EFFECT OF COARSE AGGREGATE GRADING ON PROPERTIES OF CONCRETE

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CERTIFICATION

This is to certify that I am responsible for this work submitted in this project, that the original work is mine except as specified in the acknowledgement and references and that neither the project nor the original work submitted therein has been submitted to this university or any other institution.

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APPROVAL PAGE

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DEDICATION

I dedicate this project to God Almighty who is the source of inspiration and who starting from the day I was born till this very day has been blessing, prospering and putting smiles on my face in whatever my very hands found doing.

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ABSTRACT

Coarse aggregates have a great effect on properties of concrete, so gradation of coarse aggregates will always end up giving concretes of different properties. This project is an effort to provide properly detailed information concerning the influence of coarse aggregates grading on properties of concrete. Chippings of sizes 10mm, 20mm and 25mm were selected and used for this work. Preliminary tests like sieve analysis were conducted on the fine aggregate (sand) and also on the three selected coarse aggregates. 10mm and 25mm coarse aggregates were mixed in various proportions to produce five different concretes. Concrete C1 [100% of 10mm + 0% 25mm coarse aggregates], concrete C2 [75% of 10mm + 25% of 25mm coarse aggregates], concrete C3 [50% of 10mm + 50% of 25mm coarse aggregates], concrete C4 [25% of 10mm +75% of 25mmcoarse aggregates], and concrete C5 [0% 10mm + 100% 25mm coarse aggregates], Another concrete, [concrete C6] was casted with only 20mm and used as check, as 20mm coarse aggregate is mostly used in construction. In each mixture, slump test was performed and six cubes casted. The cubes were cured in water, and at 7days and 28days the selected cubes were crushed to obtain their compressive strength. After all the crushing it was found that the compressive strength increases as the percentage of 25mm coarse aggregate increases in a mixture, while workability decreases as the percentage of 25mm increases in each mixture.. Additionally, the sieve analysis graphs of the fine and coarse aggregates, the slump histogram of the three coarse aggregates and the graph of the concretes' compressive strengths, all went a long way in throwing more light on the properties of all the concretes.

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CHAPTER ONE

INTRODUCTION

1.0: BACKGROUND OF STUDY

Concrete is a mixture of water, cement or binder and aggregates is a commonly used material for construction (Barritt, 1984). The strength of concrete depends on aggregate type, size and source (Abdullahi, 2012; Hassan, 2014: Aginam et al 2013; Jimoh and Awe 2007). Aggregates amount to at least three-quarter of the volume of normal weight of concrete (Neville, 2003) and they are cheaper than cement and also confer a considerable better durability in concrete than the ordinary cement paste. The aggregates are divided into two major divisions by size- fine and coarse. The fine aggregates are sizes not larger than 5 mm while the coarse aggregate are sizes of at least 5 mm (Neville, 2003). There has been concern about the best aggregate sizes to be adopted in the manufacturing of concrete in the Nigerian construction industry. Effect of aggregate properties on concrete like grading of aggregates depends on proportions the coarse aggregate is varied or also the proportions of coarse aggregate and fine aggregate. If grading of aggregate is varied, it also changes cement content (cost economy), workability of the mix, density and porosity.

It is an important factor and has a maximum influence on workability. Well graded aggregates result in the least amount of voids in a given volume. Less voids result in excessive paste availability in a unit volume and more lubrication. Hence the mix is cohesive and avoids segregation.

Factors affecting properties of concrete include

- Size of aggregate

- Types of aggregate
- Quantity of aggregates
- Gradation of aggregate
- The amount of mix water
- The age or maturity of the concrete
- The type and quantity of cement and/or supplementary cementitious materials

Of all these factors, “coarse aggregate grading” plays an important role in determining the properties of concrete especially its compressive strength. Coarse aggregate is usually greater than 4.75mm (retained on a No. 4 sieve) which accounts for 60 to 80 percent of the weight of the concrete. There are various types of coarse aggregate like normal aggregates and light-weight aggregates. Normal aggregates like chippings, granite, gravel, limestone and sandstone are mostly used in modern civil engineering projects. Coarse aggregate is a necessary component that defines the concrete’s thermal and elastic properties and dimensional stability. Coarse aggregate used in concrete making contain aggregate of various sizes. This particle size distribution of the coarse aggregates is termed as “Gradation”. The sieve analysis is conducted to determine this particle size distribution. There are three typical range categories of aggregate grading, they are; well graded, poor graded, and gap graded and each type of the gradation has a certain influence on the properties of concrete.

That a particular mix yields an end product of higher economy, higher strength, lower shrinkage and greater durability depends on the type of aggregate grading employed. So it is always advisable for a right choice to be made in selecting a certain size of aggregate that will be suitable for a particular type of concrete work.

Hence, effects of aggregate properties on concrete properties are huge. In fact, most of the properties exhibited by concrete are what it is made up of - aggregates.

1.1: PROBLEM STATEMENT

At times concrete after being produced and cured shrinked and cracked, deformed and creeped under pressure by applied loads. When such happens, it means that the concrete has failed in various ways, which depends on the size of coarse aggregates used for that particular concrete. Mostly in concrete production, best properties are expected to be obtained, so when unsuitable size of coarse aggregate is used, it then means there is bound to be a compromise in the concrete's initial expected properties. In avoiding such a problem, its then imperative that right grading of coarse aggregate is employed during concrete work since a certain category of aggregate grading has a certain effect on concrete's properties.

The proposed research will attempt to determine the suitable grading of coarse aggregate that will bring out the best properties in concrete.

1.2: AIMS

The aim of this project is to determine the effect of coarse aggregate grading on properties of concrete.

OBJECTIVES

The principle aims and objectives of this research study include:

- ❖ To learn more about the nature of concrete
- ❖ Characterization of sharp sand and coarse aggregates.

- ❖ Acquisition of slump value for each concrete grade.
- ❖ Obtaining through some laboratory tests the compressive strength and workability of concretes casted by mixing 25mm and 10mm coarse aggregates at different percentages.
- ❖ To determine through the study and its experiments which particular sizes of the coarse aggregates that gives a concrete the best properties.

1.3: SIGNIFICANCE OF THE STUDY

This project aims at serving as a guide for people in the construction industries/companies. Contractors and structural Engineers can use the success of this project/research to determine the percentage combinations of 25mm and 10mm coarse aggregate that gives better properties than 20mm coarse aggregate.

1.4: LIMITATION OF STUDY

This research work was done by combining 25mm and 10mm coarse aggregates only, while 20mm coarse aggregate was used as check, though there are other sizes available in the market. Also concerning the properties of concrete, the research was limited to workability and compressive strength.

1.5: SCOPE OF WORK

This research work will be limited to the effect of coarse aggregate when 25mm and 10mm are combined at varying percentages in different concrete mix. This is related to workability and compressive strength properties of the resulting concrete only.

This entails preparing and casting concrete cubes of 150mm x 150mm x 150mm using 1:2:4 mix ratio and 0.55 water-cement ratio. Combining 10mm and 25mm coarse aggregate at varying percentages for different concretes and also casting concrete with only 20mm coarse aggregate as check.

For each of the concrete mix (100% 10mm + 0% 25mm coarse aggregates, 75% of 10mm + 25% of 25mm coarse aggregates, 50% of 10mm + 50% of 25mm coarse aggregates, 25% of 10mm +75% of 25mmcoarse aggregates, and 0% 10mm + 100% 25mm coarse aggregates). six concrete cubes each will be cast and the slump test taken to check for the workability of the concrete and the cubes were cured for a period of 7and 28 days to determine respectively the compressive strength of the concrete cubes.

CHAPTER TWO

LITERATURE REVIEW

A literature review on concrete and the effect of coarse aggregate grading on the qualities of concrete was presented in this chapter.

2.0 Overview of Concrete

Concrete, specifically port land cement concrete, has the qualities of strength, durability, versatility, and economy, and can be placed or molded into virtually any shape and reproduce any surface texture. It is the most widely used construction material in the world.

2.1. Concrete Components and Mixes

Both mass concrete and reinforced concrete are composite materials. Mass or plain concrete is made up of cement or lime, fine and coarse aggregate, and water; and reinforced concrete incorporates steel, although wrought iron was used in the earliest reinforced structures before 1900. The cement or lime is used as an adhesive to bind the coarse and fine aggregates. Water is added after dry mixing, which starts a chemical reaction with the cement or lime, resulting in a fluid mixture that hardens into a solid mass with good compressive strength but poor tensile strength. Steel reinforcing is used to improve the tensile strength of the concrete, allowing it to span considerable distances, and producing a very strong and versatile building material.

2.2 Cement

Natural cement: Natural cements occurred in the form of hydraulic limes3, to which pozzolans were sometimes added. The hydraulic properties of the natural cements varied according to the type of limestone used and whether pozzolanic material was added to increase the hydraulicity. Lime concrete is both weaker and more porous than that made with Portland cement. These natural cements generally have a compressive strength of approximately one-third that of Portland cement. The fineness to which the cement was ground determined the rate and degree of hydration, and also influenced the ultimate strength. Early cements were not as finely ground as modern Portland cement. It is most likely that the earliest imports from Britain, which occurred between 1840 and 1850, were of natural cement, as Portland cement only came into general use in Britain in about the 1860s. It is known that large quantities of Roman cement was being produced in England at this time for use by the plastering trade, but this product was not imported into New Zealand. Lime-based cements were being produced in New Zealand by the late 1860s. Lime concrete was not generally reinforced, as it was not considered strong enough and its porosity meant that any reinforcing would be more likely to corrode: 'For reinforced concrete work cements of doubtful quality should in no case be employed, and for this reason natural cements must be avoided, as their behavior is very uncertain, and they are more likely to be uneven in quality than artificial cements in which the ingredients can be proportioned with exactness' (Marsh, 1905).

Portland cement: Early Portland cements were not equivalent to today's 'ordinary Portland' cement-now more generally known as 'general purpose' cement. They were produced at lower burning temperatures and had weaker hydraulic properties, but were still stronger than natural cements. They were often lighter and greyer in colour (the natural cements tended to range from brown to light brown and paler colours). The exact specifications for Portland cement were gradually refined from its first patent in 1824 through to 1920. In 1909, C.F. Mitchell noted that "the modern method of manufacture is rapidly superseding the old' (Mitchell 1909) and gave a specification issued by the British Engineering Standards Committee for Portland cement that had been revised in June 1907. By then, the product was substantially similar to modern general purpose cement. Further refinements of the burning and grinding processes, and research into hydration and the roles of silica and alumina led to a Portland cement that, by the 1920s, was equivalent to that used today. It is probable; therefore, that concrete structures built in New Zealand prior to 1900 contains natural cements of varying hydraulic properties. Testing and analysis will assist in determining the type and properties of cement used in a historic concrete structure.

2.3 Aggregate

Increasing the maximum size of aggregate will increase durability by decreasing the cement paste content that will be under the physical or chemical attack (Mindess, et al ., 2003).

However, reducing the aggregate size will increase durability when concrete is subjected to freeze-thaw condition (Mindess, et al., 2003).

Aggregates should be unsound to prevent volume change by resisting a high internal stress when water inside the aggregate is frozen. The degree of saturation, porosity, permeability, and size of aggregate determines this stress (Mindess, et al., 2003).

Use of hard, dense and strong aggregate will improve durability by providing good wear resistance (IMCP 2006; Mindess, et al ., 2003; Kosmatka, et al ., 2002; Monteiro, et al ., 1993). In addition, aggregates should be free of reactive silica that causes a chemical reaction between the alkali in the cement paste and silica in the aggregate. Because alkali-silica reaction is very damaging for concrete and it significantly decreases the durability of concrete by causing map cracking, popouts and staining (Mindess, et al ., 2003).

The aggregate (both fine and coarse) makes up about 80% of the volume of the concrete. Shape, grading, size and type of aggregate all affect the final characteristics of the concrete produced; it is not simply inert filler. Before 1900, few researchers had studied the contribution made by the aggregate material to the quality of concrete. Although the importance of using clean aggregate gradually began to be understood in the 1800s, it is unlikely that the use of clean aggregates that were free of clay coatings, organic materials or sea salts was always ensured in early concrete. The consequences of using dirty aggregates include a tendency to attract and retain water, poor setting and curing, and chemical reactions that result in corrosion of the reinforcing and accumulation of efflorescence on the concrete surface.

In modern concrete, aggregate is carefully selected crushed stone. However, in early concrete structures, the choice of aggregate was determined largely by what was readily available. For example, in the supply of material for the construction of Fort Cautley in 1889, the aggregate was specified simply as local sand and scoria (Frankham, 1889, 1890). In other examples, ceramic waste and scoria ash were incorporated in the concrete walls of a cottage in Sinton Road, Hobsonville, and the concrete walls in W.J. Wilson's house at Warkworth contained a broken brick aggregate reinforced with strained wire hawsers. It is possible that the use of such aggregates may have had an inadvertent beneficial effect by increasing the hydraulic properties of the cement and the resultant concrete. The scoria ash and burnt clay would have acted as pozzolanic materials-as the Romans discovered two millennia ago.

For many builders, economic considerations and the reality of working in a country with a rudimentary land-based transport infrastructure would have meant that the most likely sources of aggregate were those that were locally available. The most commonly used aggregates came from streams and gravel pits, and often included sea sand and shells. Grading and size of aggregate both affect the amount of water needed to obtain workability. Generally, about 30% of the volume of well-graded sand is voids, which means that 30% of this volume of cement binder will be required. This explains the commonly used proportion of 1:3 binder to sand ratio often used in mortar specifications. This is a useful guideline for mixes in general, unless the historic mortar is known to have had a different binder: aggregate ratio.

There should be a continuum in the size of grains from small to large smaller grains fill the interstices between the larger grains, keeping the amount of cement paste to a minimum. A well graded aggregate, i.e. one with a range of particle size, improves the workability, as does using the largest possible particle size that can be compacted around and over the reinforcing. The improved workability means that less water is required and a stronger concrete is produced. This in turn limits the amount of shrinkage and deformation that takes place during drying.

The shape of the aggregate will also affect the workability of the concrete. An extremely rough, angular aggregate is less workable and may require more water to be added to the mix to increase its workability, thus reducing strength and producing a more porous concrete. Sharp aggregate can also hinder compaction. It does, however, bond well with the cement paste to produce a stronger concrete. Therefore, a balance between rounded and sharp aggregate is desirable. Ideally, aggregate should have a compressive strength equal to that of the cement paste, should be chemically inert in water, and should be clean, hard, and free from clay coatings and organic materials to ensure a good bond with the cement. However, it is unlikely that the aggregates used in early structures would always have been ideal for the purpose. Testing and analysis, and knowledge of local history and conditions will assist in determining the most likely aggregate that would have been used in a historic structure.

2.3.1 Coarse aggregate effect on concrete

Modern concrete consists of aggregate (fine & coarse), cement, water, admixture and other additives. Several factors are known to influence the strength of concrete. They include their batch ratios, processes, aggregate texture and shape and nature of other constituent materials (Woode, Amoah, Aguba, & Ballow, 2015). Aggregates are mixtures of various sizes of stone or rock particles in contact with each other. They are typically combinations of gravel and crushed *Corresponding author: Jeetendra Prajapati Department of Civil Engineering, Khwopa Engineering College, Libali-08, Bhaktapur, Nepal Email: jeeten.prajapati@gmail.com (Received: March 07 2019 Accepted: October 12, 2019) materials, such as limestone, basalt and granite, but may also include blast furnace slag, or recycled concrete fragments. Particles with a diameter greater than 4.75 mm are usually classified as coarse aggregate, while smaller particles are called fine aggregate (McNally, 1998). For a long time aggregate was considered to be an inert filler which is added to cement paste simply for economic reasons. The properties of the resulting concrete were thought to be nearly independent of the properties of the aggregate (Stensatter, 1963). Since approximately three-quarters of the volume of concrete are occupied by aggregate, it is not surprising that its quality is of considerable importance. Not only may the aggregate limit the strength of concrete, but the aggregate properties JScE Vol.7, November 2019 Jeetendra Prajapati 53 greatly affect the durability and structural performance of concrete. Aggregate was originally viewed as inert, inexpensive material dispersed throughout the cement paste so as to produce a large volume of concrete. In fact, aggregate is not truly inert because its physical, thermal and sometimes, chemical properties influence the performance of concrete (Neville & Brooks, 2010). Many studies have been made to determine the effect of the physical and chemical properties of aggregate on the behavior of concrete. They include investigations into the effects of particle strength, surface texture, shape and alkali reactivity. Significant findings indicate that aggregate plays a more "active role" than was previously believed and a better understanding will result from further research (Stensatter, 1963). The compressive strength of fresh and hardened concrete is greatly affected by the type of coarse aggregate being used in concrete mixing. Since coarse aggregate occupies major volume in concrete, the overall property of coarse aggregates affect the property of concrete produced with different nominal mix. The property of coarse aggregate is governed by their source, size, shape, unit weight, texture, etc. Coarse aggregate properties (geological, physical and mechanical) are greatly influenced by the source from which they have been recovered. The variation on the aggregate properties (either mechanical or physical) also affects the property of concrete strength, workability and durability. There is significant influence of different aggregate types on concrete compressive strength, with stronger aggregate types increasing the overall strength of the concrete (Aitcin & Mehta, 1990; Zhou, Barr, & Lydon, 1995; Larrard & Belloc, 1997). Aggregate characteristics like shape, texture, and grading influence workability, finishability, bleeding, pumpability, and segregation of fresh concrete and affect strength, stiffness, shrinkage, creep, density, permeability, and durability of hardened concrete (Lafrenz, 1997. All these characteristics have an important influence on the properties of both fresh and hardened concrete (Neville & Brooks, 2010; Donza, Cabrera, & Irassar, 2002). The study on effect of content and particle size distribution of coarse aggregate on the compressive strength of concrete revealed that compressive strength is strongly linked to the coarse aggregate parameters (content, proportion of fine to coarse aggregate and grain size distribution) of concrete mixture (Mohammed, Salim, & Said, 2010). In 2003, Sahin et al., also observed that the increase in strength for a given increase in cement content depends on the type of aggregate used and the cement content itself while Ozturan and Cecen (1997) have found that for the same properties of paste, different types of coarse aggregate with different shape, texture, mineralogy and strength may result in different concrete strengths. In research on the effects of aggregate content on the behavior of concrete, Ruiz (1966) found that the compressive strength of concrete increases along with an increase in coarse aggregate content, up to a critical volume of aggregate, and then decreases. The initial increase is due to a reduction in the volume of voids with the addition of aggregate. In 1947, Glanville et al., has expressed the opinion that the shape, texture and porosity of aggregate affect concrete workability. Kaplan (1959) studied the effects of the properties of 13 coarse aggregates on the flexural and compressive strength of high strength and normal-strength concrete.. In the context of Nepal, concrete is being used as an extensive material of civil construction works of buildings, dams, bridges, highways, retaining walls, irrigation canals, etc.

2.3.2 Aggregate gradation

Aggregate gradation determines the void content within the structure of aggregate and consequently the amount of cement paste that is required to fill the void space and ensure a workable concrete. It is desirable to optimize the aggregate gradation in concrete using

Portland cement, as it is the most expensive and high carbon footprint ingredient, to minimize the void content in the aggregate and therefore the volume of cement paste required to achieve a workable, economical and an environmentally sound concrete for a given application.
The optimization of aggregate gradation also improves the rheological, mechanical and durability properties of concrete.

Proper aggregate gradation not only ensure a workable concrete mixture that can be compacted easily, but also reduces problems associated with plastic concrete such as potential for segregation, bleeding and loss of entrained air and plastic shrinkage cracking. Furthermore, most concrete that is used in construction of transportation infrastructure is often vibrated to achieve good compaction in concrete. Segregation in plastic state under vibration particularly is the most vulnerable problem in concrete containing aggregate with poor gradation. Cement paste filling the void space between the aggregate has a tendency to shrink when there is a progressive loss of moisture from concrete, either due to evaporation from surface of concrete or through internal consumption of moisture due to hydration reactions of cement. Aggregates in concrete, being much stiffer than the hardened cement paste, act to resist the shrinkage behaviour of concrete. Aggregate gradation, which determines the relative proportions of aggregate and cement paste in a concrete, therefore dictates the shrinkage behaviour of concrete and hence long-term durability of concrete.

The particle size distribution of an aggregate as determined by sieve analysis is termed as grading of the aggregates. If all the particles of an aggregate are of uniform size, the compacted mass will contain more voids whereas aggregate comprising particles of various sizes will give a mass with lesser voids .The particle size distribution of a mass of aggregate should be such that the smaller particles fill the voids between the larger particles. The proper grading of an aggregate produces dense concrete and needs less quantity of fine aggregate and cement waste, therefore, it is essential that coarse and fine aggregates be well graded to produce quality concrete.

2.3.2.1 Gradation and Its Effects in Compressive Strength of Concrete

Coarse aggregates used in concrete making contain aggregates of various sizes. The sieve analysis was conducted to determine this particle size distribution. Grading pattern is assessed by sieving a sample successively through the entire sieves mounted one over the other in order of size, with larger sieve on the top. The material retained on each sieve after shaking represents the fraction of aggregate coarser than the sieve in question and proper gradation ensures that a sample of aggregate contain all standard fractions of aggregate in required proportion such that the sample contains minimum voids. A sample of the well graded aggregate containing minimum voids will require minimum paste to fill up the voids in the concrete. Mindess, etc (1981) explained that minimum paste means less quantity of cement and less quantity of water leading to increased economy, higher strength, lower shrinkage and greater durability. The workability is improved when there is an excess of paste above that required to fill the voids in the sand, and also when there is enough water to hydrate the concrete. An excess mortar (sand plus cement) will fill the voids in the coarse aggregate because the fine material lubricates the larger particles. Cement-paste or the matrix that links together the coarse aggregates is weaker than the aggregates. It is this matrix that is vulnerable to all ills of concrete. It is more permeable and is susceptible to deterioration by the attack of aggressive chemicals. Therefore lesser the quantity of such weak link in concrete the better will the concrete be.

This objective can be achieved by having well graded aggregates. Variation in coarse aggregates gradation causes change in the workability of concrete (BS 1881, 1983). There are three typical range categories of aggregate grading, they are; Well Graded, Poor Graded, and Gap Graded. Each of the type of grading has a certain type of effect on the compressive strength of concrete. ACI Committee (1991) rightly argued that well-graded aggregate has a gradation of particle size that fairly evenly spans the size from the finest to the coarsest. A slice of a core of Well - Graded aggregate concrete shows a packed field of many different particles sizes. Well - Graded aggregate is characterized by the S - Shaped in gradation curve. Poor-Graded aggregate is characterized by small variation in size. It contains aggregate particles that are almost of the same size. This means that the particles pack together, leaving relatively large voids in the concrete. It is also called "Uniform- Grade". It is characterized by steep curve. Gap-Graded aggregate consists of aggregate particles in which some intermediate size particles are missing. A core slice of Gap-Graded, or skip size, concrete shows a field of small sized-aggregate interspersed with slightly isolated, large aggregate pieces embedded in a small sized aggregate. It is characterized by a gradation curve with a Jump in between. Montgomery (2001) explained that poor graded concrete generally require excessive amounts of cement paste to fill the voids making them uneconomical. Gap-Graded concrete fall in between Well-Graded and poorly graded in terms of performance and economy. Gap Graded is viable gradation, but not optimal. Well-Graded aggregates are tricky in proportion. The goal of aggregate proportioning and sizing is to maximize the volume of aggregate in the concrete while preserving the strength, workability and finishing. This balance the proportions of each so there are just enough of each size to fill all the voids, while preserving workability and Cast-Surface quality. Neville (1995) explained that some experiments have concluded that grading for maximum density gives the highest strength, and that the grading curve of the best mixture resembles a parabola. However such aggregates graded for maximum density give a harsh concrete that is very difficult in ordinary concreting. So the proportioning should be based on the surface area of aggregates that Is to the wetted. Other things remaining same, it can be said that the concrete made from aggregate grading having least surface area will require least water which will consequently be the strongest. Ozturan and Cecen (1997) showed that generally angular aggregate particles have rough texture and round aggregate particles are smooth textured. From the bonding point of view it seems that smooth textured rounded particles form a poor bond with cement paste. But the smooth looking surface of rounded particles is also rough enough at the microscopic level and the cement -gel that forms a bond with aggregate surfaces also has particle sizes in the level of microns. Both, surface and the cement gel reacts at the sub-microscopic level.

Angular aggregates have higher specific surface area than smooth rounded aggregate. With a greater specific surface area the angular aggregate may show higher bond strength than rounded aggregates. Also angular aggregates exhibit better interlocking effect in concrete that contributes in strength of concrete. Higher specific area of angular aggregates with rough texture demands more water for a given workability than rounded aggregates

2.4 Water

Water is another essential ingredient in concrete. It is now understood that mixing water should be kept free from salts and other impurities: generally, if it can be drunk, it is acceptable.

However, this was less well understood by the makers of early concrete, and sea water was often used when available.

On occasion, salt, sugar or glycerine was added to mixing water to prevent freezing during cold weather. Some builders also adopted the practice of adding fine clay to mixing water to improve the waterproofing characteristics of the finished concrete. All of these additions would have ultimately had a detrimental effect.

In one of the standard textbooks on reinforced concrete, Charles Marsh noted that 'for ordinary concrete work sea water does not appear to have any ill effects, it is possible that the contained salts might have an injurious action on the metal' (Marsh 1905). Although he then recommended using fresh water, this indicates that at this time there was still only a vague understanding that salts might be a problem. Salts in the water have an extremely detrimental effect on reinforced concrete, and it is probable that sea water was used in many early structures.

2.4.1 Water-to-Cement Ratio

An important parameter for durability is the w/c (IMCP 2006; Mindess, et al ., 2003; Kosmatka, et al ., 2002; Mehta and Monteiro, 1993). As w/c decreases, the porosity of the paste decreases and concrete becomes less permeable thus reducing passage of water and aggressive compounds such as chlorides and sulfates (IMCP 2006; Dhir, et al ., 2004; Mindess, et al ., 2003; Kosmatka, et al ,. 2002; Monteiro, et al ., 1993).

2.5 Admixture

Admixtures are ingredients other than port land cement, water, and aggregates that are added to the concrete mixture immediately before or during mixing. They are used to modify certain properties of the concrete and can be classified according to their function:

1. Air-entraining admixtures.
2. Water-reducing admixtures.
3. Retarding admixtures.
4. Accelerating admixtures.
5. Cementing agents.
6. Workability agents.
7. Miscellaneous agents such as bonding, damp-proofing, permeability-reducing, grouting, and gas forming agents.

Except for air entrainment, the desired concrete properties can often be obtained more easily and economically by selecting suitable materials rather than resorting to admixtures.

Air-entraining agents are the most commonly used admixtures for agricultural concrete. Air entrainment produces microscopic air bubbles throughout the concrete. Entrained air bubbles dramatically improve the durability of concrete exposed to moisture and freeze/thaw action. The resistance of the concrete surface to scaling is also improved. Scaling may result from the use of chemical deicers or exposure to mild corrosive agents, such as manure or silage. Air-entrainment is recommended for all concrete used for agricultural applications, even though it has slightly lower strength than non-air-entrained concrete.

The workability of fresh concrete is also improved with air-entrainment. Retarding admixtures are used to slow the rate of concrete set or hardening. They are particularly useful for concrete that is placed during hot weather. On the other hand, accelerating admixtures, such as calcium chloride, are used to increase the rate of set-usually during cold weather. In Nebraska, fly ash from coal fired generating plants is used both as a cementing agent and/or workability admixture.

2.6 Properties of Concrete

Concrete is essentially a manufactured material. As mentioned component above, materials, its properties but also are complex by the and varied, and are determined not the only design by of the construction procedures the cement, the structure and the manufacturing process of workmanship and the design of concrete structures are much followed on site. Today, materials, workmanship and the design of concrete structures are much more standardized than they were in the past. Concrete that has been prepared properly and more standardized than they were in placed in a well-designed building is a very durable material with a slow rate of deterioration. However, this was very often far from the case in historic structures. The properties of early concrete structures may vary considerably from each other and from modern, general purpose cement reinforced concrete. The behavior of such structures must, therefore, be individually assessed according to the materials used, and their design and detailing.

Mass or plain concrete, which was produced with hydraulic lime, natural cement or early Portland cement, is an essentially different material from modern reinforced concrete. Each mix has differing strengths and weaknesses, and is exposed to different deterioration processes. Concrete without steel or iron does not have the problems associated with corrosion and exponential deterioration due to rusting steel that reinforced concrete has, but it is far more vulnerable to seismic and tensile forces than reinforced concrete.

2.6.2 Strength

Concrete was initially used as a replacement for or component of masonry because of its adhesion to other materials and good compressive strength. The achievable compressive strength increased as the understanding of cement materials and their hydraulic properties improved. Portland cement concrete rapidly became the predominant material used for engineering and building, due to its compressive strength being approximately three times that of concretes based on hydraulic lime or natural cement. A range of factors affect the ultimate strength of concrete, including the water: cement ratio, compaction, the aggregates used and workmanship. General purpose cement concrete usually has an average compressive strength of about 25 MPa, while that of lime concrete could range from about 5 to 10 MPa (Mitchell, 1909).

As mentioned above, plain concrete was mostly used for its compressive strength, as this was about ten times its tensile strength. The addition of steel reinforcing from the 1900s resulted in a material with combined compressive and tensile strengths, which made it extremely versatile.

2.6.3 Movement

Concrete shrinks when drying (drying shrinkage). A proportion of this initial shrinkage is irreversible, but even fully cured concrete expands when wetted and shrinks as it hardens. Similarly, like most other materials, concrete expands and contracts with changes in temperature.

If the movement exceeds the tensile strength of restrained concrete, it will crack. The likelihood of moisture movement increases with the ratio between water and cement, and between cement and aggregate. 'Carbonation shrinkage' can also occur, where high levels of carbon dioxide from the atmosphere react with the hydrated cement paste. The extent of this shrinkage can be equivalent to that of wetting-drying shrinkage.

Creep is the deformation caused by a constant load. In concrete, there is a gradual increase of deformation due to the first application of a load. Initial creep is rapid at first but approaches a limit after about 5 years. The creep is roughly in proportion to the load, and is greater in weaker and less mature concrete.

2.6.4 Permeability

All concrete is to some extent permeable, particularly to water vapor. Lime concrete, however, is much more permeable than modern, general purpose cement concrete. Well-compacted concrete made with a low water: cement ratio has good resistance to water absorption, but where more water has been used in the mixing, as was often the case in early concrete, the concrete tends to be more porous, and hence more permeable. This characteristic is more pronounced where lime cements and early Portland cements were used. Conversely, poorly compacted or 'bony' concrete may also be porous because of voids between aggregate particles that were not filled with cement paste.

The permeability of early concrete can be a disadvantage where reinforcing was incorporated, as this reinforcing is more likely to corrode. In non-reinforced concrete structures, however, permeability is not necessarily detrimental, although the moist concrete may more readily support organic growths. Lime concrete has a greater ability to absorb and lose water vapor than general purpose cement. Condensation can be a problem with solid concrete walls, so the ability to 'breathe' can be an advantage.

2.6.5 Durability

Many circumstantial external factors will affect the durability of any concrete. The specific effect of these on an individual structure will depend on the nature of the particular concrete and the intensity of the external agent. External factors include frost, chemicals and fire.

2.6.5.1 Frost

Concrete can be damaged by the expansion of ice crystals, which are most likely to occur where water has lodged in pores or cracks in the concrete. A dense concrete will have a high resistance to this type of erosion. In contrast, concrete with voids, cracks or large pores will be more vulnerable to frost damage and, if reinforced, corrosion of the steel will be more likely.

2.6.5.2 Chemicals

As a general principle, the better the compressive strength, the better the chemical resistance. Lime concrete, which is softer and weaker than Portland concrete, is more vulnerable to chemical attack. In concrete that has voids and cracks or is porous, reinforcing steel will be more likely to be affected by chemicals, and this may result in corrosion damage to the structure.

2.6.5.3 Fire

Reinforced concrete is one of the most fire-resistant of common structural materials. However, although the strength of ordinary concrete increases up to temperatures of 120◦C, there is a serious loss of strength at higher temperatures. Flexural strength is more affected than compressive strength because of the effect of heat on steel reinforcing. The fire resistance of non -reinforced concrete is slightly lower than that of brick of the same thickness, although the type of aggregate will affect this. Siliceous aggregates have the poorest fire resistance, while those that include burnt clay products, pumice, well-burnt clinker, crushed limestone and pelleted fly ash have greater fire resistance.

Concrete fails in fire because of the differential expansion of the hot exposed layers over cooler internal layers. The insulation that the concrete provides is an important factor in its fire resistance, and lightweight aggregate concrete performs better in this respect. If steel reinforcing Is exposed, fire resistance and structural strength reduce dramatically as the rapid conduction of heat increases the temperature differential. One of the more destructive forces in a fire is the spontaneous expansion of water into steam, and this may be enough to shatter concrete members, especially older concretes with a high content of free lime.

2.6.6 Appearance

Early concrete structures were often rendered with plaster or clad in a veneer of brick or stone. Where the surface was left untouched after the formwork was removed, the aesthetic effect depended on the inherent color and texture of the concrete, and the quality of the formwork and workmanship.

The final color of concrete depends on the color of the cement as well as that of the aggregate; for example, where scoria was used for aggregate, the color of the concrete tended to have a reddish tinge. Early Portland cements were generally lighter in color than modern grey, general purpose cement.

However, all concrete changes appearance over time, as the initial cement 'laitance' (milkiness, i.e. fine particles in the surface) weathers away from the aggregates at the surface. As the aggregates are revealed, there may be quite dramatic changes in the appearance of the concrete.

2.7 Testing

There is a large variation in the cost, reliability and type of information provided by the different methods of testing available. The extent of testing will depend on the nature of the project, the allocation of funding and the feasibility. This section aims to give those managing the structure a general knowledge of the testing methods that are available to assist in the analysis and evaluation of repairs that may be required. A range of on-site, non-destructive tests can be undertaken. Laboratory testing can also be used to supplement the field condition survey and on-site testing as necessary. Laboratory testing will require samples to be taken on site. These can be in the form of lump, sawn or core samples. However, core samples may be difficult to obtain on remote sites, as a power source and water are necessary for the use of a core drill. It may also be inappropriate and disfiguring to take such samples from a historic structure; thus, discretion and judgment are required. The number and position of sample taken should be designed to give as accurate an assessment of the structure as possible, taking into account that the concrete may not be uniform.

.A well-equipped concrete laboratory can analyze the samples for strength, unit weight, alkalinity, carbonation, porosity, alkali-aggregate reaction, presence of chlorides and past composition. Such tests can determine approximate mix proportions and cement content. Thus, laboratory testing can aid the formulation of a compatible design mix for repair materials to historic concrete.

2.8 Curing

Concrete that has been specified, batched, mixed, placed, and finished "letter-perfect" can still be a failure if improperly or inadequately cured. Curing is usually the last step in a concrete project and, unfortunately, is often neglected even by professionals. Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance to freezing and thawing. Proper concrete curing for agricultural and residential applications involves keeping newly placed concrete moist and avoiding temperature extremes (above 90?F or below 50?F) for at least three days. A seven-day (or longer) curing time is recommended if construction constraints permit. Two general methods of curing can be used:

1. Procedures that keep water on the concrete during the curing period. These include ponding or immersion, spraying or fogging, and saturated wet coverings. Such methods provide some cooling through evaporation, which is beneficial in hot weather.

2. Procedures that prevent the loss of the mixing water from concrete by sealing the surface. This can be done by covering the concrete with impervious paper or plastic sheets, or by applying membrane-forming curing compounds. The best curing method for a particular job depends on cost, application equipment required, materials available, and the size and shape of the concrete surface. Begin the curing as soon as the concrete has hardened sufficiently to avoid erosion or other damage to the freshly finished surface. This is usually within one to two hours after placement and finishing.

2.9 Workability

This can be defined as the ease with which concrete can be compacted hundred percent having regards to mode of compaction and place of deposition. It can also be defined as the property of concrete which determines the amount of useful internal work necessary to produce full compaction. The workability of concrete depends on the quantity of water, grading of aggregates, and the percentage of fine materials in the mix. It is measured in terms of slump test, compacting factor and Vee-Bee degrees. In the test, four results can be expected; zero slump, true slump, shear slump and collapse slump. The desired one is the true slump.

2.10 Rheology

To address the shortcomings of results found in workability tests, researchers have tried to study concrete properties at a more fundamental level. Rheology is the study of the flow of materials including fluids and solids. Consequently, rheological models could be defined to describe the flow of fresh and hardened concrete. Liquids under shear stress will deform continuously. Likewise, fresh concrete will deform continuously, after a minimum shear stress, called the yield stress, has been applied. The objective of concrete rheology is to develop aptly relationships between the applied shear stress and the corresponding shear that allow predicting the behavior of concrete. For the purpose of this test the rheology of concrete will not be used.

2.11 Packing Density

Given a unit volume filled with particles, packing density or packing degree is the volume of solids in this unit volume and is equal to one minus the voids. The packing density gives an indication of how efficiently particles fill a certain volume and for that reason is such an important concept in materials science. If high volume of particles can be packed in a certain volume, the necessity for binder, which usually is much more expensive, to fill the voids and glue particles will be decreased.

The packing density or packing degree not only depends on the aggregate characteristics, but also on the compaction method and on the dimensions of the container. If the sample is just poured, the packing density will be lower than that corresponding to a sample tapped with a rod or a sample vibrated. Unfortunately, a correlation among packing densities obtained using different compaction methods has not been established, as it depends on the size, shape and texture of the particles. In fact, it is possible that a crushed aggregate has a lower loose density than a rounded one, while the vibrated density could be the opposite.

CHAPTER THREE

MATERIALS AND METHODS

3.0: GENERAL:-

Here the utilization of three sizes of commercially available chipping aggregates for concrete work were investigated. Normal concrete were produced from different sizes of aggregates and this imparts different qualities to the resulting concretes. For the purpose of this work, three sizes of aggregate, 25mm, 20mm, and 10mm were used. The selected aggregates were spread out for few days before use, to dry, in order to keep the aggregates at surface dry condition. Other foreign materials such as pebbles present were handpicked.

Normal mix (1:2:4) and water – cement ratio of 0.55 was adopted for this work and mix composition was obtained by weight method. As discussed in literature review, coarse aggregate contributes a lot to the qualities of concrete. Gradation of coarse aggregate in the same hand has great effect also on concrete in the sense that as the sizes of the coarse aggregate differs (along with their physical and mineralogical hardness) so do their qualities in concrete mixture.

3.1: MATERIALS AND METHOD

Cement:-

Commercially available ordinary Portland cement (Bua Portland cement) was used for this purpose.

Fine Aggregate

The fine aggregate used is sharp river sand obtained from a local dealer in Awka.

Coarse Aggregates:

Three sizes of commercially available chippings; 25mm, 20mm, and 10mm were used.

Water:

Clean water obtained from Civil Engineering laboratory, Nnamdi Azikiwe University, Awka was used for this work.

3.2: TEST APPARATUS AND EQUIPMENT

Some laboratory apparatus and equipment which were used in this study include: concrete mould of dimension 150mm×150mm×150mm, rammer/tamping rod, shovel, head pan, hand towel, BS sieve, weighing balance, mechanical sieve shaker, slump cone, universal testing machine and curing tank.

3.3: PRELIMINARY TEST

In order to throw more light on the materials used for this work, sieve analysis was carried out to obtain the range of particle size of the fine aggregate and that of the three selected coarse aggregate so as to ensure that the size of the aggregates was suitable for the study.

3.4: METHODOLOGY:

Here, the workability and compressive strengths of five different concretes made by using two different coarse aggregates (25mm and 10mm) in various mixed proportions were investigated. The third size which is 20mm was used as check.

By using the three different coarse aggregates, a total of six different concretes were casted.

The total six different mixtures were conducted in stages and proportions as shown below:

CALCULATIONS

Parameters

Density of concrete = 2400kg/m

Size of cubes = 150mm × 150mm = 0.15m × 0.15m

Volume of cube = 0.15m × 0.15m × 0.15m

Weight of cube = 2400kg/m ×

Calculating for the individual components using mix ratio 1:2:4 = cement: sand: aggregate

1+2+4 = 7

For cement; 1/7 × 8.1 = 1.157kg

For sand; 2/7 × 8.1 = 2.314kg

For coarse aggregate; 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 = 2.545kg

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

Estimating the weight of water for one cube given that the water cement ratio used is 0.55

Water/cement = 0.55

Therefore weight of water = weight of cement × 0.55 = 1.2727 × 0.55 = 0.7024kg = 0.7024litres

Stage 1 of concrete C1 (100% of 10mm coarse aggregate + 0% of 25mm coarse aggregate)

At this stage 100% of 10mm coarse aggregate was mixed along with sand, cement, and water to form a concrete since 25mm coarse aggregate was at 0%. Slump test was performed and six cubes were casted.

With a mix ratio of 1:2:4, the concrete's constituents appeared as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

Stage 2 of concrete C2 (75% of 10mm coarse aggregate +25% of 25mm coarse aggregate):

At this stage 25% of 25mm coarse aggregate was mixed with the remaining 75% of 10mm coarse aggregate. After the proportioning, the whole aggregates were mixed along with sand, cement, and water to form a concrete. Slump test was performed and six cubes were casted.

With a mix ratio of 1:2:4, the concrete constituents appeared as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

25% of 20mm coarse aggregate = 25/100 × 30.5514 =7.6378kg

Therefore 7.6378kg of 25mm coarse aggregate were used.

75% of 10mm coarse aggregate =75/100× 30.5514kg = 22.9136kg

Therefore 22.9136kg of 10mm coarse aggregate were used.

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

Stage 3 of concrete C3 (50% of 10mm coarse aggregate + 50% of 25mm coarse aggregate):

At this stage 50% of 25mm coarse aggregate was mixed with the remaining 50% of 10mm coarse aggregate. After the proportioning, the whole aggregates were mixed with sand, cement, and water to form a concrete. Slump test was performed and six cubes were casted.

With a mix ratio of 1:2:4, the concrete's constituents appeared as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

50% of 25mm coarse aggregate = 50/100 ×30.5514 = 15.2757kg

Therefore 15.2757kg of 25mm coarse aggregate was used

50% of 10mm coarse aggregate = 50/100 ×30.5514 = 15.2757kg

Therefore 15.2757kg of 10mm coarse aggregate were used

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

Stage 4 of concrete C4 (25% of 10mm coarse aggregate + 75% of 25mm coarse aggregate)

At this stage 75% of 25mm coarse aggregate was mixed with the remaining 25% of 10mm coarse aggregate. After the proportioning, the two aggregates were mixed together along with sand, cement, and water and prepared as concrete. Slump test was performed and six cubes were casted.

With a mix ratio of 1:2:4, the concrete's constituent appeared as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

75% of 25mm coarse aggregate = 75/100 × 30.5514kg = 22.9136kg

Therefore, 22.9136kg of 25mm coarse aggregate were used.

25% of 10mm coarse aggregate = 25/100 × 30.5514 =7.6378kg

Therefore 7.6378kg of 10mm coarse were used.

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

Stage 5 of concrete C5 (0% of 10mm coarse aggregate + 100% of 25mm aggregate)

Here the only coarse aggregate used in concrete mix was 25mm coarse aggregate because 10mm was at 0%. The 25mm coarse aggregate was mixed with sand, cement and water to prepare a concrete. Slump test was performed. Six cubes were casted.

With a mix ratio of 1:2:4, the concrete's materials used were as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

Stage 6 of concrete C6 (100% of 20mm coarse aggregate):

At this stage 100% of 20mm coarse aggregate was mixed along with sand, cement, and water to form a concrete. Slump test was performed and six cubes were casted.

With a mix ratio of 1:2:4, the concrete's constituents appeared as follows:

Cement = 1.2727 ×6 = 7.662kg

Sand = 2.545 × 6 = 15.27kg

Total coarse aggregate = 5.0919 × 6 = 30.5514kg

Water = 0.7024× 6 = 4.2144litres =4.2144 ×1000 = 4214.4ml

3.5: MIXING OF THE CONCRETE

Hand mixing method was employed in mixing all the various concretes. On a hard dry concrete floor, the required volumes of all the concrete's constituents needed for a certain concrete mix were measured out, and by using shovel they were thoroughly mixed together. After mixing slump test was taken and finally the concrete was casted into the cubes.

By following the same mixing method, all the individual concretes were mixed, slump tests taken and were casted into cubes.

3.6: SLUMP TEST

Slump test is conducted to determine the consistency as well as workability of freshly mixed concrete.

Apparatus

- Slump cone (mould)
- Steel tamping rod
- Measuring tape
- Baseplate

Procedure

The mould of the slump test, which is the cone of about 305mm (12 inches) high, is used. It has base diameter 203mm (8inches) and top diameter 102 (4 inches). Moisten the inside of the cone to reduce friction that may influence slump variations. The base is placed on a smooth surface. The cone id then filled with concrete in three layers. Each layer is tamped 25 times with a standard 16mm (5\8 inches) diameter steel rod with rounded end. After filling the three layers, the top surface of the cone is struck off and levelled with a steel rod. Clean the area around base of the cone after levelling. The cone is slowly lifted and the concrete will slump. The lifted cone is placed beside the slumped concrete. place straight edge on top of the cone to cover the slumped concrete. Take the measure between the centre of the concrete and the straight edge with a rule. The height taken is the slump. The slump should be up to 125mm (5 inches). If the slump is more than 125mm the workability has then been failed.

3.7: CASTING OF CONCRETE

The casting of concrete after mixing was done by using a 150mm x 150mm x150mm cube mould. The side plates of the mould were fixed to the base plates and all the nuts tightened. The moulds were properly lubricated before filling the moulds with mixed concrete. The concrete was filled to about one-third of the mould. Then tamping rod was used to compact the concrete inside the mould especially in the corners for 25times. The second layer was filled to about two-third of the mould and also compacted for 25times using the stamping rod. The final layer was overflown and also tamped again for 25 times. The surface of the moulds was then given a smooth finish using the trowel. Hence, the specimens were prepared in accordance with BS 1881.

3.8: CURING OF THE CON CRETE:

The test specimens (the concrete cubes) were stored in the laboratory at a place free from vibration for 24hours after which the specimens were removed from the moulds and immediately submerged in a clean fresh water (curing tank). The specimens were left in the curing tank until taken out just prior to the compression test in range of 7 days and 28 days. For accurate result, the water that contained the specimens was renewed every 7days, while the specimens were not allowed to become dry at any time until they were crushed.

3.9: COMPRESSIVE STRENGTH TEST

This is to determine the comprehensive strength of the concrete specimens prepared in a cube crushing machine shown. The procedure for the cube crushing includes;

1. The specimen was removed from the water after the specified curing time and excess water was wiped from the surface and allowed to dry
2. The bearing surface of the testing machine was cleared
3. The specimen was placed in the machine in such a manner that the load shall be applied to the opposite side of the test cubes.
4. The specimen was aligned centrally on the base plate of the machine.
5. Then the movable portion was rotated gently by hand so that it touches the top surface of the specimen.
6. The load was applied gradually without shock and continuously at the rate of 140kg/cm^2 /minute till the specimen fails.
7. The maximum load was recorded.

By following the depicted procedures mentioned above and also maintaining the standards, the individual concretes made by the three different sized coarse aggregates were worked on and their respective average compressive strengths noted and recorded.

CHAPTER FOUR

ANALYSIS AND DISCUSSION

This study investigated how the sizes (gradations) of a commercially available chippings influence the compressive strength of concrete. Three different sizes 20mm, 10mm and 25mm of the selected chippings were investigated so as to know their effects on the concrete compressive strength.

In order to ensure that high degree of accuracy was achieved, each and every one of the selected gradation was singled out and every phase of the research carried out one after the other. The phases of the experiments were the same for all the gradations.

4.0 ANALYSIS AND RESULTS

Sieve Analysis of Aggregates

The results for the sieve analysis for the fine aggregate grading for the work is shown belowWeight of sample used = 300kg

Table 4.1: Sieve analysis result for fine aggregate

sieve size (mm)	mass retained (g)	cumulative mass retained (g)	Cumulative % retained	cumulative % passing
4.75	1.21	1.21	0.40	99.60
2	7.83	9.04	3.01	96.99
1.18	15.44	24.48	8.16	91.84
0.6	225.21	249.69	83.23	16.77
0.3	40.99	290.68	96.89	3.11
0.15	8.62	299.30	99.77	0.23
0.075	0.34	299.64	99.88	0.12
Tray	0.36	300.00	100.00	0.00
	300			

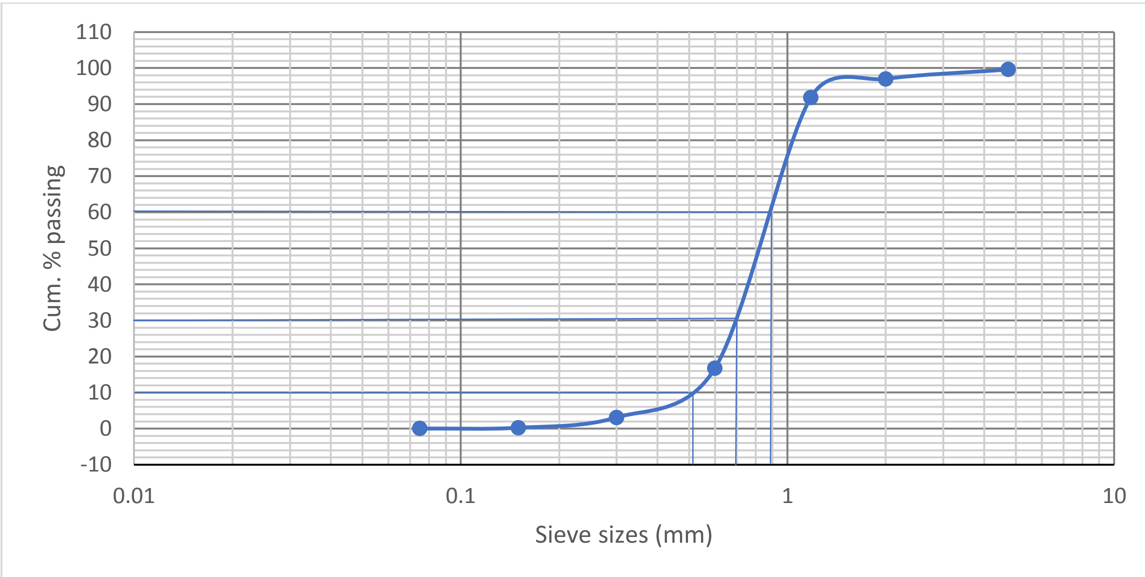


Figure 4.1: Sieve Graph for fine aggregate

Calculating for coefficient of curvature (Cc) = $D30^2/D60 * D10$

$$Cc = 0.7^2/0.9 * 0.52 = 1.05$$

Soil particle with coefficient of curvature between 1 and 3 shows that the particle is well graded and the soil is poorly graded when it is less than 1and uniform at 1. Since the result gotten (1.05) is approximately 1, the particle is uniformly graded.

Coefficient of uniformity (Cu) = D60/D10 = 0.9/0.52 = 1.73

Soil particle with coefficient of uniformity above 4 shows that the particle is well graded and the soil is uniformly graded when it is less than 4. Since the result gotten is 1.73, which is less than 4, the particle is uniformly graded.

SIEVE ANALYSIS FOR 10MM COARSE AGGREGATE

WEIGHT OF SAMPLE USED = 2000g

Table 4.2: Sieve analysis result for 10mm coarse aggregate

Sieve size	Mass retained (g)	% Mass retained	Cumulative % mass retained	Cumulative % passing
26.5	50	2.5	0	100
25	1200	60	60	40
20	500	25	85	15
14	200	10	95	5
10	50	2.5	97.5	2.5
4.7	0	0	97.5	2.5
Tray	0	0	97.5	2.5
Total	2000	100		

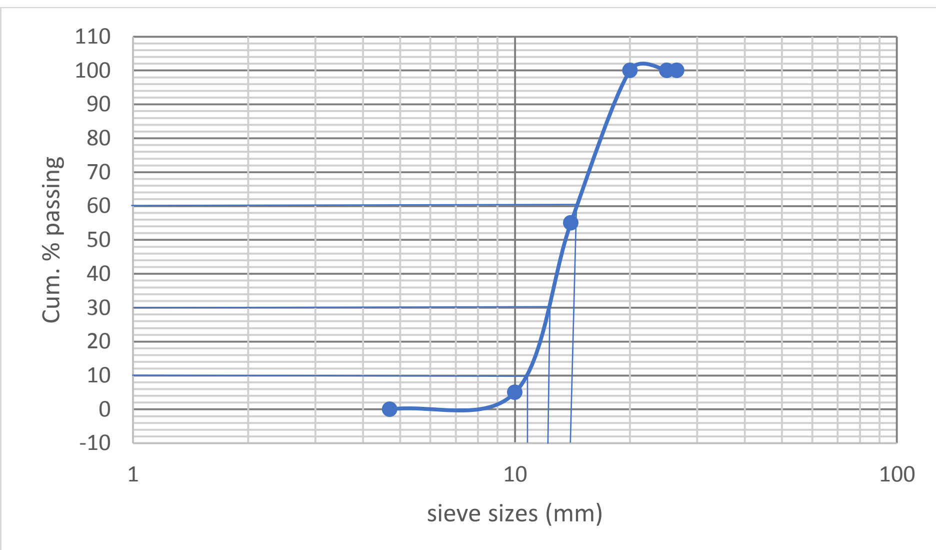


Figure 4.2: Sieve graph for 10mm coarse aggregate

Calculating for coefficient of curvature (Cc) = $D30^2/D60 * D10$

$$Cc = 13^2/15 * 11 = 1.02$$

Coefficient of uniformity (Cu) = D60/D10 = 15/11 = 1.36

The aggregate is uniformly graded.

SIEVE ANALYSIS FOR 20MM COARSE AGGREGATE

WEIGHT OF SAMPLE USED = 2000g

Table 4.3: Sieve analysis result for 20mm coarse aggregate

Sieve size	Mass retained (g)	% Mass retained	Cumulative % mass retained	Cumulative % passing
26.5	50	2.5	0	100
25	1200	60	60	40
20	500	25	85	15
14	200	10	95	5
10	50	2.5	97.5	2.5
4.7	0	0	97.5	2.5
Tray	0	0	97.5	2.5
Total	2000	100		

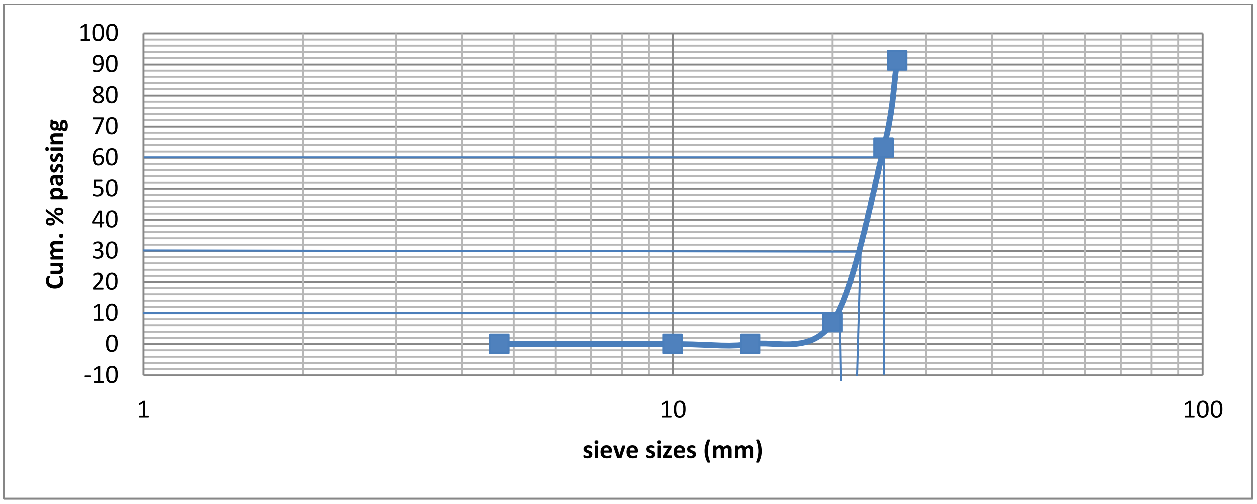


Figure 4.3: Sieve graph for 20mm coarse aggregate

Calculating for coefficient of curvature (Cc) = $D30^2/D60 * D10$

$$Cc = 23^2/20.5 * 25.5 = 1.01$$

Coefficient of uniformity (Cu) = D60/D10 = 25.5/20.5 = 1.24

The aggregate is uniformly graded.

SIEVE ANALYSIS FOR 25MM COARSE AGGREGATE

WEIGHT OF SAMPLE USED = 2000g

Table 4.4: Sieve analysis result for 25mm coarse aggregate

Sieve size	Mass retained (g)	% Mass retained	Cumulative % mass retained	Cumulative % passing
26.5	50	2.5	0	100
25	1200	60	60	40
20	500	25	85	15
14	200	10	95	5
10	50	2.5	97.5	2.5
4.7	0	0	97.5	2.5
Tray	0	0	97.5	2.5
Total	2000	100		

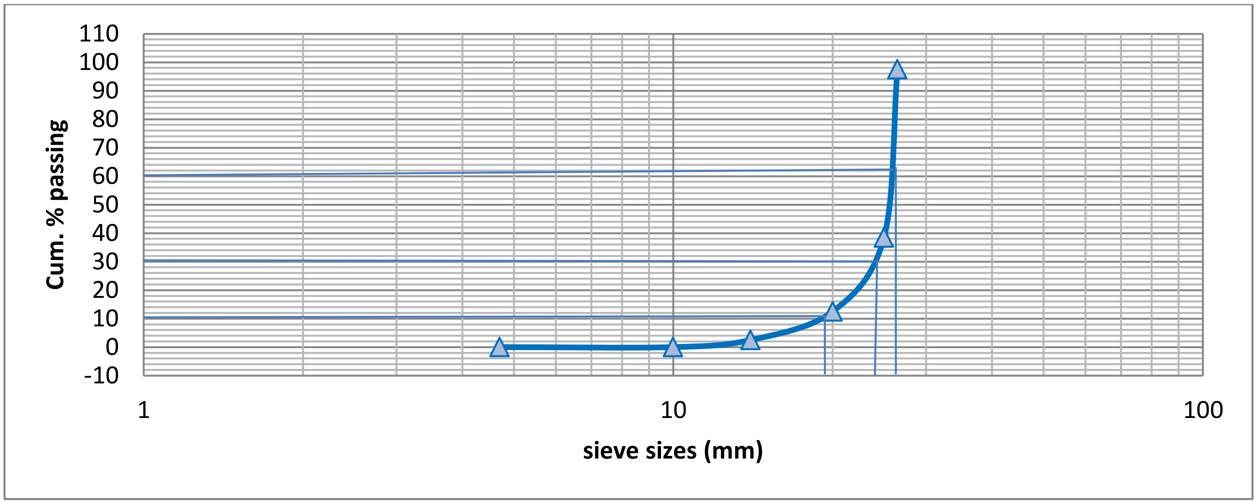


Figure 4.4: Sieve graph for 25mm coarse aggregate

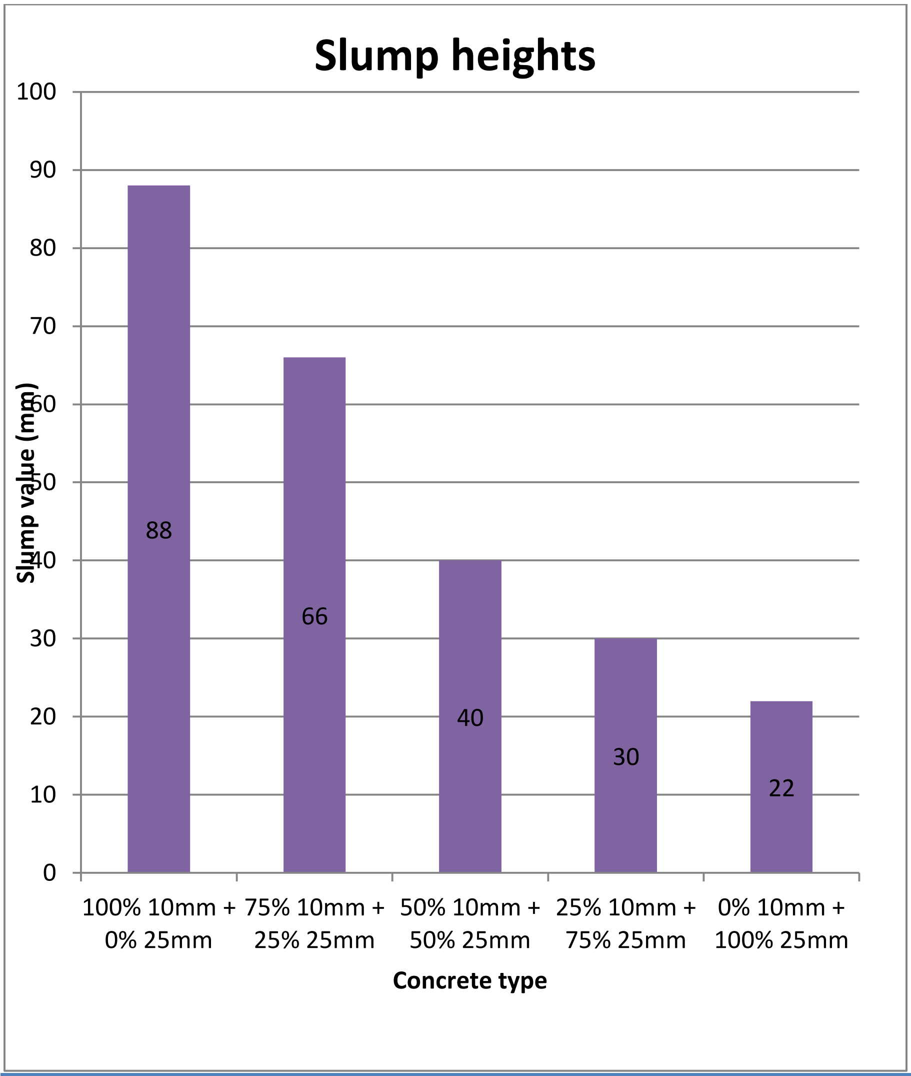
Calculating for coefficient of curvature (Cc) = $D30^2/D60 * D10$

$$Cc = 25^2/27 * 19.5 = 1.19$$

Coefficient of uniformity (Cu) = D60/D10 = 27/19.5 = 1.38

From the results obtained, the aggregate is uniformly graded.

SLUMP



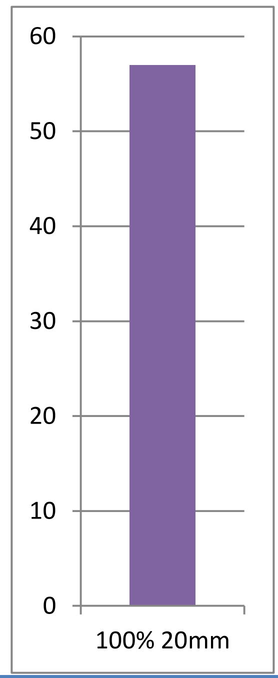


Figure 4.5: Slump values of the concretes

It is known that as sizes of aggregate increases, the workability decreases. From the slump histogram, 100% 10mm is found to be the highest; this shows that it is more workable than others. The workability keeps decreasing as the ratio of 25mm increases in each concrete.

COMPRESSIVE STRENGTHS

Table 4.5: Compressive strength results

Cube type	Age (days)	Weight of cube (Kg)	Test load (KN)	Strength (N/mm2)	Average Strength (N/mm2)
100% 10mm+ 0% 25mm	7	8.7	305.28	13.50	13.85
		8.9	320.40	14.24	
		8.6	310.52	13.84	
	28	8.8	426.06	18.93	18.30
		8.9	386.00	17.16	
		8.7	424.00	18.80	
75% 10mm + 25% 25mm	7	8.2	345.41	15.35	15.50
		8.2	360.00	16.00	
		8.4	340.88	15.15	
	28	8.3	460.06	20.40	20.30
		8.5	450.00	20.00	
		8.3	440.80	19.68	
50% 10mm + 50% 25mm	7	8.7	416.25	18.50	18.99
		8.7	443.25	19.70	
		8.5	442.55	18.78	
	28	8.8	573.75	25.50	24.53
		8.7	575.00	24.80	
		8.6	524.25	23.30	
25% 10mm + 75% 25mm	7	8.2	496.74	22.00	21.80
		8.4	467.04	20.70	
		8.4	510.70	22.67	
	28	8.5	577.80	25.68	26.33
		8.5	617.63	27.45	
		8.6	582.08	25.87	
0% 10mm + 100% 25mm	7	8.6	397.43	17.66	17.60
		8.5	395.54	17.50	
		8.6	386.00	17.20	
	28	8.8	530.66	23.50	23.85
		8.7	554.48	24.64	
		8.9	526.60	23.40	
100% 20mm	7	8.3	418.67	18.60	19.86
		8.1	465.56	20.69	
		8.3	456.56	20.29	
	28	8.5	530.66	23.50	25.30
		8.3	580.56	25.80	
		8.6	598.60	26.60	

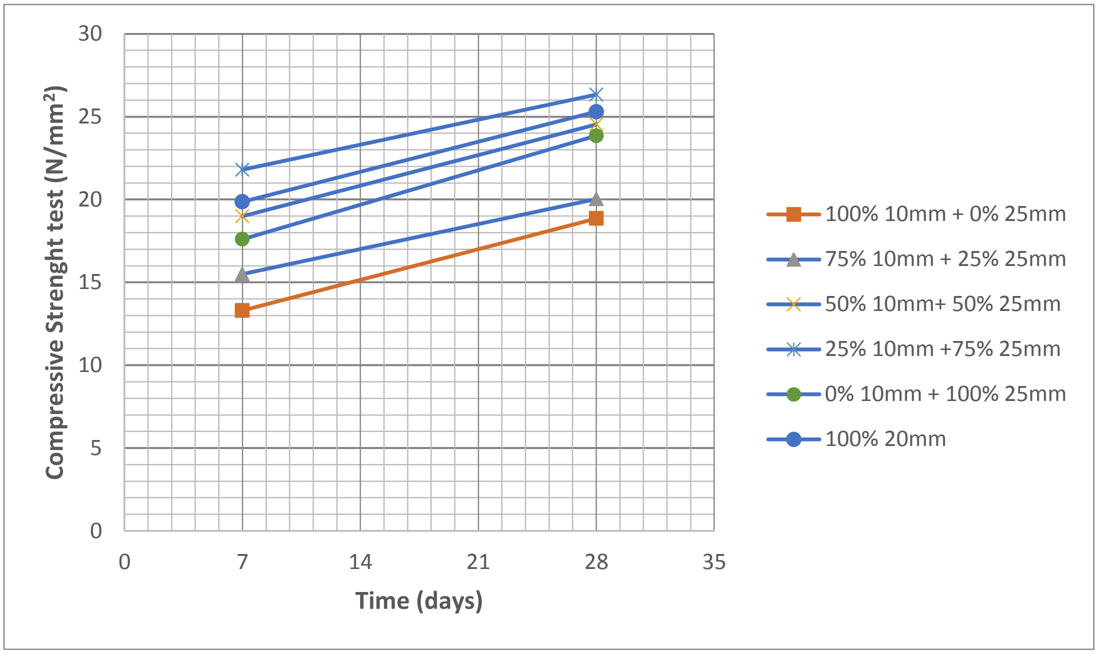


Figure 4.1: Compressive strength of the concretes at 7days and 28 days

The graph shoes that for each concrete, the compressive strength increases as the curing days increases. That is 28days curing gave more strength in each concrete than 7 days.

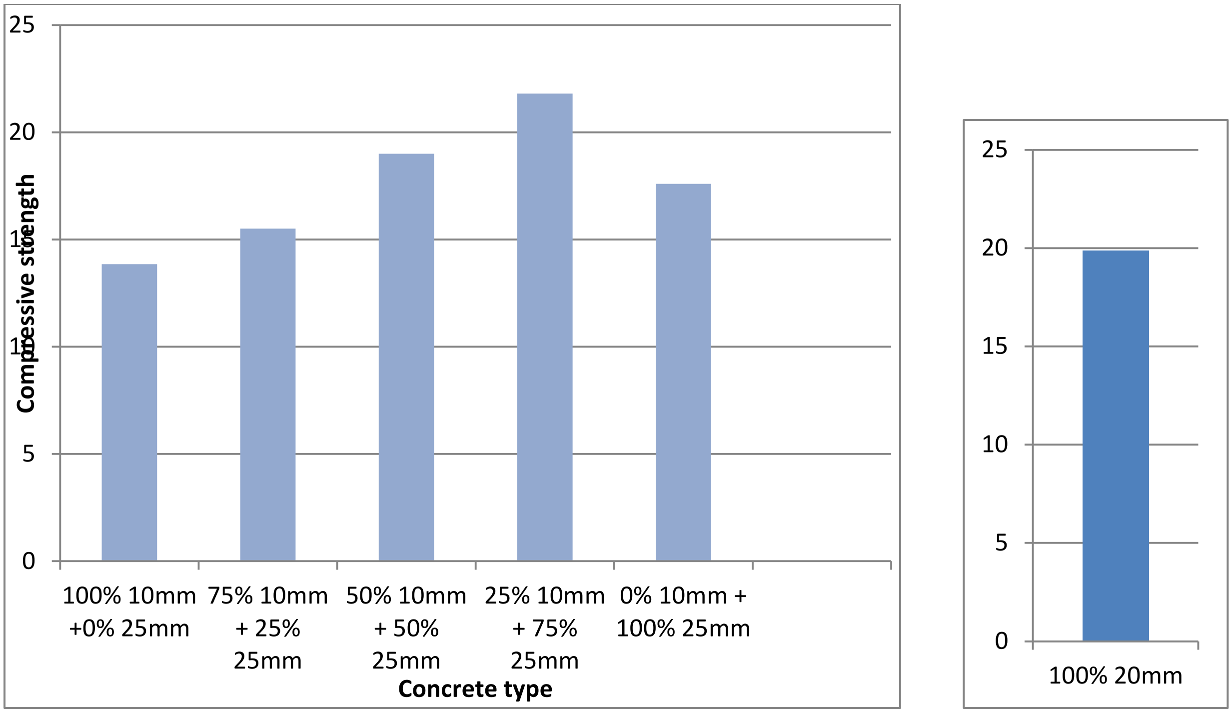


Figure 4.2: Compressive strength of the concretes at 7days

Figure 7 above shows that as the ratio of the bigger aggregate size increases (25mm), so do the compressive strength of the concrete. However the compressive strength decreased at 100% 0f 25mm.

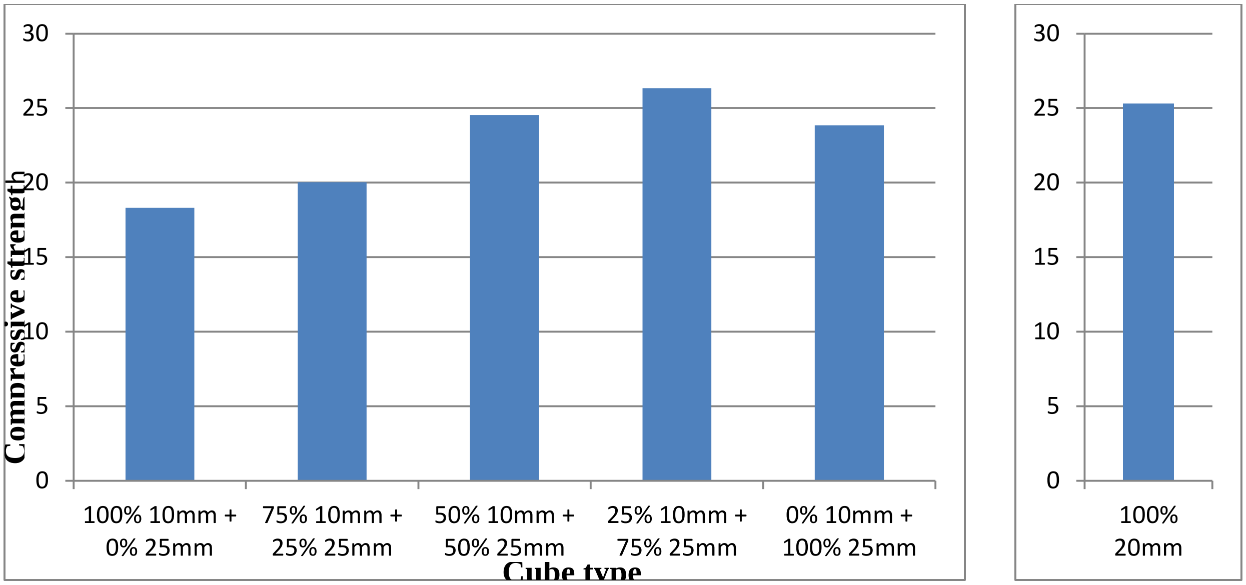


Figure 4.3: Compressive strength of the concrete at 28days

Figure 8 shows same result as figure 7.That is as the ratio of the bigger aggregate size increases (25mm), so do the compressive strength of the concrete. However the compressive strength decreased at 100% 0f 25mm. concrete made of 25%% 10mm + 75% 25mm gave more strength than concrete made with 100% 20mm.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

SUMMARY AND CONCLUSION

The study examined the influence of coarse aggregate grading on the compressive strength of concrete. Three different sized aggregates were selected and after working with them their individual concretes compressive strength were recorded. The specimens used were ordinary available chippings, sharp sand, and BUA Portland cement. The information obtained include the physical properties of the three aggregates and how they individually affect the mixed concrete, the workability of the selected aggregates determined through slump test and their compressive strength by crushing.

The study recognizes the importance of selecting a suitable sized aggregate in obtaining a concrete mix with maximum compressive strength, great durability and an increased economy. After the study, it was found that the compressive strength increases as the percentage of 25mm increases in the concretes, while it is the opposite for workability. Therefore depending on the property wanted at a time in a concrete, different percentages of 25mm and 10mm can be used. For workability 100% 10mm + 0% 25mm can be used, while 25% 10mm + 75% 25mm can be used in terms of strength. The usage of an appropriate sized aggregate will significantly reduce the lesser compressive strengths obtained when poorly sized coarse aggregates are used in concrete mix, it also increases the structure’s durability, reduces unnecessary expense encounters atimes for usage of more cement (for an increased workability through lubrication by the cement paste) and unnecessary compaction in elimination of voids when poorly graded aggregates are used. The information presented in chapter four of this study represents the observed properties of the selected aggregate as used in the concrete mix.

This concluding portion of the study is aimed at obtaining the importance of the test results obtained after working with the specimens in respect to the compressive strength of the concrete.

RECCOMMENDATIONS

Since concrete is widely used in civil Engineering practices aand since urbanization is increasingly boosted by infrastructures, it is imperative to note that a durable structure will only be achieved when a standard concrete is used. The possibility of obtaining a perfect concrete is when all its constituents are of standard and are in order, which is mostly achieved by the selected coarse aggregates. The usage of an appropriate coarse aggregate which meet up to standard in concrete mix will always enable that a strong and stable Engineering structures are constructed at an increased economy with longer durability and atimes of an outstanding aesthetic values.

The following are generally recommended by the researcher for accomplishment of the above mentioned objectives after the overall study, along with the tests and the results were conducted and obtained.

- Recognizing the uppermost importance of type and gradation of coarse aggregate in concrete mix as selecting right one will not only produce a concrete of higher compressive strength, but also enable a strong and durable concrete structure(s) to be constructed with greater economy.
- Making sure that during a concrete mix, that better constituents are selected because they will always boost the strength of the concrete.

- Depending on the particular property needed in a particular concrete when using 25mm and 10mm coarse aggregate, 100% 10mm + 0% 25mm combination should be adopted for workability, while for the best strength, 25% 10mm + 75% 25mm should be adopted.

FUTURE WORK

Future work should be done on other properties of concrete like permeability, density e.t.c, using same mix percentages of 25mm and 10mm. Other sizes can also be combined and the concrete properties checked.

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