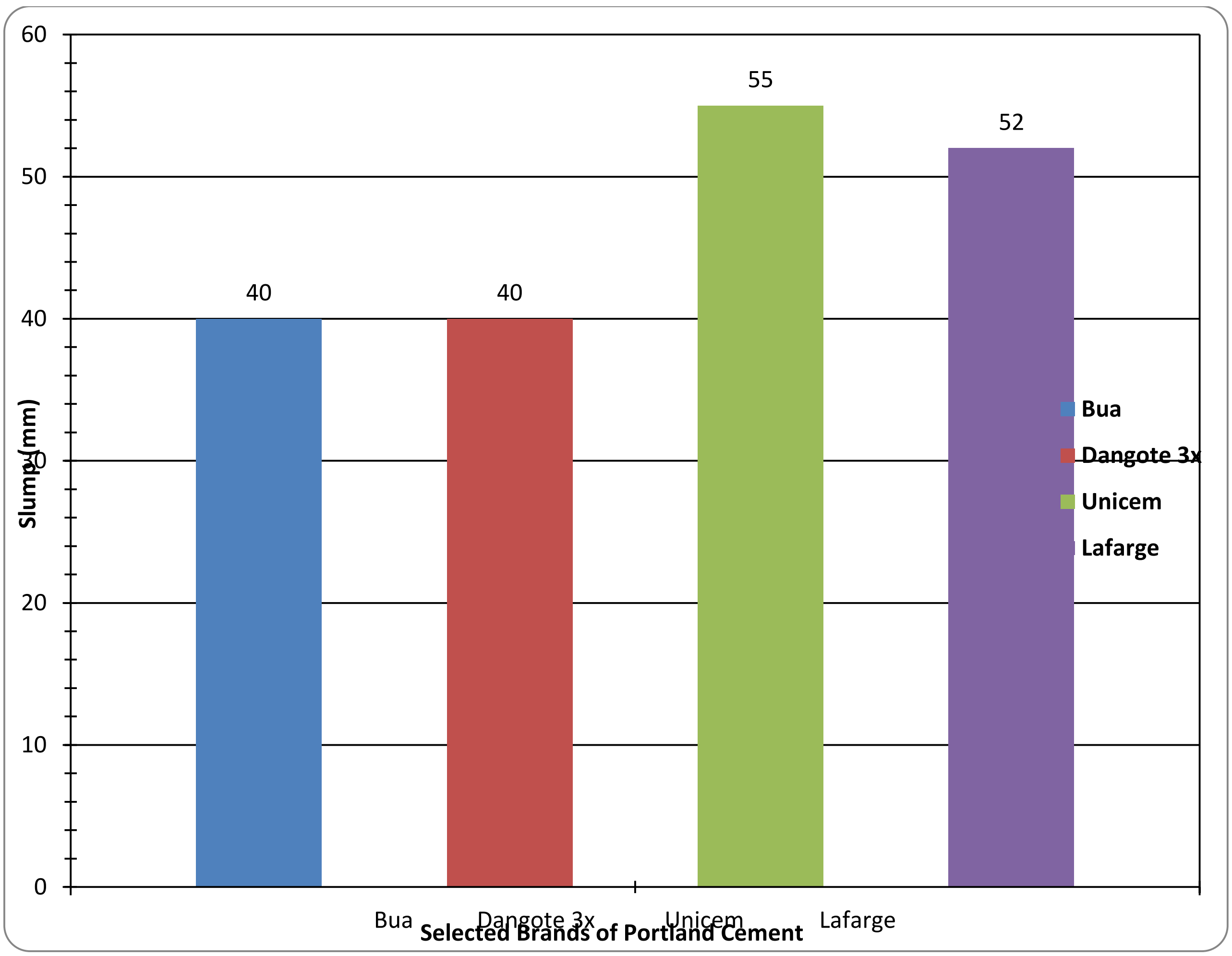

Figure C1: Charts Showing the Slump of Concrete Produced with Different Brands of Portland cement

APPENDIX D

Density Test

Table D1: Density Test Results for Bua cement

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
7 days	7.45		2207	
	7.52	7.52	2228	2229
	7.6		2252	
14 days	7.75		2296	
	7.82	7.79	2317	2309
	7.8		2311	
21 days	8.14		2412	
	8.20	8.15	2430	2414
	8.11		2400	
28 days	8.24		2441	
	8.15	8.22	2415	2436
	8.28		2453	

Table D2: Density Test Results for Dangote 3x cement

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
7 days	7.58		2246	
	7.65	7.62	2267	2257
	7.62		2258	
14 days	7.85		2326	
	7.82	7.82	2317	2318
	7.80		2311	
21 days	7.9		2341	
	7.94	7.91	2353	2343
	7.88		2335	
28 days	8.25		2444	
	8.31	8.31	2462	2463
	8.38		2483	

Table D3: Density Test Results for Lafarge cement

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
7 days	7.68		2276	
	7.72	7.73	2287	2291
	7.78		2309	
14 days	7.8		2311	
	7.82	7.83	2317	2321
	7.88		2335	
21 days	8.01		2373	
	7.98	8.05	2364	2384
	8.15		2415	
28 days	8.28		2453	
	8.18	8.27	2424	2449
	8.34		2471	

Table D4: Density Test Results for Unicem cement

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
7 days	7.78		2305	
	7.81	7.81	2314	2315
	7.85		2326	
14 days	7.84		2323	
	7.91	7.90	2344	2341
	7.95		2356	
21 days	8.18		2424	
	8.25	8.24	2444	2440
	8.28		2453	
28 days	8.34		2471	
	8.42	8.35	2495	2475
	8.31		2459	

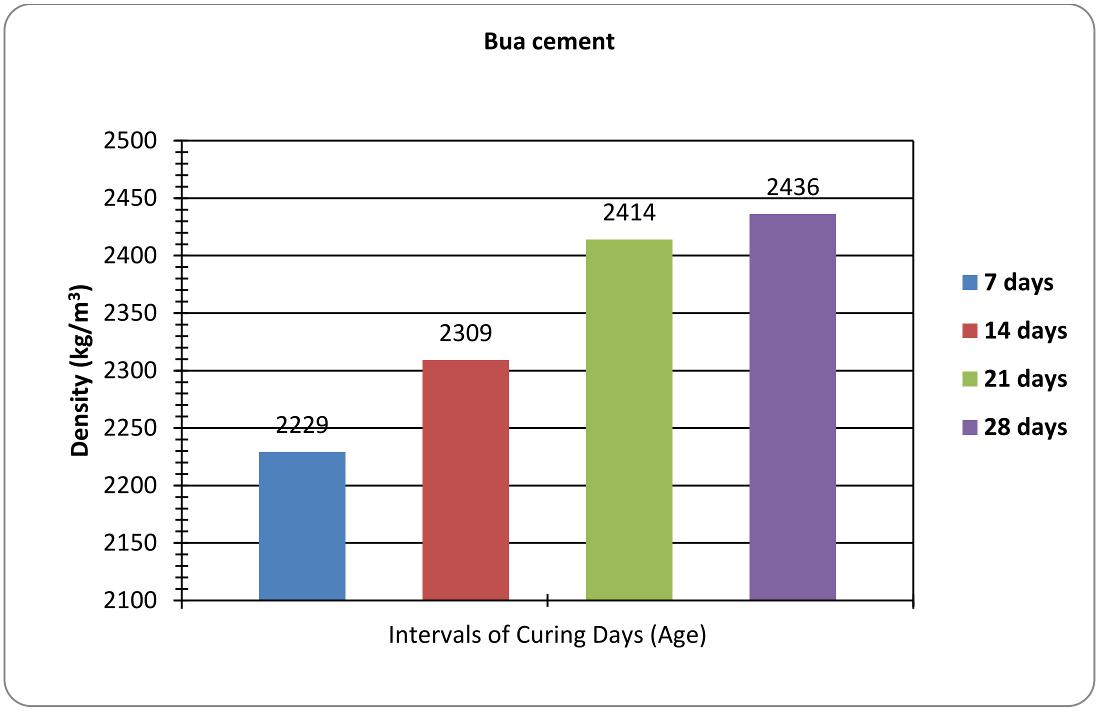

Figure D1: Graph of Density against Curing Days for Bua cement

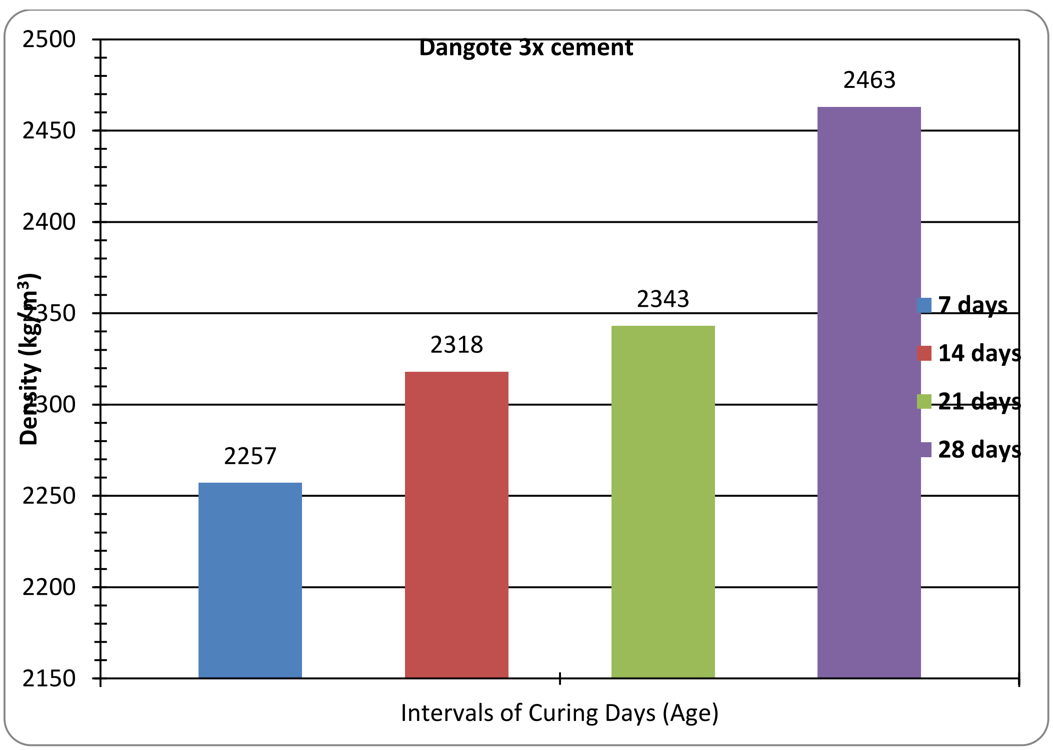

Figure D2: Graph of Density against Curing Days for Dangote 3x cement

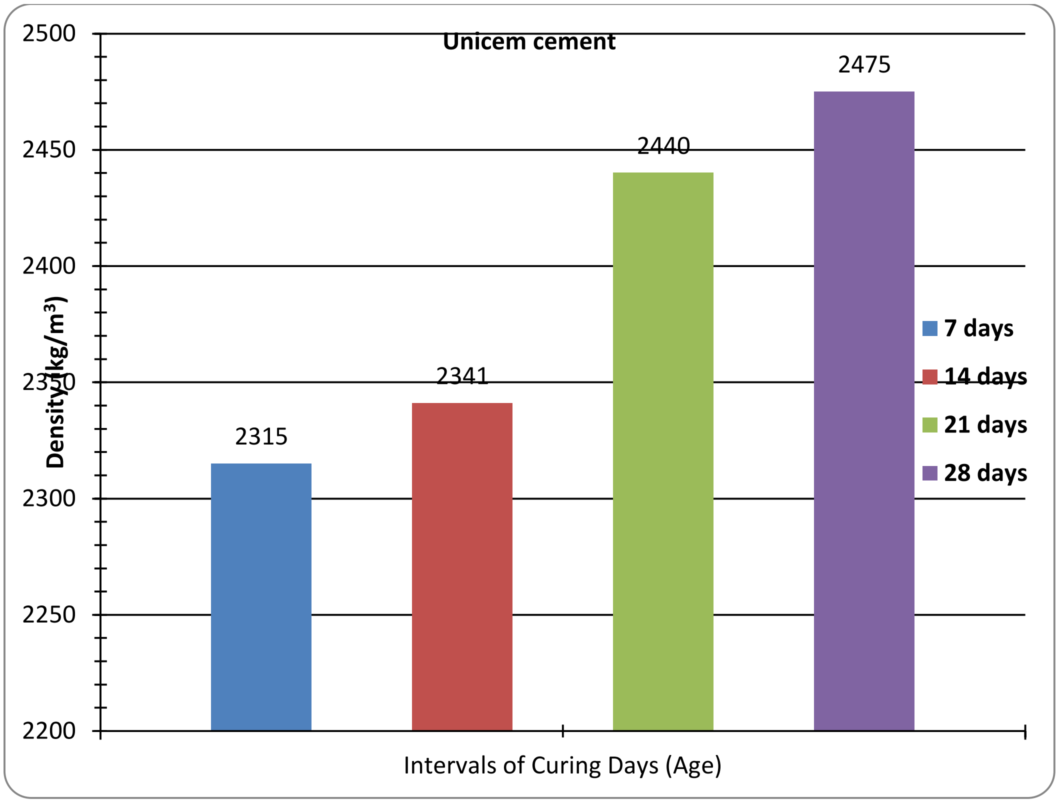

Figure D3: Graph of Density against Curing Days for Unicem cement

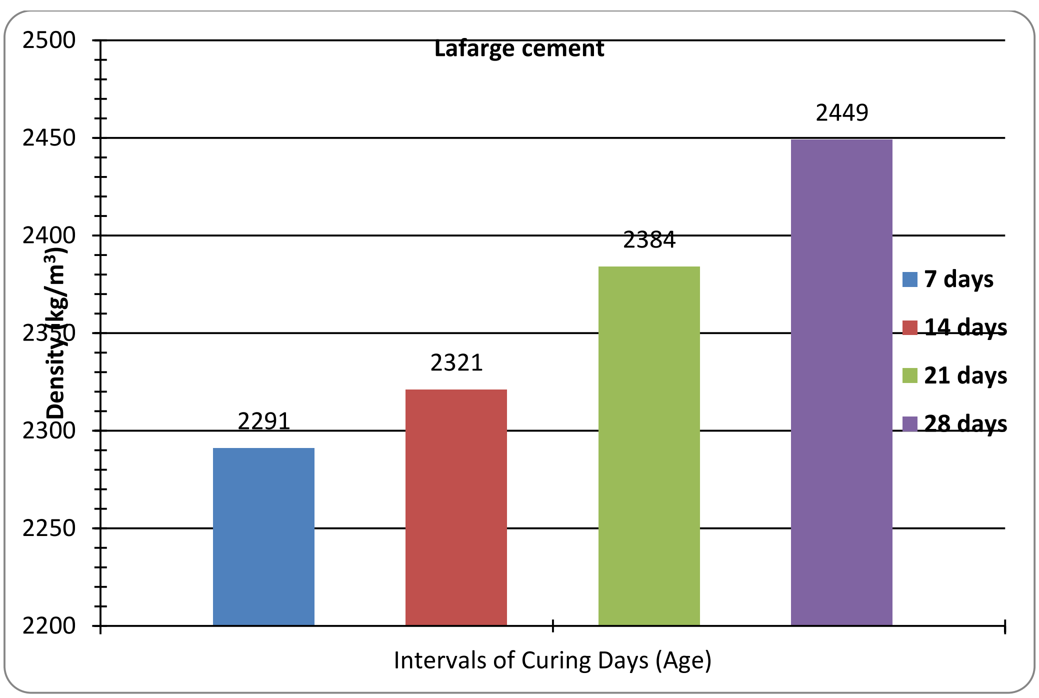

Figure D3: Graph of Density against Curing Days for Lafarge cement

APPENDIX E

Compressive Strength Test

Table E1: Compressive Strength Test Result for Bua cement

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	520.5	23.13	23.24
		525.6	23.36	
		522.4	23.22	
14 days	1: 2: 4	538.5	23.93	24.02
		540.4	24.02	
		542.5	24.11	
21 days	1: 2:4	548.5	24.38	24.54
		553.3	24.59	
		554.8	24.66	
28 days	1: 2: 4	558.5	24.82	24.91
		560.2	24.90	
		562.5	25.00	

Table E2: Compressive Strength Test Result for Dangote 3x cement

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	540.5	24.02	24.11
		544.3	24.19	
		542.8	24.12	
14 days	1: 2: 4	553.8	24.61	24.69
		555.2	24.68	
		557.8	24.79	
21 days	1: 2:4	564.3	25.08	25.07
		562.8	25.01	
		565.5	25.13	

28 days	**1: 2: 4**	**571.2**	**25.39**	**25.38**
		568.8	**25.28**	
		573.4	**25.48**	

Table E3: Compressive Strength Test Result for Lafarge cement

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**	**590.5**	**26.24**	**26.33**
		598.6	**26.60**	
		588.4	**26.15**	
14 days	**1: 2: 4**	**598.5**	**26.6**	**27.11**
		602.4	**27.7**	
		608.5	**27.04**	
21 days	**1: 2:4**	**612.4**	**27.22**	**27.26**
		609.2	**27.08**	
		618.5	**27.49**	
28 days	**1: 2: 4**	**624.8**	**27.77**	**27.90**
		628.4	**27.93**	
		630.2	**28.01**	

Table E4: Compressive Strength Test Result for Unicem cement

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**	**608.5**	**27.04**	**26.74**
		594.5	**26.42**	
		602.3	**26.77**	
14 days	**1: 2: 4**	**611.8**	**27.19**	**27.21**
		614.5	**27.31**	
		610.2	**27.12**	

21 days	**1: 2:4**	**620.8**	**27.59**	**27.69**
		622.7	**27.68**	
		625.6	**27.80**	
28 days	**1: 2: 4**	**632.4**	**28.11**	**28.25**
		633.5	**28.16**	
		640.8	**28.48**	

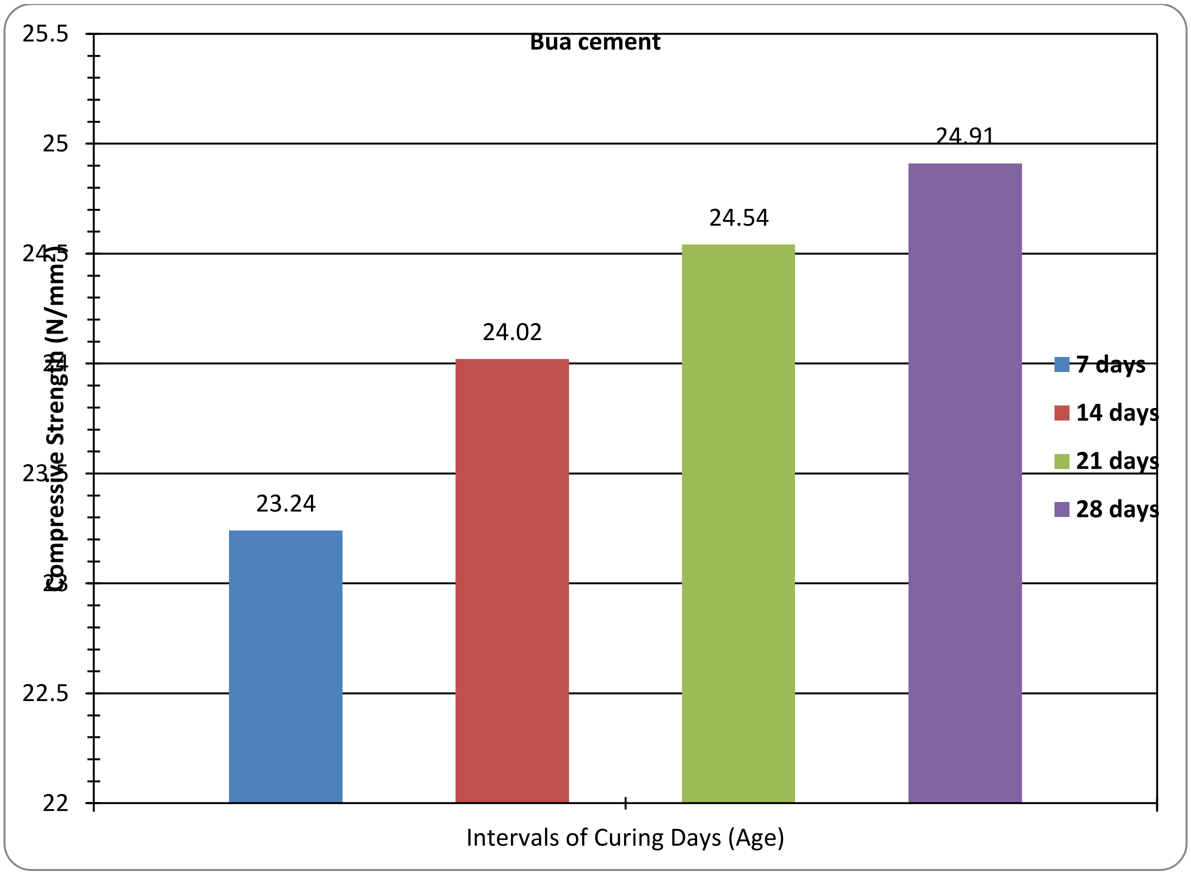

Figure E1: Graph of Compressive Strength against Curing Days for Bua cement

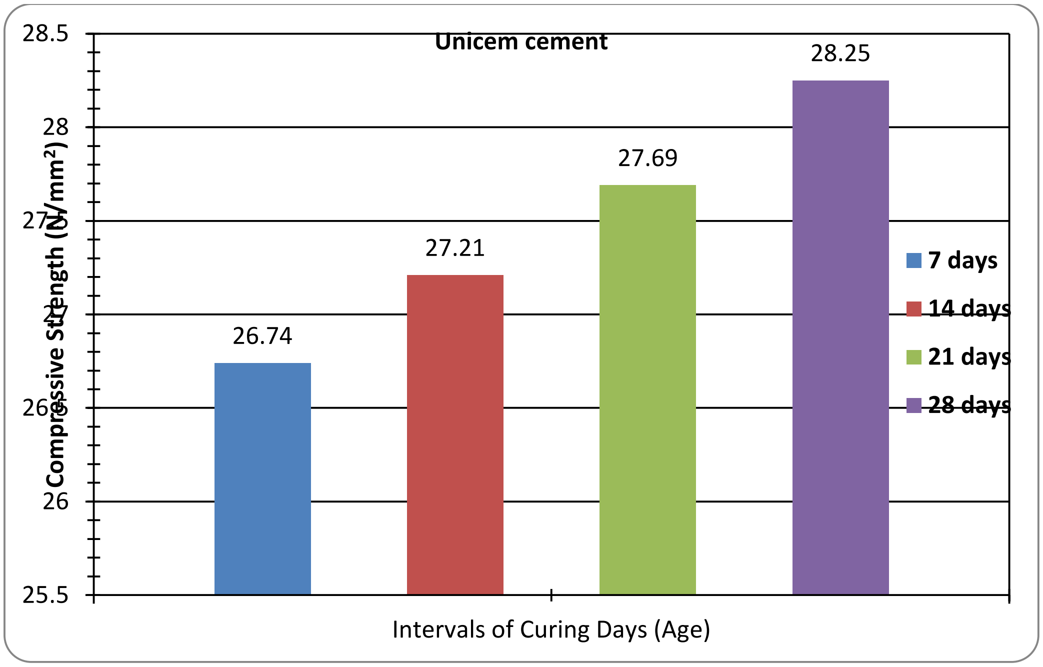

Figure E2: Graph of Compressive Strength against Curing Days for Unicem cement

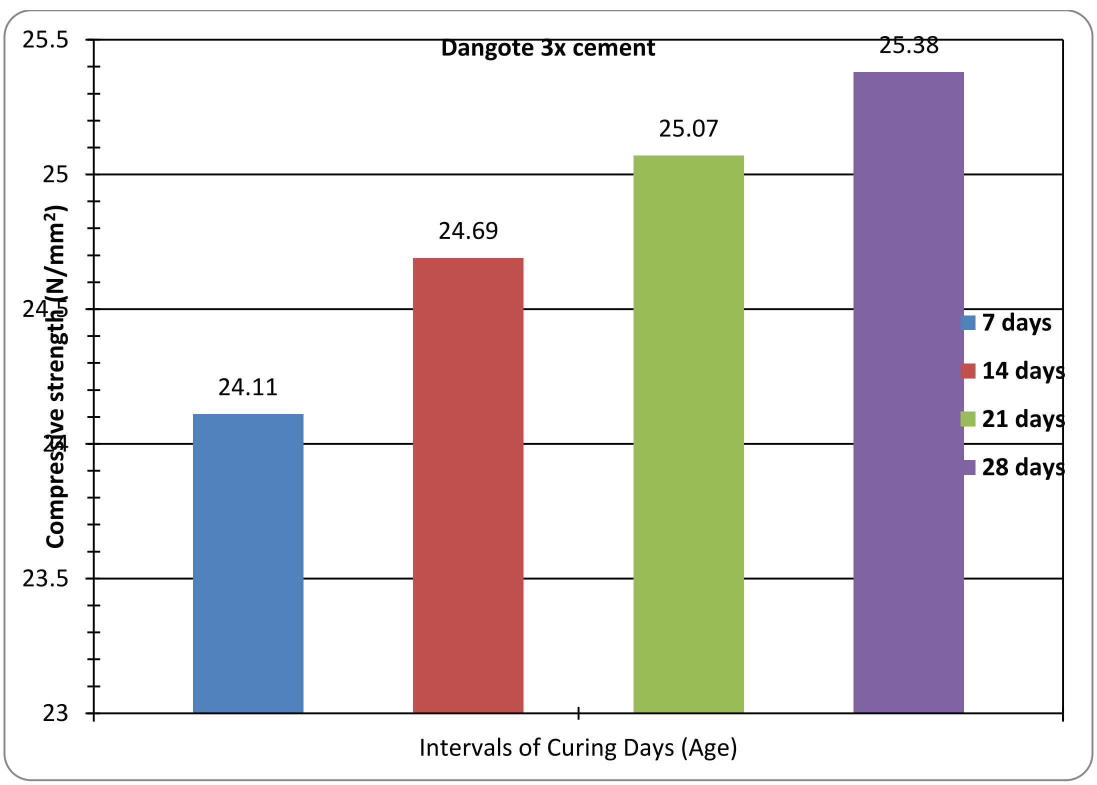

Figure E3: Graph of Compressive Strength against Curing Days for Dangote 3x cement

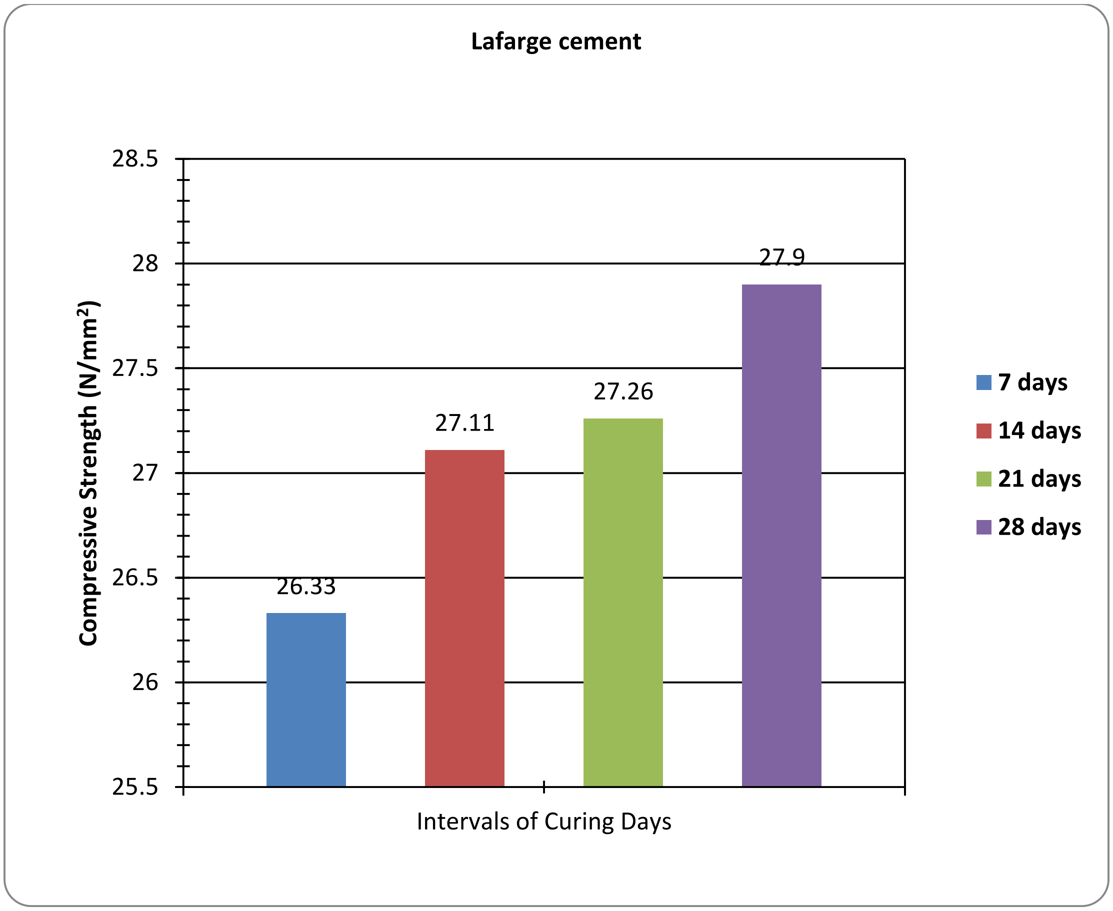

Figure E4: Graph of Compressive Strength against Curing Days for Lafarge cement

APPENDIX F

Setting Time Test

Table F1: Setting Time Results for Different Brands of Portland cement

Properties/ Portland cement Types	Bua	Dangote 3x	Unicem	Lafarge
Initial Setting Time (min)	30	30	28	28
Final Setting Time (min)	600	580	560	600

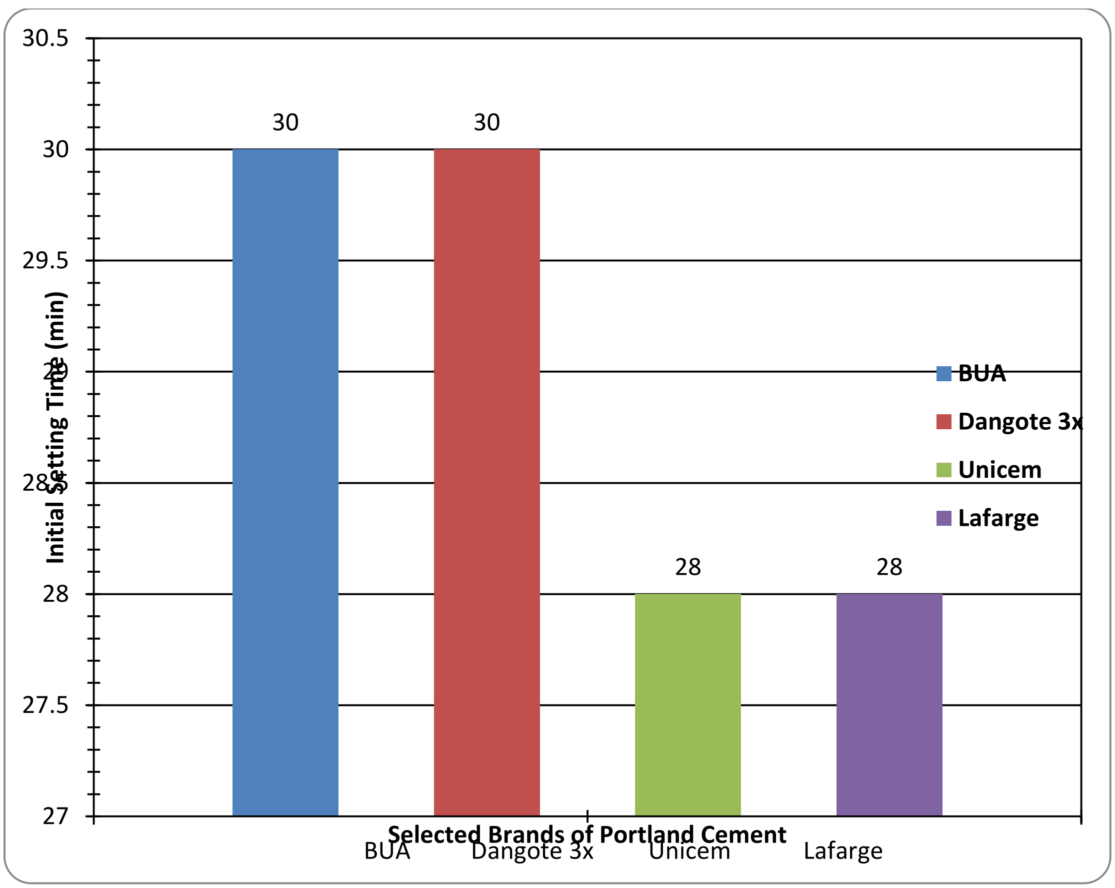

Figure F1: Initial Setting Time Values of Selected Brands of Portland cement

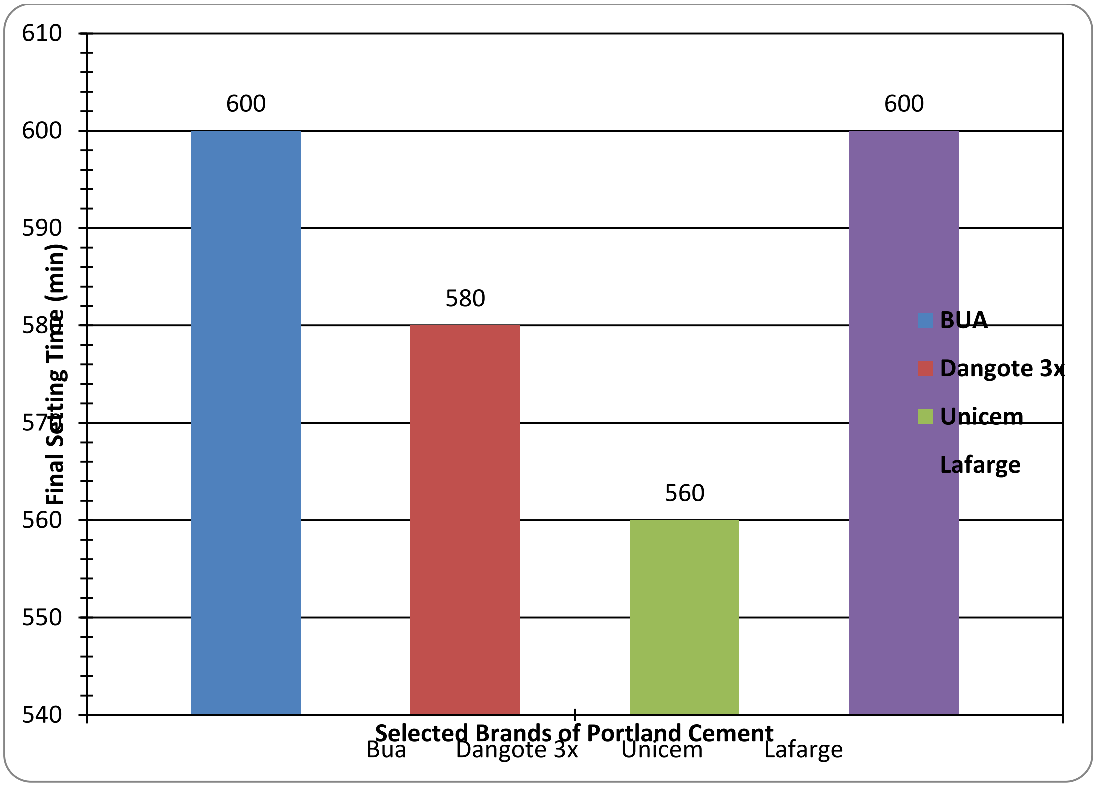

Figure F2: Final Setting Time Values of Selected Brands of Portland cement

APPENDIX G

Fineness Test of Portland cement

Table G1: Fineness Test Results for Selected Brands of Portland cement

Portland cement Types	Weight of cement (W1)	Weight of Residue After Sieving (W2)	Fineness (%)
Bua	50	12.4	24.8
Dangote 3x	50	13.2	26.4
Unicem	50	14.3	28.6
Lafarge	50	13.8	27.6

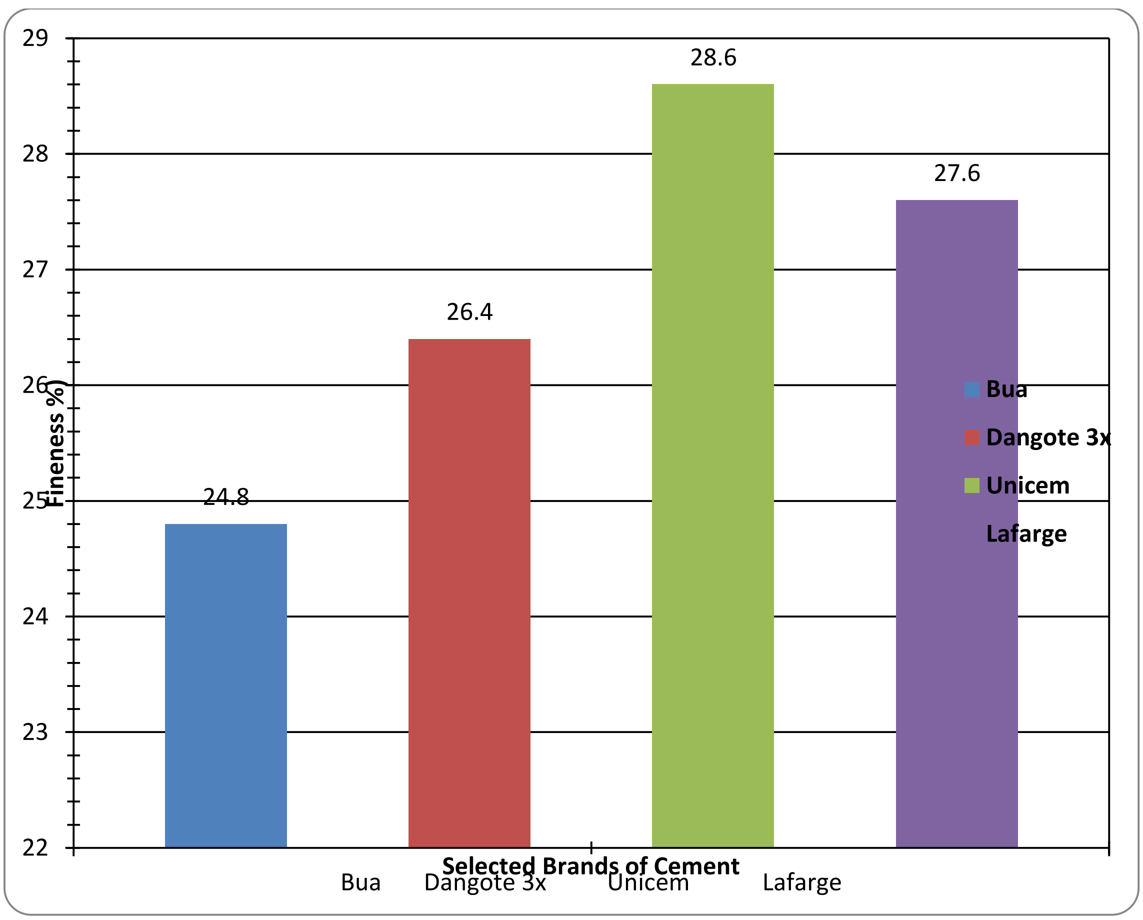

Figure G1: Graph Showing the Fineness values of Selected Brands of Portland cement

APPENDIX H

Soundness Test of Portland cement

Table H1: Soundness Test Results for Selected Brands of Portland cement

Portland cement Type	Distance Separating Indicator Submerged at room temperature for 24 hours	Distance Separating Indicator Submerged in Boiling Water for 3 hours	Expansion (mm)
Bua	52.4	46.5	8.3
Dangote 3x	52.8	46.4	6.7
Unicem	54.3	47.6	6.4
Lafarge	56.6	48	5.9

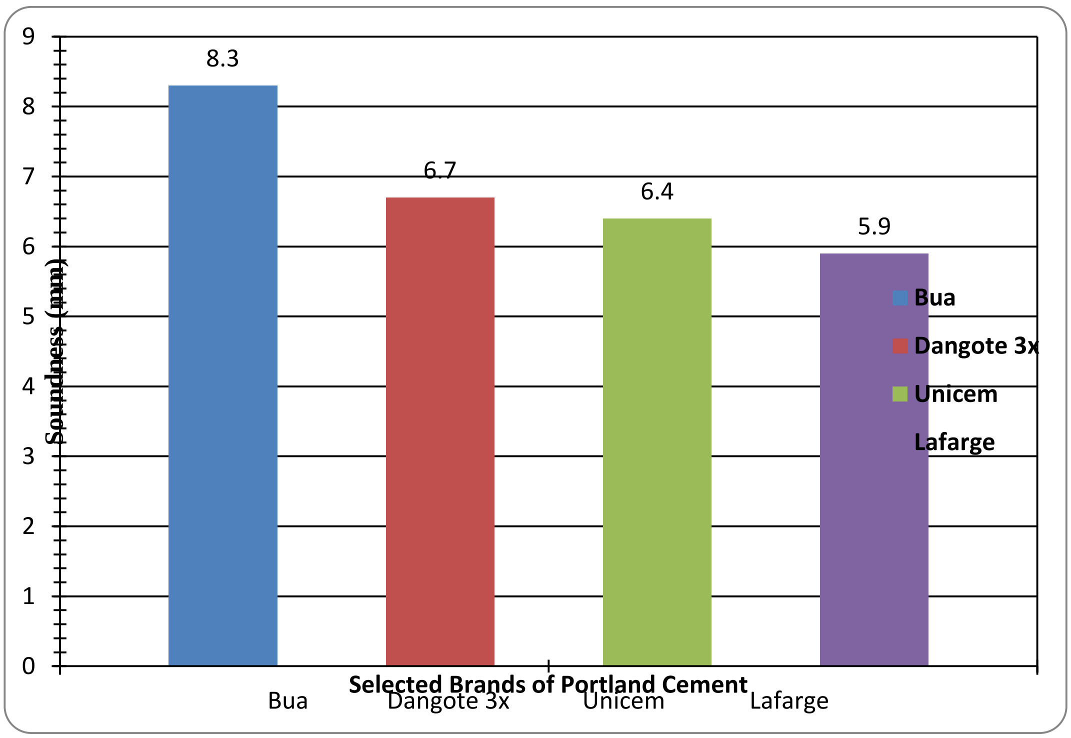

Figure H1: Charts Showing the Soundness Values of Selected Brands of Portland cement

APPENDIX I

Aggregate Impact and Crushing Value Test

Table I1: Impact Test Results for Granite Samples

Test No	Test 1	Test 2
Weight of oven-dry sample (W1)	650	650
Weight of fraction passing through 2.36mm sieve (W2)	175.5	182.5
Aggregate impact Value (%)	27	28.1

Aggregate Impact Value = $\frac{27+28.1}{2}$ **= 27.6%**

Table I2: Crushing Test Results for Granite Samples

Test No	Test 1	Test 2
Weight of aggregate sample in cylinder measure (excluding weight of cylindrical measure) W1	650	650
Weight of crushed aggregate passing through 2.36mm sieve (W2)	168.5	170.5
Aggregate Crushing Value (%)	25.9	26.2

Aggregate Crushing Value = $\frac{25.9+26.2}{2}$ **= 26.1%**

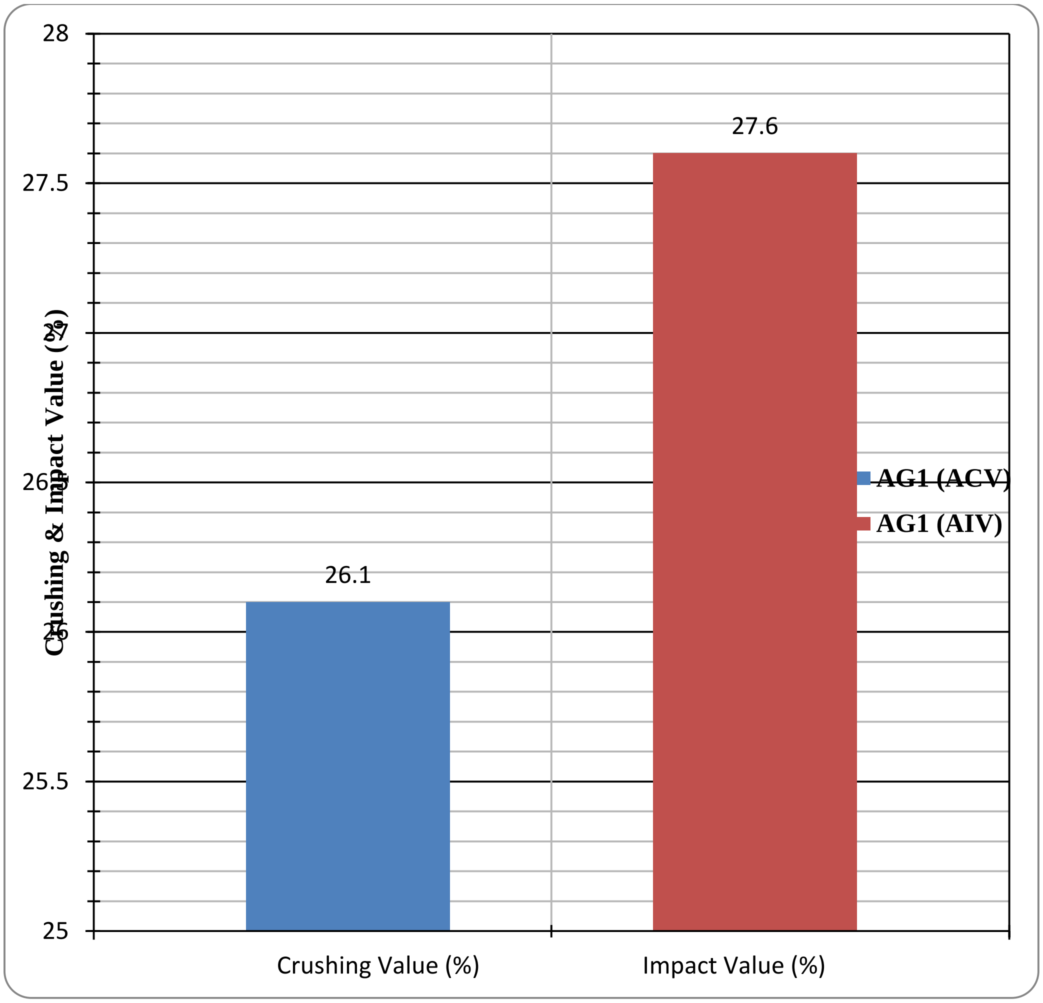

Figure I1: Charts Showing the Impact and Crushing Value of Aggregate