EFFECTS OF DIFFERENT SIZE OF COARSE AGGREGATE ON THE COMPRESSIVE STRENGTH OF CONCRETE

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CERTIFICATION

This is to certify that this work titled "Effects of different size aggregate on the compressive strength of concrete" was carried out by me, Muoneke Vivian Chisom with registration number 2016224045 in the Department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka.

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APPROVAL

This project titled "Effects of different size of coarse aggregate on the compressive strength of concrete" has been approved for submission in the Department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka.

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DEDICATION

I dedicate this work to God Almighty for his providence, grace and love he showed me throughout my stay in this university.

ACKNOWLEDGEMENT

I give tremendous thanks to Almighty God who made this work a success. My sincere gratitude goes to my impeccable project supervisor, Engr. I. K. Omaliko for his efforts, guidelines and encouragement which led to the success of this work.

I appreciate the Head of Department, Dr. A.C. Ezeagu for his dedication towards the affairs of the department, my lecturers and the entire staff of the Department of Civil Engineering for their various forms of assistance.

This acknowledgment will be incomplete without mentioning my beloved parents Chief and Lolo Lawrence Muoneke for your lovely care and dedication towards my life and my education, May God reward you. To my siblings, Chinenye, Kosi, and Chinaemerem I say, “I love you”. I appreciate my supportive uncle, Hon, Chief Fabian Muoneke. I cherish also the time we shared my darling friends of mine, Chinenye, Chidera, Ruth, Bernard, Eke Emmanuel, Mairo, and Rafaela.May the good Lord continue to bless and guide you all in Jesus name.

ABSTRACT

Coarse aggregates, which is the interest of this study, make the difference. Three different types of coarse aggregates, with 20mm maximum size, employed in this investigation, these are; 12mm, 16mm, and 20mm. The grading and compressive strength of the aggregates were studied. The mix ratio and water/cement ratio adopted for the study was 1:2:4 and 0.55 respectively. Two concrete cubes (150mm x 150mm x 150mm) were cast for each coarse aggregate type of which two were crushed at each curing age namely; 7, 14, 21, and 28 days. The 28 day strengths of the concretes made with 20mm, 16mm, and 12mm were 26.20N/mm^2, 24.02N/mm^2, and 22.03N/mm^2 respectively, The 21 day strengths of the concretes made with 20mm, 16mm, and 12mm were 23.23N/mm^2, 21.85N/mm^2, and 18.17N/mm^2 respectively, The 14 day strengths of the concretes made with 20mm, 16mm, and 12mm were 21.24N/mm^2, 20.03N/mm^2, and 17.47N/mm^2 respectively and The 7 day strengths of the concretes made with 20mm, 16mm, and 12mm were 19.34N/mm^2, 17.55N/mm^2, and 15.53N/mm^2 respectively. Therefore, result shows that as the aggregate size increases, the compressive strength increases also with increasing curing days.

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CHAPTER ONE

INTRODUCTION

1.0 Introduction

Concrete is a composite material made of aggregate bonded together by liquid cement, which hardens over time (Woodford, 2016). The major components of concrete are cement, water, and aggregates (fines and coarse aggregate) with aggregates taking about 50 to 60% of the total volume, depending on the mix proportion. The amount of concrete used worldwide is twice that of steel, wood, plastics, and aluminum combined (Rajith and Amritha, 2015). According to Yaqub and Bukhari (2006), concrete's use in the modern world is exceeded only by that of naturally occurring water.

Concrete can be used either singular or reinforced with steel in order to achieve the required strength. Concrete builds durable, long lasting structures that will not rust, rot, or burn. It is widely used for making architectural structures, foundations, brick walls, bridges and many other civil engineering works. Concrete is used in large quantities almost everywhere humanity has a need for infrastructure because of its high compressive strength and durability (Ajamu and Ige, 2015).

Concrete is one of the most widely used construction materials. The raw material from which it is prepared: cement, aggregates and water affect both the quality and cost of construction. Aggregates are usually cheaper than cement and constitute over 70% of the volume of concrete. The availability and proximity of aggregate to the construction site also affect the cost of construction.

The compressive strength of concrete is one of its major properties that structural engineers take into consideration before erecting any structure (Hollaway, 2010). This property can be affected by many factors including water to cement ratio, degree of compaction, aggregate size and shape. Aggregate gradation plays an important role in concrete mixing. Unsatisfactory gradation of aggregates leads to segregation of mortar from the coarse aggregates, internal bleeding, need for chemical admixtures to restore workability, excessive water use and increased cement use (Loannides and Mills, 2006).

Aggregates constitute about 50 to 60% of the concrete mix depending on the mix proportion used. The larger the aggregate percentage in concrete mix, the stronger the concrete becomes (Waziri et al., 2011). Aggregates are the most mined material in the world. They are a component of composite materials such as concrete and asphalt concrete.

Curing can be achieved by keeping the concrete element completely saturated or as much saturated as possible until the water-filled spaces are substantially reduced by hydration products. According to (Hassan and Mohammed, 2014), curing concrete increase strength by up to 50% and also improve durability, making it more water tight and improve its appearance. If the concrete is not cured and is allowed to dry in air, it will gain only 50% of the strength of continuously cured concrete (Raheem, 2013).

A number of concrete structures around the globe cracks and lose stiffness when subjected to external load. Having premature deterioration of concrete is an international problem; the building industry needs to increase the load carrying capacity of structures by using concrete of high strength. In concrete structures, the mix proportion of the different components together with the aggregate type and size determine the compressive strength of hard concrete. According to (Adiseshu and Ganapati, 2011), larger aggregates demand lower water on its mix thus reducing the workability and increasing the compressive strength of concrete.

1.1 Background of study

Coarse aggregate plays an important role in concrete. To predict the behavior of concrete under general loading requires an understanding of the effects of aggregate type, aggregate size, and aggregate content. This understanding can only be gained through extensive testing and observation.

In normal-strength concrete, failure in compression almost exclusively involves deboning of the cement paste from the aggregate particles at what, for the purpose of this report, will be called the matrix-aggregate interface (Rozalija K., David D., 1997). In contrast, in high-strength concrete, the aggregate particles as well as the interface undergo failure, clearly contributing to overall strength. As the strength of the cement paste constituent of concrete increases, there is greater compatibility of stiffness and strength between the normal stiffer and stronger coarse aggregate and the surrounding mortar. Thus, micro cracks tend to propagate through the aggregate particles since, not only is the matrix-aggregate bond stronger than in concretes of lower strength, but the stresses due to a mismatch in elastic properties are decreased. Thus, aggregate strength becomes an important factor in high-strength concrete.

1.2 Statement of problem

It is a common practice in Nigeria to use locally found aggregates (washed and unwashed gravels) for construction purposes. The integrity of these aggregates should be investigated to ascertain their performance in structural members. Recent constructions in Nigeria, especially in Awka and its environs make indiscriminate use of aggregates notwithstanding their sources and not considering their physical condition at the time of use.

Coarse aggregates are obtained naturally or artificially and occupies up to 60% by weight or volume of the concrete, depending on the mix proportion adopted which, in turn, depends on the expected compressive strength. The compressive aggregate strength is an important factor in the selection of aggregate. When determining the strength of normal concrete, most concrete aggregates are several times stronger than the other components in concrete and therefore not a factor in the strength of normal strength concrete. For this reason, the quality of the coarse aggregates is essential when considering the quality of the concrete itself. The properties of coarse aggregates do grossly affect the durability and structural performance of concrete. Such properties as size, shape, and surface conditions of aggregates are considered alongside the mineral composition of the rock material from which theaggregate formed a part.

1.3 Aims and objectives

The aim of this project is to investigate the effects of different size of coarse aggregate on the compressive strength of concrete.

The objectives of this research are as follows:

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

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

3 To design the mix proportions.

4 To determine the workability of the fresh concrete.

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

6 To determine the compressive strength of the hardened concrete.

1.4 Scope of work

The present work aims to determine the effects of different coarse aggregate sizes on the compressive strength of concrete using aggregates of sizes; 12mm, 16mm and 20mm, sieve analysis conducted to grade the aggregate. A cement mix ratio of 1:2:4, water cement ratio of 0.55 and curing days of 7, 14, 21 and 28 days was adopted for 24 cubes of size 150mm×150mm×150mm. They were casted with the components of the concrete batched by weight. The concrete cubes cured in water 24 hours after casting using the ponding method of curing. The compressive strength of the concrete at each aggregate size is determined using the load-testing machine available at the Engineering Laboratory Nnamdi Azikiwe University Awka.

1.5 Significance of study

Aggregate is commonly considered an inert filler, which accounts for 60 to 80 percent of the volume and 70 to 85 percent of the weight of concrete. Although aggregate is considered an inert filler, aggregates are necessary component that defines the concrete’s thermal and elastic properties and dimensional stability.

For this reason, the quality of the coarse aggregates is essential when considering the quality of the concrete itself. The results from the work aim to serve as a guide in the building and construction industry while recommending the optimum size of coarse aggregate to use at a mix ratio of 1:2:4 and a water cement ratio of 0.55 to achieve maximum strength of hardened concrete after curing.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Concrete is a relatively new construction material when compared to earth, stone, timber and steel. However it is now the most widely used material for building and civil engineering constructions.

In 2011 alone, over of 27 billion tons was used (in comparison to only about 0.7 billion used in 1993) (Garba, 2014). Besides, if a concrete is to be suitable for a particular purpose, it is necessaryto select the constituent materials and combine them in such a manner as to develop constituents of concrete depends on the quality and economy of the particular concrete required.

Concrete is a composite material composed of coarse granular material (the aggregate) embeddedin a hard matrix of material (the cement or binder) that fills the space between aggregate particlesand glues them together. We can also consider concrete as a composite material that consists of a binding medium within which are embedded particles of fragments of fine aggregates (sand) and coarse aggregate (crushed granite, quartzite, or river gravel). So basically the simplest representation of concrete is;

Concrete = cement + fine aggregate +coarse aggregate +water

In light of the controversy, this report describes work that is aimed at improving the understandingof the role that coarse aggregate plays in the compressive strength of concrete. The role of coarse aggregate in concrete is central to this report. While the topic has been under study for many years,an understanding of the effects of coarse aggregate has become increasingly more important with the introduction of high strength concretes, since coarse aggregate plays a progressively more important role in concrete behavior as strength increases.

Concrete is the most widely used construction material in the world. It is used in many different structures such as dams, pavements, building frames and bridges. Also its worldwide production exceeds that of steel by a factor of 10 in tonnage and by more than a factor of 30 in volume. The present consumption of concrete is over 10 billion tons a year. It is more than 10 times of the consumption of steel by weight.

Concrete is the most inexpensive and the most readily available material. The cost of production of concrete is low compared with other engineering construction materials. Because concrete is a low temperature bonded inorganic material and its reaction occurs at room temperature, concrete can gain its strength at ambient temperature.

It can be formed into different into different desired shapes and sizes right at the construction sites. Concrete has low energy consumption for production compared with that of steel. Unlike wood and steel, concrete can harden in water and can withstand the action of water without serious deterioration. This makes concrete an ideal material for building structures to control, store and transport water examples include dams and concrete pipelines. Concrete conducts heat slowly and is able to store considerable quantities of heat from the environment and thus can be used as protective coating for steel structures.

2.2 Limitations of concrete

Besides being an ideal construction material, it does have the following limitations. Concrete has low tensile strength and hence cracks easily. Therefore, concrete is to be reinforced with mild steel bars, high tensile steel or mesh. Concrete expands and contracts with the changes in temperature.

Hence expansion joints are to be provided to avoid the formation of cracks due to thermal movements.

Fresh concrete shrinks on drying. It also expands and contracts with wetting and drying. Provision of contraction joints is to be made to avoid the formation of cracks due to dry shrinkage and moisture movements. Concrete is not entirely impervious to moisture and contains soluble salts which may cause efflorescence. This requires special care at the joints. Creeps develop in concrete under sustained loads and this factor is to be taken care of while designing dams and pre- stressed concrete structures.

2.3 Classification of concrete

based on Unit Weight

1. Ultra-light concrete: < 1,200 kg/m^3
2. Lightweight concrete: 1200- 1,800 kg/m^3
3. Normal-weight concrete: 2,400 kg/m^3
4. Heavyweight concrete: > 3,200 kg/m^3

Based On Strength

1. Low-strength concrete: < 20 MPa compressive strength
2. Moderate-strength concrete: 20 -50 MPa compressive strength
3. High-strength concrete: 50 - 200 MPa compressive strength
4. Ultra high-strength concrete: > 200 MPa compressive strength

2.4 Properties of concrete

To obtain a good quality concrete, its properties in both fresh and hardened states play important rules.

2.4.1 Properties of fresh concrete

Workability

Workability is a general term to describe the properties of fresh concrete. Workability is often defined as the amount of mechanical work required for full compaction of the concrete without segregation. This is useful definition because the final strength of the concrete is largely influenced by the degree of compaction. A small increase in void content due to insufficient compaction could lead to a large decrease in strength. The primary characteristics of workability are consistency (or fluidity) and cohesiveness. Consistency is used to measure the ease of flow of fresh concrete. And cohesiveness is used to describe the ability of fresh concrete to hold all ingredients together without segregation and excessive bleeding.

Segregation

Segregation of concrete means separation of ingredients from design fresh concrete resulting in the non-uniform mix. More specifically this implies the separation of coarse aggregates from the mortar because of differences in size, density, shape and other properties of ingredients in which they are composed. Because of segregation honeycomb is created in the concrete and it basically affects the strength of the concrete and its porosity. During construction work, segregation and concrete can occur on site and it affects the durability of your structures. If you are constructing your own house or working on a site you have to understand about segregation and concrete. In good concrete all the ingredients are properly distributed and make a homogeneous mixture. If a concrete sample exhibits a tendency for separation of coarse aggregates from the rest of the ingredients, it indicates segregation and concrete depending upon the dryness or wetness of the concrete mix.

Types of Segregation of Concrete

There are mainly 2 types; the coarser and the heavier particles tend to separate out or setting down from the rest of the mix because they tend to travel faster along a slope or settle more than finer materials. This type of segregation may occur if the concrete mix is too dry. Grout (water + cement) separating out from the rest of the material because of lowest specific gravity. This type of segregation may occur if the concrete mix is too wet. A well-designed concrete does not segregate if rightly mixed and batched.

Causes of Segregation in Concrete

The following are the major causes:

1. The difference in the specific gravity of the mix constituents (fine aggregates and coarse aggregate).
2. The difference in the size of aggregate.
3. Improper grading of aggregates.
4. Improper handling of aggregates.
5. Bad practices and handling and transporting of concrete.
6. Too much vibration of concrete.
7. Concrete that is not proportioned properly and not mixed adequately for 2 workable mix.
8. Placing of concrete from a greater height.
9. Concrete is discharged from a badly designed mixer or from a mixture with worn-out blades.

How to Prevent Segregation of Concrete

1. At the time of construction, especially while using transit mixers care should be taken that the concrete is not poured from a height greater that 1.5 meter.
2. Aggregates should be properly graded as it will prevent the segregation.
3. To improve the viscosity of concrete which prevents the segregation, air entraining agents can be used.
4. In case of mass concreting where mechanical vibrators are used care should be taken that they are not used for longer period.

Bleeding

Concrete mix design is a very precise science to achieve design concrete strength. If concrete ingredients are not mixed properly many concrete related problems can result and affect the strength and durability of concrete. Bleeding is one of the concrete related problems. It is mostly observed in a highly wet mix and badly proportioned concrete ingredients after placing of the fresh concrete. Free water in a mix rises upward to the concrete surface due to the settlement of solid particles by gravity action. This process is known as 'Bleeding of Concrete". In certain situation though bleeding water does not come up to the surface but bleeding does take place. The bleeding water gets trapped on the underside of coarse aggregates or of reinforcements. This is known as internal bleeding.

Effects of bleeding of concrete

1. The main effect of is that the concrete mixture loses its homogeneity, which results in weak and porous concrete.
2. It affects the bond between hardened cement paste and aggregates for reinforcement on account of higher water cement ratio.

3. Such concrete is easily prone to the micro cracking due to shrinkage stresses caused by dissipation of heat of hydration and drying shrinkage.
4. If the bleeding water carries with it more amount of the cement particles, a layer of laitance will be formed.
5. Due to bleeding the ability of pumping is very much reduced, which makes it difficult where concrete is to be pumped for higher elevations.

How to prevent bleeding of concrete

1. Bleeding of concrete depends on the properties of cement. Bleeding gets decreased by increasing the fineness of cement because finer particles hydrate earlier and also their rate of sedimentation is lower.
2. The properties of cement are not an only soul factor influencing the bleeding of concrete.
3. The presence of fine aggregates and higher water cement ratio also lead to bleeding. A higher rate of the water cement ratio can lead to excessive bleeding and if evaporation of water from the surface of the concrete is faster than the bleeding rate plastic shrinkage cracking may result.
4. Use of air entraining admixtures can also reduce the bleeding in concrete

2.4.2 Properties of Hardened Concrete

Hardness

The hardness of concrete is referenced by its compressive strength. The higher the compressive strength, the harder the material.

Strength

Strength with regard to concrete for structural purposes it can be defined as the unit force required to cause rupture. Concrete is considered by many to be a strong and durable material, and rightfully so. But there are different ways to assess concrete strength. Perhaps even more importantly, these strength properties each add different qualities to concrete that make it an ideal choice in various use cases

Compressive strength

Concrete is used mainly so as to exploit its good compressive strength. The compressive strength of concrete is the load applied on hardened concrete per unit area of the specimen symbolized by N/mm^2. Neville and Brooks (2000) consider the fracture mechanics approach for concrete under bi-and tri-axial stresses and under uniaxial compression.

Tensile strength of concrete

Tensile strength is the ability of concrete to resist breaking or cracking under tension. It affects the size of cracks in concrete structures and the extent to which they occur. Cracks occur when tensile forces exceed the tensile strength of the concrete.

Traditional concrete has a significantly lower tensile strength as compared to compressive strength. This means that concrete structures undergoing tensile stress must be reinforced with materials that have high tensile strength, such as steel.

It is difficult to directly test the tensile strength of concrete, so indirect methods are used. The most common indirect methods are flexural strength and the split tensile strength.

The split tensile strength of concrete is determined using a split tensile test on concrete cylinders. The test should be performed according to the ASTM C496 standard.

Flexural strength of concrete

Flexural strength is used as another indirect measure of tensile strength. It is defined as a measure of an unreinforced concrete slab or beam to resist failure in bending. In other words, it is the ability of the concrete to resist bending.

Flexural strength is usually anywhere from 10 to 15 percent of the compressive strength, depending on the specific concrete mixture.

There are two standard tests from ASTM that are used to determine the flexural strength of concrete C78 and C293. Results are expressed in a Modulus of Rupture (MR) in psi.

Flexural tests are very sensitive to concrete preparation, handling, and curing. The test should be conducted when the specimen is wet. For these reasons, results from compressive strength tests are more typically used when describing the strength of concrete, as these numbers are more reliable.

Factors affecting the strength of concrete

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

Cement

Cement is considered as the main constituent of concrete in terms of strength development. (Gupta and Gupta 2012) define cement as a material having adhesive and cohesive properties which makes it capable of bonding material fragments into a compact mass. Cement and water constituents of concrete chemically react to form a binding medium (Garba, 2014). When cement paste hardens, it binds the aggregate into an artificial stone-like material called concrete. According to

Dunuweera (2017), Cement is produced by utilizing an extensive amount of raw materials treated and reacted at extreme conditions such as high temperatures.

Aggregate

Aggregates constitute the skeleton of concrete. Approximately three-quarters of the volume of conventional concrete are occupied by aggregate. It is inevitable that a constituent occupying such a large percentage of the mass should contribute important properties to both the fresh and hardened product. Aggregate is usually viewed as an inert dispersion in the cement paste. However, strictly speaking, aggregate is not truly inert because physical, thermal, and, sometimes, chemical properties can influence the performance of concrete (Neville and Brooks, 2000).

Water

Water is one of the most important ingredients of concrete as it actively participates in the chemical reaction with cement. This is why (Neville and Brook2000) reiterates that the quality of water is important because impurities in it may interfere with the setting of cement, may adversely affect the strength of the concrete or cause staining of its surface, and may also lead to corrosion of reinforcement.

However, according to Shetty (2009), MacCarthy (2010), Sabraini (2010) Garba et al. (2014), mixing water induce hydration process in concrete production (which is responsible for strength development) and assist in workability (which enables concrete to be easily mixed, transported placed and compacted). The reaction between cement and water is as follows;

$$2Ca_3SiO_5 + 6H_2O \rightarrow 3Ca(OH)_2 + Ca_3Si_2O_7.3H_2O \quad (2.1)$$

$$Ca_3(AlO_3)_2 + 6H_2O \rightarrow Ca_6(AlO_3)_2.6H_2O \quad (2.2)$$

Numerous studies have been carried out on the effect of water quality on the strength and durability characteristics of a cement concrete. It was generally observed by virtually all the researchers suchas McCarthy (2010), Sabraini (2010), Gupta and Gupta (2012) and Garba (2014) that the quality of mixing water for concrete production should be as good as drinking water. However, this statement was not agreed by Shetty (2009), he argues that some water containing small amount ofsugar could be suitable for mixing concrete and conversely water suitable for mixing concrete maynot necessary be fit for drinking.

He emphasizes that the best course to find out whether a particular type of water is suitable for concrete making or not, is, to make concrete with this water and compare its 7 days' and 28 days' strength with comparison cubes made with distilled water. If the compressive strength is up to 90%, the source of water may be accepted. Besides that, there is relationship between the quality of mixing waters used in the construction of a structure with the setting time strength, stability, safety and serviceability of that structure. Noruzman et al. (2012) carried out a research in which they noted that the initial setting time of cement paste and the compressive strength tests are the two methods by which questionable water may be tested with respect to its suitability for concrete production.

Also, the presence of harmful oxides, such as MgO, SO_3 and other alkalis, in mixing water affects the quality of the hardened concrete (Reddy, 2013). Since water may contain some impurities suchas clay, sugar, oil, salt etc., which may not be within the tolerable concentration as clarified by (Shetty 2009). The quality of water is to be critically monitored and controlled during the process of concrete making.

Water to cement ratio

Water to cement ratio (W/C) ratio is one of the most important parameters governing the strength of concrete. The density of hardened cement (in terms of a gel/space ratio) is governed by the water/cement ratio. With higher w/c ratio, the paste is more porous and hence the strength is lower. The strength continues to increase with decreasing w/c ratio only if the concrete can be fully compacted.

For concrete with very low w/c ratio, if no water-reducing agent is employed, the workability can be so poor that a lot of air voids are entrapped in the hardened material. The strength can then be lower than that for concrete with higher w/c ratio. For a given set of materials and environment conditions, the strength of a concrete age depends only on the water-cement ratio, providing full compaction can be achieved. The standard water-cement ratio is 0.5.

Coarse to fine aggregate ratio

The following points should be noted for coarse/fine aggregate ratio:

1. If the proportion of the aggregate is increased in relation to the coarse aggregate, the overall aggregate surface area will increase.
2. If the surface area of the aggregate has increased, the water demand will also increase.
3. Assuming the water demand has increased, the water-cement ratio will increase.
4. Since the water-cement ratio has increased, the compressive strength will decrease.

Aggregate to cement ratio

The following points should be noted for aggregate-cement ratio:

1. If the volume remains the same and the proportion of cement in relation to that of sand is increased, the surface area of the solid will increase.

2. If the surface area of the solid has increased, the water demand will stay the same for the constant workability.
3. Assuming an increase in cement content for no increase in water demand, the water-cement ratio will decrease.
4. If the water-cement ratio reduces, the strength of the concrete will increase.

Age of concrete

The degree of hydration is synonymous with the age of concrete provided that the concrete has not been allowed to dry out or the temperature is too low. In theory, provided that the concrete is not allowed to dry out, then it will always be increasing albeit at an ever reducing rate. For convenience and for most practical applications, it is generally accepted that the majority of the strength has been achieved by 28 days.

The 7^{th} day strength can range from 60% - 80% of the 28^{th} day strength, with a higher percentage for a lower w/c ratio. After 28 days, the strength can continue to go up. Experimental data indicates that the strength after one year can be over 20% higher than the 28 days strength. The reliance on such strength increase in structural design needs to be done with caution, as the progress of cement hydration under real world conditions may vary greatly from site to site.

Compaction of concrete

Once the concrete has been placed, it is ready to be compacted. The purpose of compaction is to get rid the air voids that are trapped in loose concrete. Air voids reduce the strength of the concrete. For every 1% of entrapped air, the strength falls by somewhere between 5% and 7% (Gambhir, 1999). This means that concrete containing a mere 5% air voids due to incomplete compaction can lose as much as one third of its strength. Air voids also increase concrete permeability. That in turn reduces its durability.

If the concrete is not dense and impermeable, it will not be watertight. It will be less able to withstand aggressive liquids and its exposed surfaces will weather badly. The difference between air voids and entrapped air bubbles should be noted at this stage. The air bubbles that are entrained are relatively small and spherical in shape, increase frost resistance. Entrapped air on the other hand tends to be irregular in shape and is detrimental to the strength of the mix. In order to remove both, the concrete must be properly compacted.

Curing of Concrete

It should be clear from what has been said above, that the detrimental effects of storage of concrete in a dry environment can be reduced if the concrete is adequately cured to prevent excessive moisture loss. Curing is the process of protecting the freshly poured concrete from evaporation and temperature extremes which might adversely affect cement hydration. Curing ensures the continuation of hydration of cement and the strength gain of concrete. Concrete surfaces are cured by sprinkling with water. Most of the strength gain and take place within the first month of concrete's life cycle but hydration continues at slower rate for many years. Concrete continues to get stronger as it gets older.

Durability

Concrete has been considered as a material that can bear both internal and external exposure conditions requiring little or no maintenance. This assumption proved valid except when it is subjected to severe or aggressive environment. A durable concrete is one that serves the purpose for which it was designed for, for the specified service condition and the lifespan. Gambo (2014), defines durability of cement concrete as its resistance to deteriorating agencies to which it may be exposed during its service life or which may inadvertently reside inside the concrete itself.

The durability of concrete is affected by physical, mechanical and chemical causes but is mostly affected by chemical causes, which result in volume change, cracking of concrete and ultimately leading to deterioration of concrete. This is the reason why Gupta and Gupta (2012) discussed the effect of chemical causes on the durability of concrete under the following headings: sulphate attack; acid attack; Sea water attack; alkali aggregate reaction; deicing salts effect and carbonation.

Impermeability

The impermeability of concrete refers to the property of concrete that cannot be pervaded by water oil and other liquids with pressures. It plays an important role in the durability of concrete.

Dimensional change

The dimensions of concrete change when there is elastic deformation under applied loading, creep deformation under sustained loading, thermal expansion or contraction under temperature variation, and swelling or shrinkage under moisture content variation.

Workability of concrete

Workability is a general term to describe the properties of fresh concrete. Workability is often defined as the amount of mechanical work required for full compaction of the concrete without segregation. This is useful definition because the final strength of the concrete is largely influenced by the degree of compaction. A small increase in void content due to insufficient compaction could lead to a large decrease in strength.

The primary characteristics of workability are consistency (or fluidity) and cohesiveness. Consistency is used to measure the ease of flow of fresh concrete. And cohesiveness is used to describe the ability of fresh concrete to hold all ingredients together without segregation and excessive bleeding.

Factors affecting workability

1. **Water content**: Except for the absorption by particle surfaces, water must fill the spaces among particles. Additional water "lubricates" the particles by separating them with a water film. Increasing the amount of water will increase the fluidity and make concrete easy to be compacted. Indeed, the total water content is the most important parameter governing consistency. But, too much water reduces cohesiveness, leading to segregation and bleeding. With increasing water content, concrete strength is also reduced.
2. **Aggregate mix proportion**: For a fixed w/c ratio, an increase in the aggregate/cement ratio will decrease the fluidity. (Note that less cement implies less water, as w/c is fixed.) Generally speaking, a higher fine aggregate/coarse aggregate ratio leads to a higher cohesiveness.
3. **Maximum aggregate size**: For a given w/c ratio, as the maximum size of aggregate increases, the fluidity increases. This is generally due to the overall reduction in surface area of the aggregates.
4. **Aggregate properties**: The shape and texture of aggregate particles can also affect the workability. As a general rule, the more nearly spherical and smoother the particles, the more workable the concrete.
5. **Cement**: Increased fineness will reduce fluidity at a given water-cement ratio, but increase cohesiveness. Under the same water-cement ratio, the higher the cement content, the better the workability (as the total water content increases).
6. **Admixtures**: Air entraining agent and super plasticizers can improve the workability.

7. **Temperature and time**: As temperature increases, the workability decreases. Also, workability decreases with time. These effects are related to the progression of chemical reaction.

Workability test

Workability of concrete has never been precisely defined, but for practical purposes it generally implies the ease with which a concrete mix can be handled from the mix to its final compacted shape. The measurement of workability of fresh concrete is important in assessing the practicability of compacting the mixture and also in maintaining consistency throughout the job. In addition, workability tests are often used as an indirect check on the water content and therefore on the water/cement ratio of the concrete (Barnbrook et al., 1979).

The types of workability test are;

a. Slump test.
b. Compaction factor test.
c. Flow test.
d. Vee-Bee consistometer test.
e. Kelly ball test.

Slump test

The concrete slump test or slump cone test is the most common test for workability of freshly mixed concrete which can be performed either at the working site/field or in the laboratory. To maintain the workability and quality of fresh concrete, it is necessary to check batch by batch inspection of the concrete slump. This can be easily done with the concrete slump test. The slump test is the simplest test to determine workability of concrete that involves low cost and provides immediate results. Slump test is done in accordance to BS 1881: 103 :1993.

Three different kinds of possible slumps exist; true slump, shear slump, and collapse slump. Conventionally, when shear or collapse slump occur, the test is considered invalid. However, due to recent development of self-compact concrete, the term of collapse slump has to be used with caution.

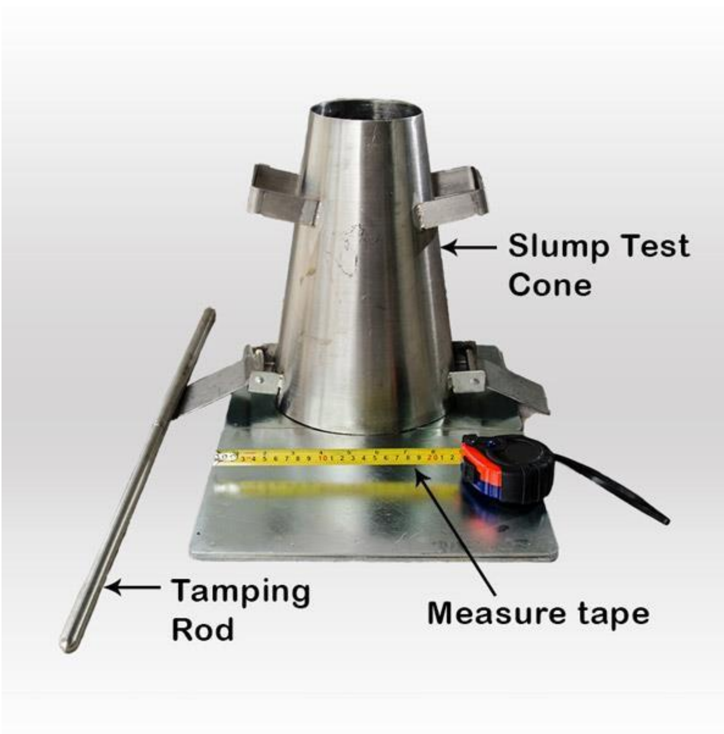

Plate 2.1: Slump Test Apparatus.

Compaction factor test

Compaction factor test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. This is specially designed for laboratory use, but if the circumstances favours, it can also be used on the working site/field.

Compaction factor test of concrete is more precise and sensitive than the concrete slump test; hence it is more favorable and useful for low workable concrete or dry concrete which is generally used when concrete is to be compacted by vibration. Compaction factor test is done in accordance to BS 1881: 103 :1993.

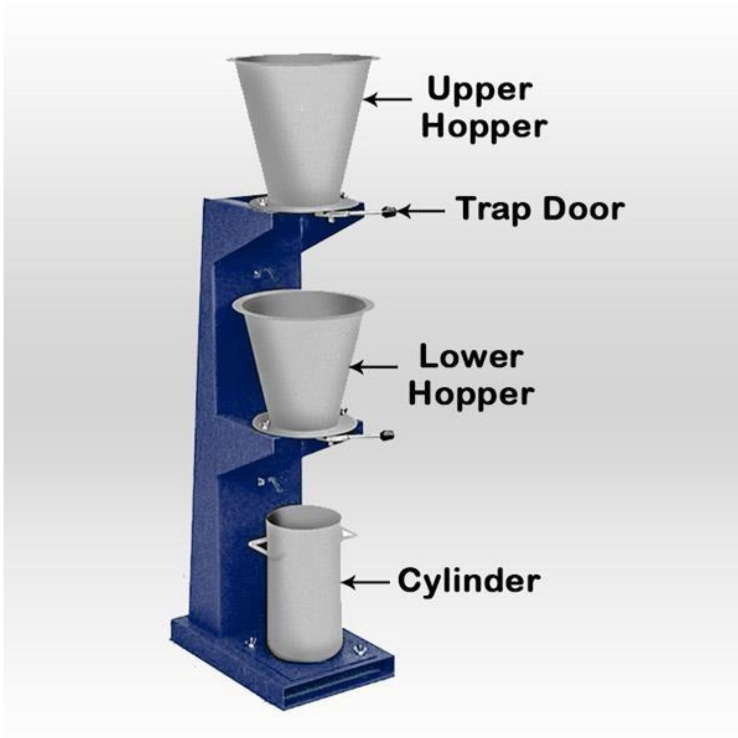

Plate 2.2: Compaction Factor Apparatus

The flow test

The flow test is a laboratory test, which gives an indication of the quality of concrete with respect to consistency or workability and cohesiveness. In the flow test, a standard mass of concrete is subjected to jolting. This test is generally used for high/ very high workability concrete.

Similar laboratory test named ‘Flow Table Test ‘was developed in Germany in1933 and it has been described in ‘BS 1881:105: 1984’. This method is used for the high and very high workable concrete which would exhibit the collapse slump.

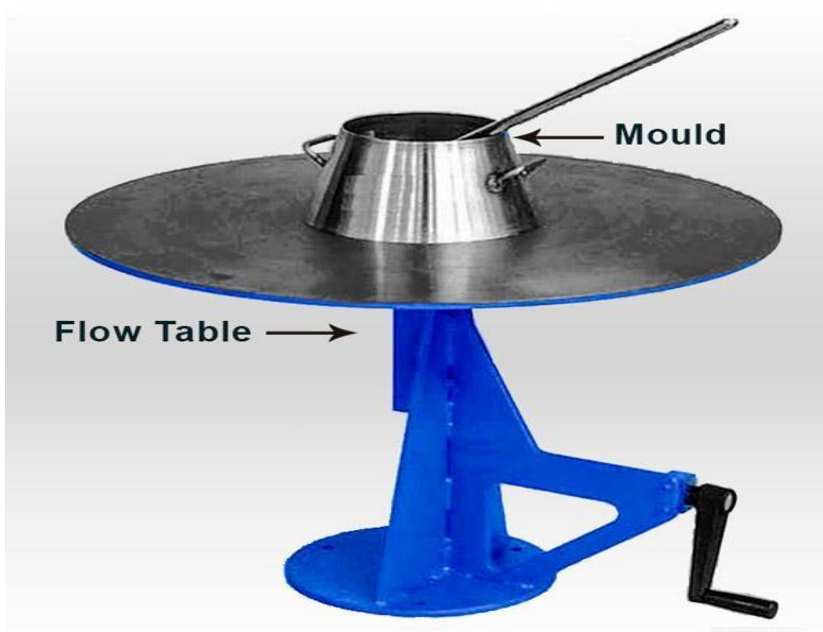

Plate 2.3: Flow Test Apparatus

Vee bee consistometer test

Vee bee consistometer test is a good laboratory test on fresh concrete to measure the workability in an indirect way by using a Vee-Bee consistometer. Vee bee test is usually performed on dry concrete and it is not suitable for very wet concrete. Vee bee consistometer test determines the mobility and to some extent compatibility of concrete. In the vee bee consistometer test vibrator is used instead of jolting. Vee bee test determines the time required for the transformation of concrete by the vibration. This test is done in accordance to BS EN 12350-3: 2009.

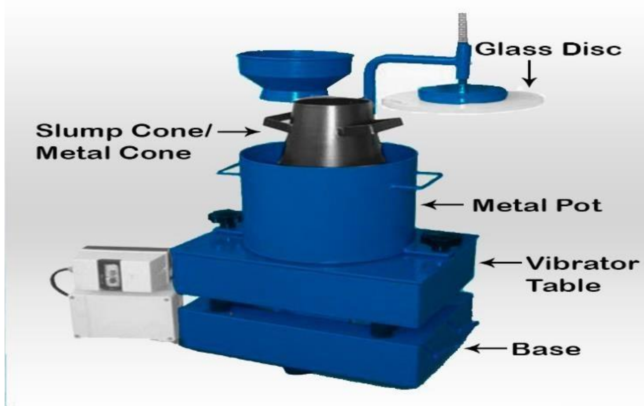

Plate 2.4: Vee-Bee Apparatus

Kelly ball test

This test is developed by J.W Kelly, hence it's known as a Kelly ball test. Kelly ball test is a simple and inexpensive field test which measures workability of fresh concrete with the similar to the concrete slump test, but it is more accurate and faster than a slump test. This test uses a device that consist of metal hemisphere (ball) thereby indicating the consistency of fresh concrete by its level of penetration when the metal hemisphere drops. Thus, in this test, depth is determined through metal hemisphere, which sinks under its own weight into fresh concrete. This test is done in accordance to ASTM C360-92 – For ball penetration test

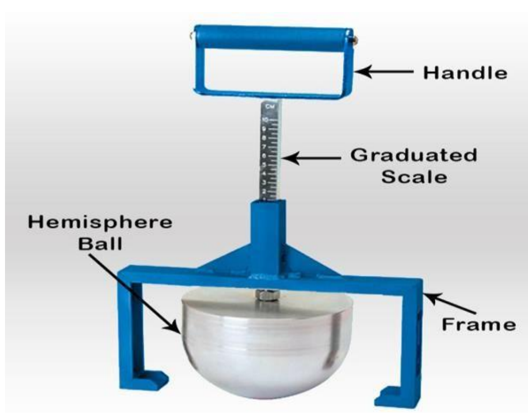

Plate 2.5: Kelly Ball Apparatus

Setting of concrete

Setting is defined as the onset of rigidity in fresh concrete. It is different from hardening, which describes the development of useful and measurable strength. Setting precedes hardening although both are controlled by the continuing hydration of the cement.

2.5 Review Of The Existing Literature

Young and Sam (2008) reported that smooth rounded aggregates was more workable but yielded a lesser compressive strength in the matrix than irregular aggregates with rough surface texture. They were also of the opinion that a fine coating of impurities such as silt on the aggregate surface could hinder the development of a good bond and thus affects the strength of concrete produced with the aggregates.

Chen and Liu (2004) as well as Rao and Prasad (2002) viewed aggregates as the skeleton of concrete and consequently persuaded that all forms of coatings should be avoided in order to achieve a good concrete. When a concrete mass is stressed, failure may originate within the aggregates, the matrix, or at the aggregate-matrix interface. The aggregate-matrix interface is an important factor determining the strength of concrete.

Bloem and Gaynor (1963) studied the effect of shape, surface texture, fine coatings, and maximum size of aggregates on the water requirement and strength of concrete. The study reported that at equal water/cement ratio, irregular shaped smaller sized aggregates without coatings achieved a better strength than smooth rounded large sized aggregates. They also opined that individual properties of aggregates and the magnitude of the size difference may lead to increase or decrease in concrete strength at a fixed cement content.

Aginam et al. (2013) investigated the effect of coarse aggregate types on the compressive strength of concrete on three different types of coarse aggregates, with 20mm maximum size, was employed in the investigation, namely; crushed granite, washed gravel, and unwashed gravel. The grading and relative densities of the aggregates was studied. The mix ratio and water/cement ratio adopted for the study was 1:3:6 and 0.6 respectively. The target mean strength at 28 days was $15N/mm^2$. Twelve concrete cubes (150mm x 150mm x 150mm) were cast for each coarse aggregate type of which four were crushed at each maturity age namely; 7, 14, 21, and 28 days. All cubes reached the target mean strength after 7 days of curing. The 28 days strengths of the concretes made with crushed granite, washed gravel, and unwashed gravel were 25.1 N/mm^2, 20.0 N/mm^2, and 16.9 N/mm^2 respectively. Consequently, the authors concluded that the strength of concrete depends greatly on the internal structure, surface nature and shape of aggregates.

According to Bruce and Ndlangamandla (2016), the effect of aggregate size on the compressive strength of concrete. The experiment had three treatments, which were the aggregate sizes (9.5 mm, 13.2 mm and 19.0 mm) and the control. A constant mix of 1: 2: 4 with a water/cement ratio of 0.5 used throughout the experiment. Three cubes (150 mm× 150 mm) were casted from each batch and the compressive strength was determined using a concrete load-testing machine (Pro-Ikon cube press) after 7 days curing. The results reflected that workability (slump) increased with increasing aggregate size. The concrete made from the 9.5 mm, 13.2 mm and 19.0 mm aggregate sizes had workability (slumps) of 10 mm, 13.5 mm and 20 mm, respectively. The mean compressive strength for the 9.5 mm, 13.2 mm, and 19 mm were 15.34 N/mm^2, 18.61 N/mm^2 and 19.48 N/mm^2, respectively. They concluded that concrete workability was directly proportional to aggregate size. The mean concrete compressive strength increased with increasing aggregates size.

Abdullahi (2012) investigated the effect of aggregate type on compressive strength of concrete for a nominal mix (1:2:4), 75 cubes (150x150mm) were cast to allow the compressive strength to be monitored at 3, 7, 14, 21, and 28 days. Test result showed that concrete made from river gravel has the highest workability followed by crushed quartzite and crushed granite aggregates. Highest compressive strength at all ages with concrete made from quartzite aggregate followed by river gravel and then granite aggregate. The author proposed compressive strength models as a function of age at curing. In addition, where concrete practitioners have options, aggregate made from quartzite is advisable for concrete works.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Materials

3.1.1 Cement

The Portland-Limestone cement with the brand name of Dangote cement was purchased at Agu-Awka in Anambra state. It was stored in a dry environment to protect it from moisture to avoid the occurrence of lumps before the experiment.

3.1.2 Fine Aggregates

Fine aggregate used was dry river sand sourced locally from Ezu River in Anambra state and bought from the retailers in Agu-Awka. The sand was sun-dried before sieve analysis was carried out to rid it of impurities such as crushed stones and twigs. It was sieved to a particle size range between 0.15 -2.36mm which is within the range specified by BS112 (1971).

Plate 3.1: Sharp Sand

3.1.3 Coarse Aggregates

The type of coarse aggregate used throughout this investigation was washed granite. The effects of three different sizes of coarse aggregates were investigated in this research these sizes are 20mm, 16mm, and 12mm. These sizes were sourced from the quarries of Abakaliki and were bought from the local retailers in Agu-Awka in Anambra state. Sieve analysis tests were also conducted on the coarse aggregates for adequate confirmation of the sizes of the samples after they have been washed and dried.

Plate 3.2: Coarse aggregates

3.1.4 Water

Portable water at the Nnamdi Azikiwe University was used throughout this investigation and the tests were carried out at the Civil Engineering laboratory of the same University.

3.2 Methodology

The concrete mix proportions were batched by weight and the casting, curing and crushing were done in accordance with the guidelines specified by BS1881; Part108 (1983), BS8110; Part1, (1985), and BS1881; Part3 (1992).

150x150x150mm cubes were casted and the compressive strengths were investigated at 7, 14, 21 and 28 days of curing.

Each concrete mix proportion was the same except the variation in aggregate size. Eight cubes were cast for each aggregate size, two cubes for each curing age. The hardened concrete cubes are retrieved from the steel molds 24hours after casting and are placed in curing tanks. The concrete cubes are withdrawn from water in the curing tanks and allowed to dry for some hours before crushing. The average compressive strength is taken from the two cubes in each curing age

3.2.1 Mix Proportion

A nominal mix ratio of 1:2:4 (cement: fine aggregates: coarse aggregates) was adopted for the purpose of this work and water-cement ratio of 0.55 was used throughout the investigation. The mix composition was computed using the weight method and the batch compositions are shown below. To calculate the quality of materials required to cast 1 concrete cube at a mix ratio of 1:2:4by batching by weight.

Parameters

i. Density of concrete = 2400kg/m^3

ii. Size of cubes =150mm x 150mm

iii. Converting to meters = 0.15m by 0.15m

iv. Volume of cube = 0.15m × 0.15m × 0.15m = $0.00375m^3$

v. Weight of cube = $2400kg/m^3$ x $0.153m^3$= 8.1kg.

To determine the weight of the individual components

1:2:4 = cement: sand: aggregates; 1:2:4 = 7

Cement: 1/7 × 8.1 = 1.157kg

Sand: 2/7 × 8.1 = 2.314kg

Coarse aggregates: 4/7 × 8.1 = 4.629kg

Provide additional 10% on all concrete components to take care of wastage;

Cement = 1.157 + (10/100 × 1.157) = 1.157 + 0.1157 =1.2727kg

Sand = 2.314 + (10/100 × 2.314) = 2.314 + 0.2314 = 2.5454kg

Aggregate = 4.629 + (10/100 × 4.629) = 4.629 + 0.4629= 5.0919kg

To estimate the weight of water for one concrete cube using the chosen water-cement ratio of 0.55;

1.2727 x 0.55 = 0.6999kg

Converting water in kg to liters

1kg of water is approximately 1liter of water therefore for each concrete cube

0.6999liters of water must be maintained.

Table 3.1: Mix design for one concrete cube

CEMENT (Kg)	SAND (Kg)	COARSE AGGREGATE (Kg)	WATER (Kg)
1.2727	2.5454	5.0919	0.6999

3.2.2 Preliminary Test

In controlling the quality of aggregates, it is important to ensure that the aggregate is clean and does not contain any organic impurities which might retard or prevent the setting of the cement and that the proportions of the different sizes of the particles within a graded material remain uniform. Sometimes excessive silt and clay contained in the fine and coarse aggregates may result in increased shrinkage or increased permeability in addition to poor bond characteristics. It may also necessitate greater water requirement for workability.

Accurate tests for determining the proportions of clay, silt and dust in fine or coarse aggregates are given in clause 12 and 13 of BS 812 (Barnbrook et al., 1979), but these tests are suitable only for the laboratory. On site cleanness can be assessed visually, though for natural sands the field settling tests will give an approximate guide to the amount of clay or silt. Cleanness tests on the coarse aggregates was not considered as the coarse aggregate was visibly clean from silt and clayey components as the aggregates used were washed crushed quarry stones.

Sieve Analysis

Sieve analysis is referred to as the simple operation of separating a sample of aggregates into factions (groups) each consisting of particles of the same size. The main aim is to determine various sizes of particles present in aggregates and appropriately grading the aggregates.

Apparatus

a. Standard B.S test sieve

b. A weighing scale

c. Container used in the weighing.

Procedure for the sieve analysis

i. The aggregate specimen to be used (fine aggregate) is dried for 24 hours to rid specimen of any traces of moisture.

ii. Sieves are arranged from top to bottom in descending order.

iii. Weight of the container to be used in the specimen measurements is ascertained.

iv. Before the sample is used, they are sieved through a 4.75mm sieve for uniform sample; and the portion retained in the sieve was discarded while those passing were used to perform the particle size analysis.

v. A considerable measured quantity of the aggregate is placed in the sieves from the top.

vi. Sieving is done for about 5 hours manually.

For the coarse aggregate used, the aggregate was sieved through the 1inch sieve (25mm sieve) and those passing the sieve aperture and retained in the (20 mm) sieve were used to obtain that particular size of aggregate as those not passing the 1 inch sieve were discarded. This was to bring about uniformity in the aggregate used. The same procedure was repeated for sieve sizes 16mm, 12mm. Aggregates subsequently retained in sieve sizes 6.3mm, 5mm, 3.35mm and the pan were discarded.

Testing on fresh concrete

Slump Test

Workability of concrete has never been precisely defined, but for practical purposes it generally implies the ease with which a concrete mix can be handled from the mix to its final compacted shape. The measurement of workability of fresh concrete is important in assessing the practicability of compacting the mix and also in maintaining consistency throughout the job. The slump test was carried out on the fresh concrete after the mixing of each batch, the slump value is taken down and the used concrete is poured back into the mix and reblended. The slump test was carried according to specifications on BS EN 12350-2: 2009.

Determination of workability of concrete is as follows;

Apparatuses Used

a. A truncated slump cone (Truncated conical mold)
b. A tampering rod (16mm diameter and 600mm long)
c. Metallic rule
d. Flat tray (metallic)
e. Trowel
f. Spirit level

Procedure of the Test

i. Concrete is mixed with a water/cement ratio of 0.55 for 12mm, 16mm and 20mm aggregate size for uniformity throughout the project research.
ii. The inside of the mold should be cleaned before each testing and mold applied with lubricant (diesel oil) to prevent concrete from sticking to mold surface. The mold is then placed on the flat hard tray such that the wider surface is on the flat form or tray.

iii. The mold (height 300mm, top diameter 100mm and bottom diameter 200mm) is then filled with concrete in 3 layers of equal height with the use of a trowel. Compacting or rodding is carried on each layer with a minimum of 25 strokes with the tampering rod. After the top layer has been rodded, the surface of the concrete is struck off level with the top of the mold with a trowel.

iv. After leveling and smoothing top of the concrete with the mold/cone height, any spillage around the mold is cleaned away from around the base of the mold, and the mold is the lifted vertically from the concrete.

v. The slump is the difference between the height of the concrete before and after the removal of the mold. The tampering rod is placed on top of the cone to span across the concrete slump. The metallic rule is the used to measure the difference in height between the top of the cone and the top of the cone and the top of the slumped concrete.

Testing on hardened Concrete

Compressive test cubes

For aggregates with nominal size of 20mm (¾ inch) or less can be done in 100mm (4 inches) cubes. The 150mm cube was used in this investigation.

$$\text{Compressive strength} = \frac{Compressive\ Load, P\ (KN)}{Surface\ Area, A\ (mm^2)} \tag{3.1}$$

Details of the testing cubes, beams and cores as stated before are given in part 4 of BS 1881. The testing procedure is as follows;

Apparatuses Used

a. Steel molds (150 x150x150) mm^3 with base plates.

b. Tampering rods

c. Shovels for the concrete mixing

d. Hand trowels

e. Weighing balance

Procedure for the Manufacturing of the Test Cubes

i. The molds for the testing would be properly assembled, cleaned up and lubricated to prevent concrete from sticking to the molds surfaces or sides.

ii. Freshly prepared concrete mix is then placed in the molds in 3 layers, with each layer being effectively rammed with the tampering/ramming rod. The ramming of the concrete is carried out methodically, the strokes being evenly distributed over the surface of the concrete in regular pattern and not concentrated in one particular spot.

iii. The test specimens are kept in conditions of constant room temperature and allowed to set for 24hrs of which they are subsequently demolded and marked before putting them in curing tanks until time of testing.

iv. Cube is removed from the curing tank and dimensions and weight of the cube is duly noted.

v. The bearing surface of the testing machine is wiped clean and the cube placed in the compression machine in such a way that the load is applied to the surface of the cube. The axis of the cube must be carefully aligned with the center thrust of the machine.

vi. The load from the machine is applied to the cube by pulling on the machine level handle repeatedly until such a point when the concrete cube show signs of failure or crushing.

vii. The compressive strength is then recorded.

Batching

Generally, the components of concrete in various proportions can be batched by weight or volume. The batching process was done by weight as this is preferable in most cases because of its degree of accuracy. All the concrete constituents were weighed out, from calculations of required mix quantities using the bulk densities of the constituents as well as the volume of mix required to obtain the weights required. The mixing was performed on the floor of the laboratory premises by hand mixing using a shovel and a trowel.

The mixing process was done with measured amount of water, measured amount of fine aggregate, and a well measured amount of coarse aggregate (which could be of 20mm, 16mm, 12mm size) and was mixed together with a mix design ratio of 1:2:4 before it was poured into a concrete cube of 150mm by 150mm.

The coarse aggregates used were of approximately uniform grading at each size and water/cement ratio was also constant throughout the mixing as effectively calculated. This is because it is a well-known fact that concrete strengths vary with aggregate (coarse) grade or sizes as well as water/cement ratio. These were all done to provide for a uniform basis for clearly distinguishing the effects of the coarse aggregate sizes on the compressive strength of concrete.

Mixing Procedure

As obtained from the mix calculations by weight, 1.2727kg of cement, 2.5454kg of sand and5.0919kg of coarse aggregate was the quantity of components adequate for one concrete cube. Subsequently for 8 cubes 10.1816kg was weigh out and mixed with20.3632kg of fine aggregate (sand) until an even mix was obtained. Thereafter, 40.7352kg of gravel was weighed out and added to the cement and sand mixture and water of 5.5992kg in conformity with a 0.55 water-cement ratio was gradually added to the mixture. The mixture was gradually stirred with a shovel as the water was added to bring about an even concrete paste.

Plate 3.3: Hand mixing of concrete

Details of the testing of cubes, beams and cones as stated before are given in part 4 of BS 1881.The testing procedure is as follows. Cube is removed from the curing tank and dimensions and weight of then cube duly noted. The Bearing surface of the testing machine is wiped clean and the cube placed in the compression machine in such a way that the load is applied to the surface of the cube. The axis of the cube must be carefully aligned with the center thrust of the machine. The load from the machine is applied to the cube by pulling on the machine lever handle repeatedly until such a point when the concrete cube show signs of failure or crushing. The compressive strength is then recorded.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Sieve Analysis For Fine Aggregates

Weight of container used for measurements – 110.42 grams

Weight of sample plus the container - 410.42 grams

Weight of test sample used - 300 grams

Table 4.1: Sieve analysis results for fine aggregates

Sieve Size (mm)	**Weight Retained (g)**	**% Weight Retained**	**Cumulative % Retained (g)**	**Cumulative % Passing (g)**
2.00	6.03	2.01	2.00	97.99
1.60	1.61	0.54	2.50	97.45
1.40	49.03	16.34	18.90	81.11
0.80	140.03	45.67	65.60	34.44
0.40	77.52	25.84	91.40	8.60
0.25	23.23	7.74	99.00	0.86
Sieve Pan	2.55	0.85	100	0.00
Total	**300**	**100**		

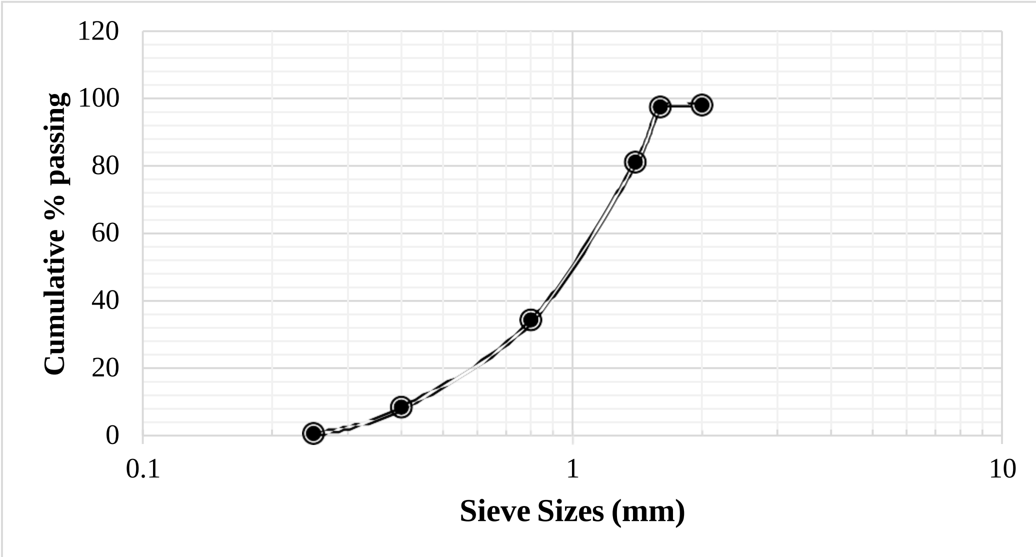

Figure 4.1: Sieve analysis for fine aggregate

4.2 Sieve Analysis for Coarse Aggregates

Table 4.2: Sieve analysis results for coarse aggregate (20mm)

Sieve Size (mm)	Weight Retained (g)	% Weight Retained	Cumulative % Retained (g)	Cumulative % Passing (g)
31.50	0.0	0.00	0.00	100.00
26.50	175.0	8.75	8.75	91.25
20.00	561.5	28.08	36.83	63.17
14.00	112.3	56.15	92.98	7.02
10.00	140.5	7.02	100.00	0.00
4.75	0.0	0.00	100.00	0.00
Tray	0.0	0.00	0.00	0.00
Total	**2000.00**	**100.00**		

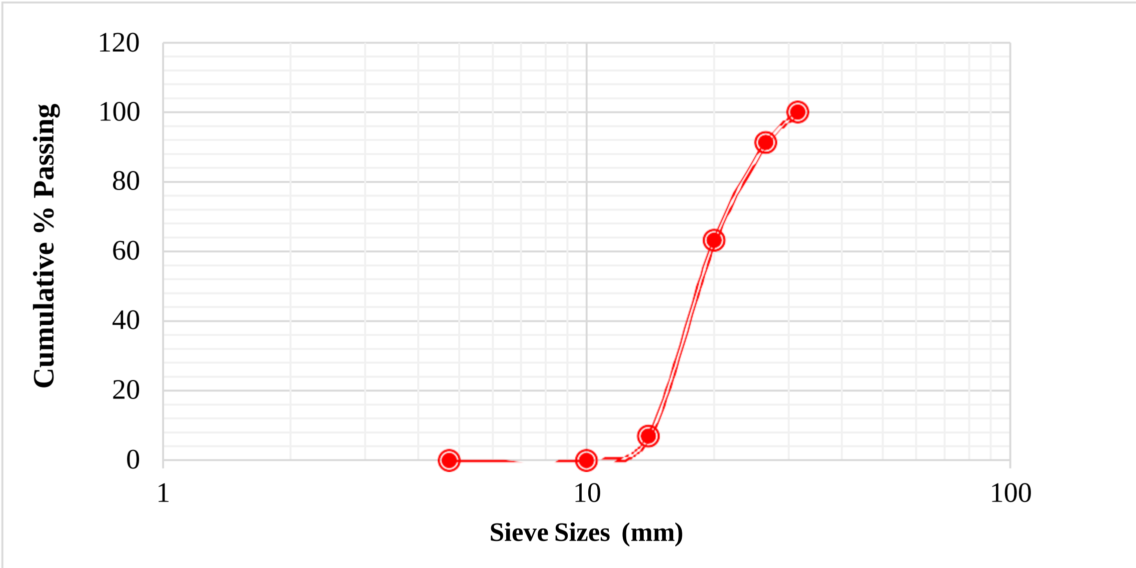

Figure 4.2: Sieve analysis graph for 20mm coarse aggregates

Table 4.3: Sieve analysis results for coarse aggregate (16mm)

Sieve Size (mm)	**Weight Retained (g)**	**% Weight Retained**	**Cumulative % Retained (g)**	**Cumulative % Passing (g)**
31.50	0	0.00	0.00	100
26.50	250	12.50	12.50	87.50
20.00	450	22.50	35.00	65.00
14.00	1000	50.00	85.00	15.00
10.00	200	10.00	95.00	5.00
4.75	100	5.00	100.00	0.00
Tray	0	0.00	0.00	0.00
Total	**2000**	**100.00**		

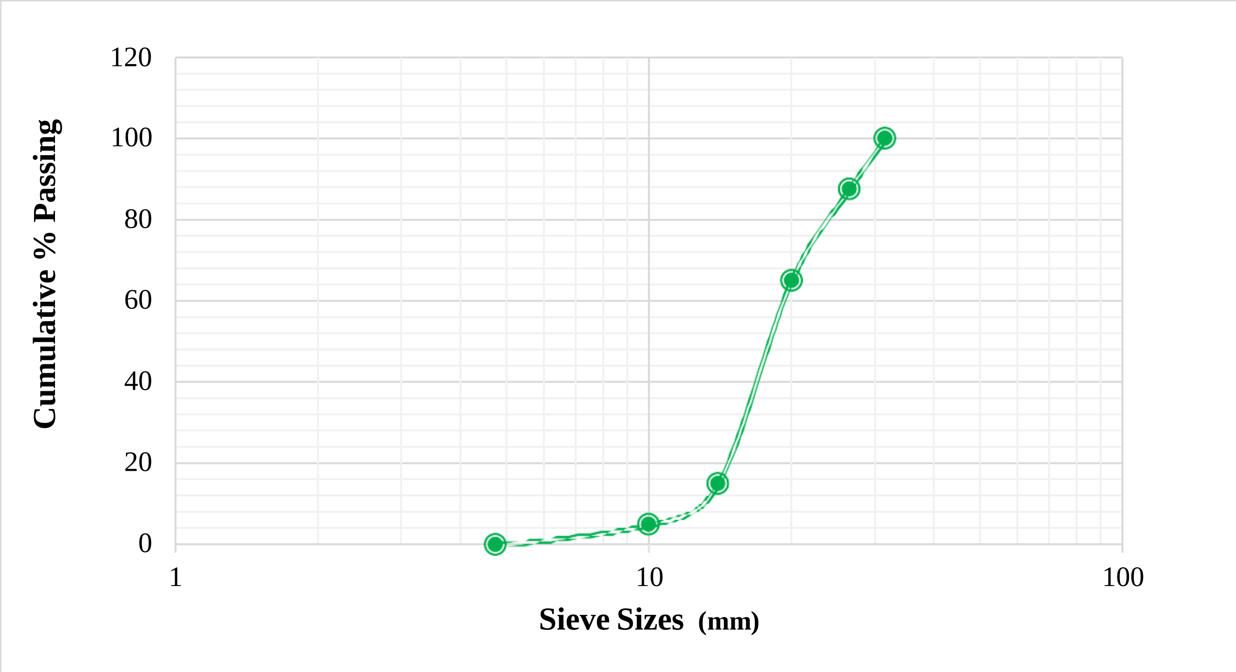

Figure 4.3: Sieve analysis results for 16mm coarse aggregate

Table 4.4: Sieve analysis results for coarse aggregate (12mm)

Sieve Size (mm)	Weight Retained (g)	% Weight Retained	Cumulative % Retained (g)	Cumulative % Passing (g)
31.50	0	0	0	100
26.50	0	0	0	100
20.00	0	0	0	100
14.00	900	45	45	55
10.00	1000	50	95	5
4.75	100	5	100	0
Tray	0	0	0	0
Total	**2000**	**100**		

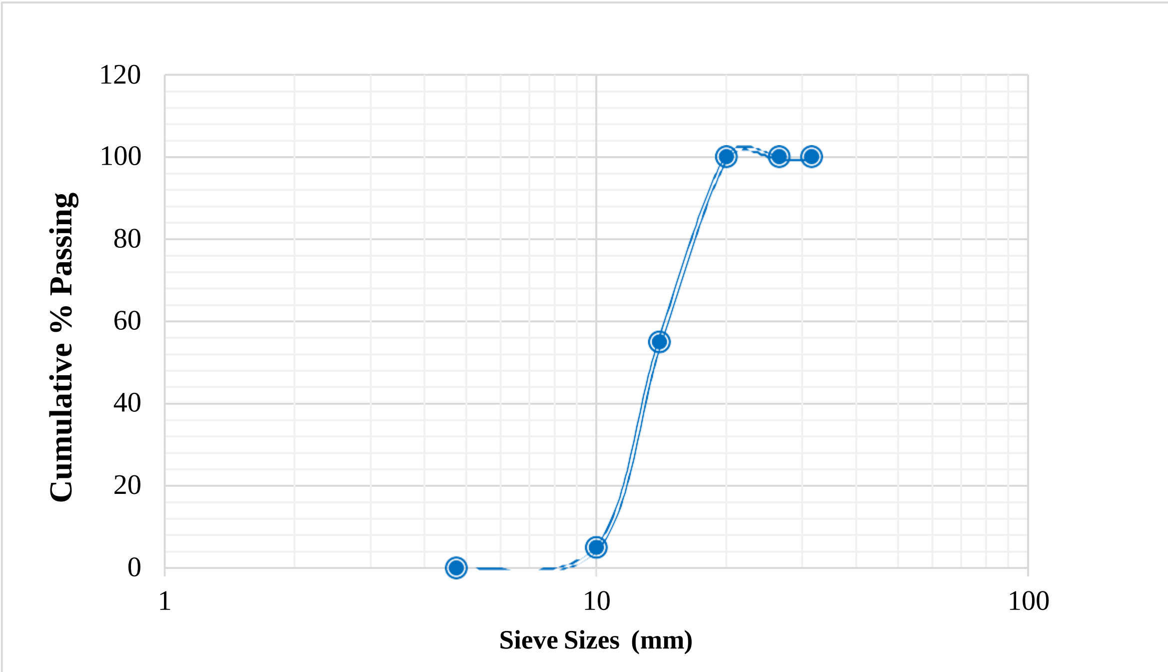

Figure 4.4: Sieve analysis results for 12mm coarse aggregate

The results for sieve analysis test on the aggregates shown in tables 4.1 to 4.4. The grading curve for the aggregates in fig 4.1 to 4.4 falls within the lower and upper limit of grading requirement for aggregate from natural sources BS882 (1992). This implies that the aggregates are suitable for construction work. The following results obtained from graphs for coefficient of uniformity and curvature of each aggregate size

For fine aggregate

$$C_c = \frac{D_{60}}{D_{10}} = \frac{1.10}{0.40} = 2.74$$

$$C_u = \frac{{D_{30}}^2}{D_{60} \times D_{10}} = \frac{0.60^2}{1.10 \times 0.40} = 0.82$$

For 20mm aggregate size;

$$C_c = \frac{D_{60}}{D_{10}} = \frac{10.99}{10.50} = 1.05$$

$$C_u = \frac{{D_{30}}^2}{D_{60} \times D_{10}} = \frac{10.65^2}{10.99 \times 10.50} = 0.98$$

For 16mm aggregate size;

$$C_c = \frac{D_{60}}{D_{10}} = \frac{10.99}{10.40} = 1.06$$

$$C_u = \frac{{D_{30}}^2}{D_{60} \times D_{10}} = \frac{10.80^2}{10.99 \times 10.40} = 1.02$$

For 12mm aggregate size

$$C_c = \frac{D_{60}}{D_{10}} = \frac{10.50}{10.10} = 1.04$$

$$C_u = \frac{{D_{30}}^2}{D_{60} \times D_{10}} = \frac{10.25^2}{10.50 \times 10.10} = 0.99$$

4.3 Slump

The results obtained for the slump test on the 12mm, 16mm and 20mm aggregate size are 97mm, 94mm and 92mm respectively as shown in table 4.5 and figure 4.5 below. Showing an increase in workability as the aggregate size increases which in agreement with Bruce et al, (2016). Findings.

Table 4.5: Slump Test Results

Mix Size (mm)	Mix Ratio	Height of Cone (mm)	Height of Slump Concrete (mm)	Slump Value
12	1:2:4	300	203	97
16	1:2:4	300	206	94
20	1:2:4	300	208	92

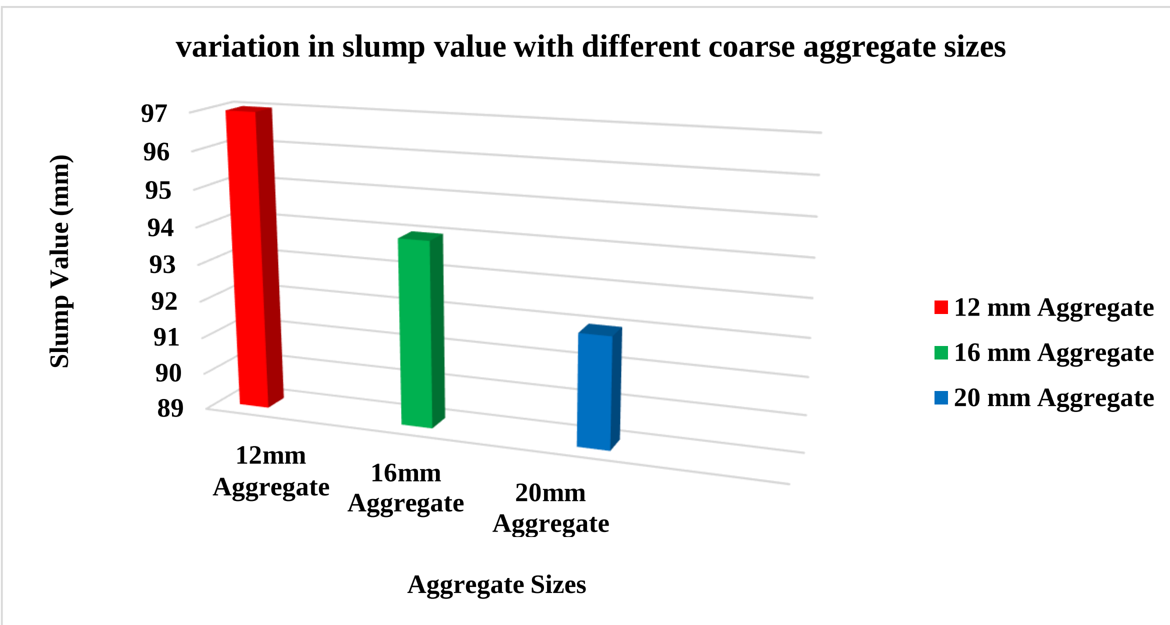

Figure 4.5: Variation in Slump with Different Coarse Aggregate

4.4 Compressive Strength

Table 4.6 to 4.8 and figure 4.6 and 4.7 shows the variation in the compressive strength of concrete using aggregate sizes of 12mm, 16mm and 20mm for 7, 14, 21 and 28 curing days at a water cement ratio of 0.55 and a mix ratio of 1:2:4 throughout the work.

For the 7 curing day been the first shows an increase in compressive strength as the aggregate size increases. With compressive strength of 15.53, 17.55 and 19.34 N/mm^2 for 12mm, 16mm and 20mm aggregate sizes respectively.

For the 28 curing day been the first shows an increase in compressive strength as the aggregate size increases. With compressive strength of 22.03, 24.02 and 26.20 N/mm^2 for 12mm, 16mm and 20mm aggregate sizes respectively.

All through the test 20mm showed the highest compressive strength followed by 16mm then 12mm in this order for each of the curing days showing that the compressive strength of concrete increases with increase in curing days and aggregate size as represented in figure 4.6 and 4.7. this increase in strength as the curing age increases is in agreement with the findings of James et al, (2011) and Joseph et al, (2012)

Table 4.6: Compressive strength of concrete test results for coarse aggregate of 12mm

Specimen	**Curing Age (Days)**	**Area of Specimen (150mm×150mm)**	**Average Weight of Specimen (kg)**	**Average Crushing load (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
A12	7	22,500	8.30	349.38	15.53
A12	14	22,500	8.25	393.00	17.47
A12	21	22,500	8.40	426.68	18.17
A12	28	22,500	8.40	495.65	22.03

Table 4.7: Compressive strength of concrete test results for coarse aggregate of 16mm

Specimen	**Curing Age (Days)**	**Area of Specimen (150mm×150mm)**	**Average Weight of Specimen (kg)**	**Average Crushing load (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
A16	7	22,500	8.45	394.50	17.55
A16	14	22,500	8.55	450.67	20.03
A16	21	22,500	8.40	492.69	21.85
A16	28	22,500	8.45	540.54	24.02

Table 4.8: Compressive strength of concrete test results for coarse aggregate of 20mm

Specimen	**Curing Age (Days)**	**Area of Specimen (150mm×150mm)**	**Average Weight of Specimen (kg)**	**Average Crushing Load (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
A20	7	22,500	8.70	435.84	19.34
A20	14	22,500	8.60	478.15	21.24
A20	21	22,500	8.65	530.86	23.23
A20	28	22,500	8.60	589.73	26.20

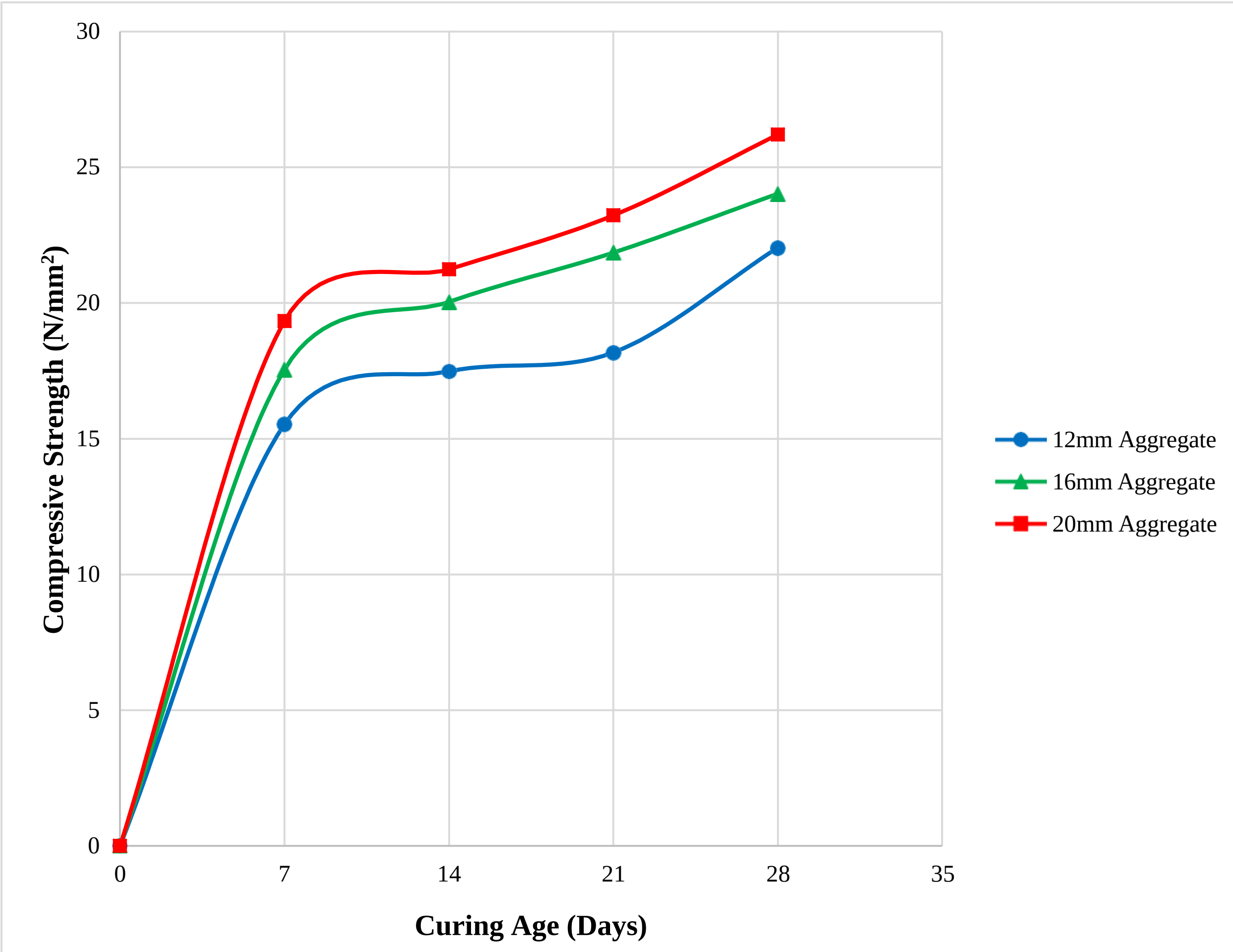

Figure 4.6: Graph of compressive strength against curing age

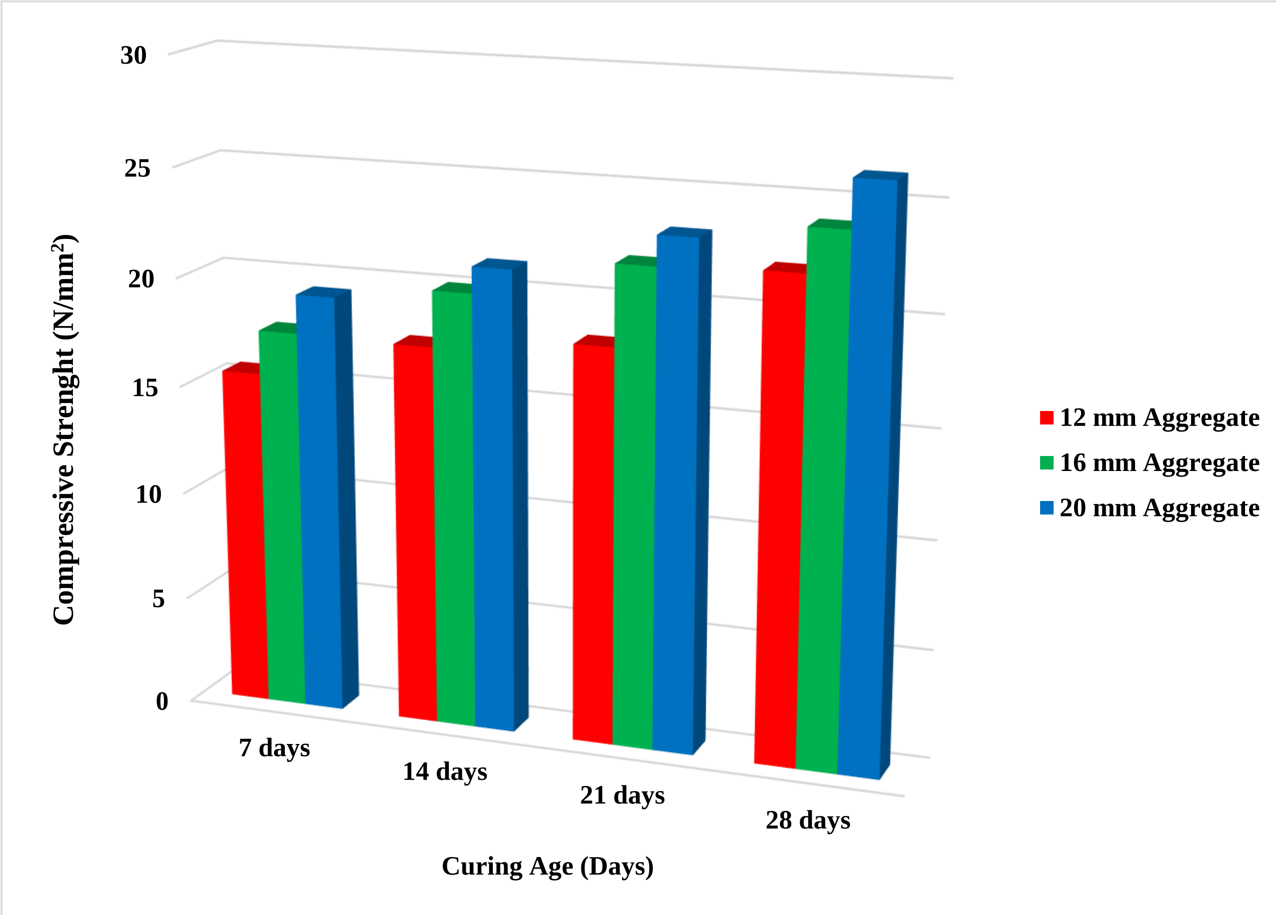

Figure 4.7: Effects of different coarse aggregate sizes on the compressive strength of concrete

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the results obtained and discussed, the following conclusions were drawn:

1. Concrete made with 20mm showed the highest workability for mix ratio of 1:2:4 and a water cement ratio of 0.55 used throughout the research and therefore it is the bet in terms of workability.
2. Concrete made with 12mm aggregate showed the less workability as compared to 16mm and 20mm for the same condition all through.
3. Concretes made with 20mm aggregates performed best in compression than that of 16mm and 16mm better than 12mm in this descending order.
4. Compressive strength of the different sizes of aggregates also increase as the curing days increases.
5. Concrete with 12mm showed the least compressive strength value throughout the project for each of the curing days.
6. 20mm aggregate showed the highest average compressive strength of 26.20N/mm^2 at 28 curing days as seen in figure 4.5 and 4.6. Which makes it more suitable and the best for compressive structural element.
7. 20mm aggregate showed higher compressive strength on each of the curing days as compared to 16mm and 12mm. shown in figure 4.5 and 4.6 graphically.

8. Bigger sizes of aggregates should be used (notwithstanding the cost) in high rise buildings and other massive structures in which high factors of safety for the strength of concrete is required.

5.2 Recommendation

1. The investigation should be extended to the effect of different shape of coarse aggregates on the compressive strength of concrete.
2. The flexural and tensile strength of concrete with aggregate size should be studied so as to draw a general conclusion on the strength of concrete.
3. The effect of water cement ratio of each aggregate size should be studied to see the effect on compressive strength.
4. More studies can be done on the effect different brands of cement produced in Nigeria on compressive strength of concrete.

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APPENDICE

Plate 1: Sieve Analysis on Coarse Aggregate**.**

Plate 2: Sieve Analysis on 20mm Coarse Aggregate**.**

Plate 3: Batching of Concrete**.**

Plate 4: Removal of Cubes from Metallic Molds

Plate 5: Getting Cubes Ready for Curing.