REPLACEMENT OF SAND WITH QUARRY DUST IN CONCRETE PRODUCTION

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A PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG), IN CIVIL ENGINEERING.

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ABSTRACT

Concrete is a mixture of fine aggregate (sand), coarse aggregate (rock), cement, and water. The increasing demand of concrete for construction and development of infrastructure has drawn the attention of many researchers in searching for less expensive alternatives to the traditional materials employed in the construction industries in an attempt to reduce the high cost of construction. This paper features an experimental study on the replacement of sand with quarry dust and its influences on the properties of fresh and hardened concrete. The project is about replacing sand in concrete production with quarry dust at varying percentage (0%, 25%, 50%, 75% and 100%) to check if the strength matches that of grade M15 with a mix ratio of 1:2:4 and also the proportion which has the highest strength. The test carried out includes particle size analysis, slump test, and compressive test. Sand was replaced with Quarry dust by weight at 0%, 25%, 50%, 75% and 100%. The slump value obtained from the control mix of the washed sample was 110 mm while sand replaced by quarry dust at 25 %, 50%, 75%, and 100% were 87 mm, 78 mm, 55 mm and 48 mm respectively and also the slump value obtained from the control mix of the unwashed sample was 53 mm while sand replaced by quarry dust at 25 %, 50%, 75%, and 100% were 80 mm, 72 mm, 35 mm and 83 mm respectively. The control mix of the washed at 28 days has a compressive strength of 22.96 N/mm^2 while the replaced mix at 25 %, 50%, 75%, and 100% has 23.14 N/mm^2, 15.84 N/mm^2, 16.87 N/mm^2 and 17.18 N/mm^2 respectively and also The control mix of the unwashed at 28 days has a compressive strength of 16.21 N/mm^2 while the replaced mix at 25 %, 50%, 75%, and 100% has 18.15 N/mm^2, 18.9 N/mm^2, 19.47 N/mm^2 and 22.03 N/mm^2 respectively. This research concludes that at the 25% replacement of the washed sample, was found to give a higher strength than that of the control mix as it approaches 14, 28 and 60 days of curing. A partial replacement of 25% gives the highest compressive strength. And according to the result, it meets up with the target strength of the control mix (M15). Concrete with washed fine aggregate has a higher compressive strength compared to that of concrete produced with unwashed fine aggregate. The variation in strength of concrete is as a result of the presence of silt in the unwashed material. The silts reduces the strength of concrete.

CERTIFICATION

This is to certify that this proposal was prepared by OLOJO-KOSOKO ADEBOWALE OLUWATOYIN (CVE/11/0375) under my supervisor, in partial fulfilment of the requirement for the award of Bachelor of Engineering (B.Eng) Degree in Civil Engineering, Federal University Oye-Ekiti, Ekiti State, Nigeria.

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DEDICATION

I dedicate this project to God Almighty for helping me through it all and my parent for being my guide.

ACKNOWLEDGEMENT

I express my most sincere acknowledgement to my supervisor Mr.T.C. Okeke for his supervision, assistance, patience, encouragement, and his thorough understanding of the project work. I am also grateful for the knowledge impacted through numerous discussions.

Mr. Akinyemi and Mr. Seun really assisted me with the practical. I kept coming to the University of Ibadan on frequent occasions and each time they were happy to be of help, only God can repay them.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 General Background

Concrete is the most widely used construction material on earth, commonly made by mixing Portland cement with sand, crushed rock, and water. Concrete is a composite material produced by the homogenous mixing of selected proportions of water, cement and aggregates (fine and coarse) (Kong and Evans, 1987). Strength is the most desired quality of a good concrete. In the U.S. 63 million tons of Portland cement were converted into 500 million tons of concrete, which is five times the consumption by weight of steel. In many countries, the ratio of concrete consumption to steel consumption exceeds ten to one. The total world consumption of concrete in a year is estimated at three billion tons, or one ton for every living human being. Man consumes no material except water in such quantity in a year (Chandana et,al, 2013).

It plays a vital role in our daily life/in many construction companies, concrete infrastructure comprises about 60% of the built environment (Donn and Thomas, 2011). Today, it is indispensable in the development of infrastructure, industry and housing. Without concrete, the built environment would fail to accommodate our modern and demanding lifestyles (Balkrishna et. al, 2012).

The increasing demand of concrete for construction and development of infrastructure has drawn the attention of many researchers in search for less expensive alternatives to the traditional materials employed in the construction industries in an attempt to reduce the high cost of construction and replace material that are not readily available. Common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. As environmental transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete industry needs to be found. River sand is most commonly used fine aggregate in the production of concrete which poses the problem of acute shortage in many areas, whose continued use has started posing serious problems with respect to its availability, cost and environmental impact. (Ilangovana et al., 2008).

Taking Ekiti-state as a focus point, there is scarcity of natural sand in the area due to the lack of rivers around, so therefore, there is the problem of transportation of sand from the place extraction to the point of use and also the availability of good quality sharp sand. Sand collected from this aeolian deposit is expensive due to unwanted cost of transportation from natural sources. River sand is most commonly used fine aggregate in concrete but due to its acute shortage, availability, cost and environmental impact in many areas in Ekiti- State, this has resulted in the increased need to identify substitute material to sand in the production of concretes. In such a situation the Quarry rock dust can be an economic alternative to the river sand.

Quarry dust is a by-product from the crushing process during quarrying activities. It's also known as Quarry waste. Generally considered as a waste material after the extraction and processing of rocks to form fine particles less than 4.75mm, causes an environmental load due to disposal problem. Hence, the use of quarry dust in concrete mixture will reduce not only the demand for natural sand but also the environmental burden of disposal. Quarry dust have been used for different activities in the construction industry such as for road construction and manufacture of building materials such as lightweight aggregates, bricks, tiles and autoclave blocks. (Ilangovana et al., 2008).

1.2 Aim and Objectives

1.2.1 Aim

The aim of this research study is to analyze the strength behavior of concrete mix with varying proportion of washed and unwashed sand and quarry dust from different Kopek quarry sites in Ikere-Ekiti State.

1.2.2 Objectives

The following objectives are presented:

i. To achieve the best workability with varying ratio of sand to quarry dust.
ii. To obtain the proportion of quarry dust to sand mix ratio that will give the best concrete strength.
iii. To determine the effect of dust on concrete strength.

1.3 Description of Study Area

The quarry sites for this project is Kopek Quarry (located in Ikere-Ekiti towards Ife Road). Ekiti is a state in western Nigeria, declared a state on October 1, 1996 alongside five others by the military government of General Sani Abacha. The state, carved out of the territory of old Ondo State, covers the former twelve local government areas that made up the Ekiti Zone of old Ondo State. On creation, it took off with sixteen (16) Local Government Areas (LGAs), having had an additional four carved out of the old ones. Ekiti State is one of the thirty-six states (Federal Capital Territory (Nigeria)) that constitute Nigeria.

The State is mainly an upland zone, rising over 250 meters above sea level. It lies on an area underlain by metamorphic rock. It is generally undulating country with a characteristic landscape that consists of old plains broken by step-sided out-crops that may occur singularly or in groups or ridges. Such rocks out-crops exist mainly at Aramoko, Efon-Alaaye, Ikere-Ekiti,Igbara-odo- ekiti and Okemesi-Ekiti. The State is dotted with rugged hills, notable ones being Ikere-Ekiti Hills in the south, Efon-Alaaye Hills on the western boundary and Ado-Ekiti Hills in the centre. Wikipedia (2016).

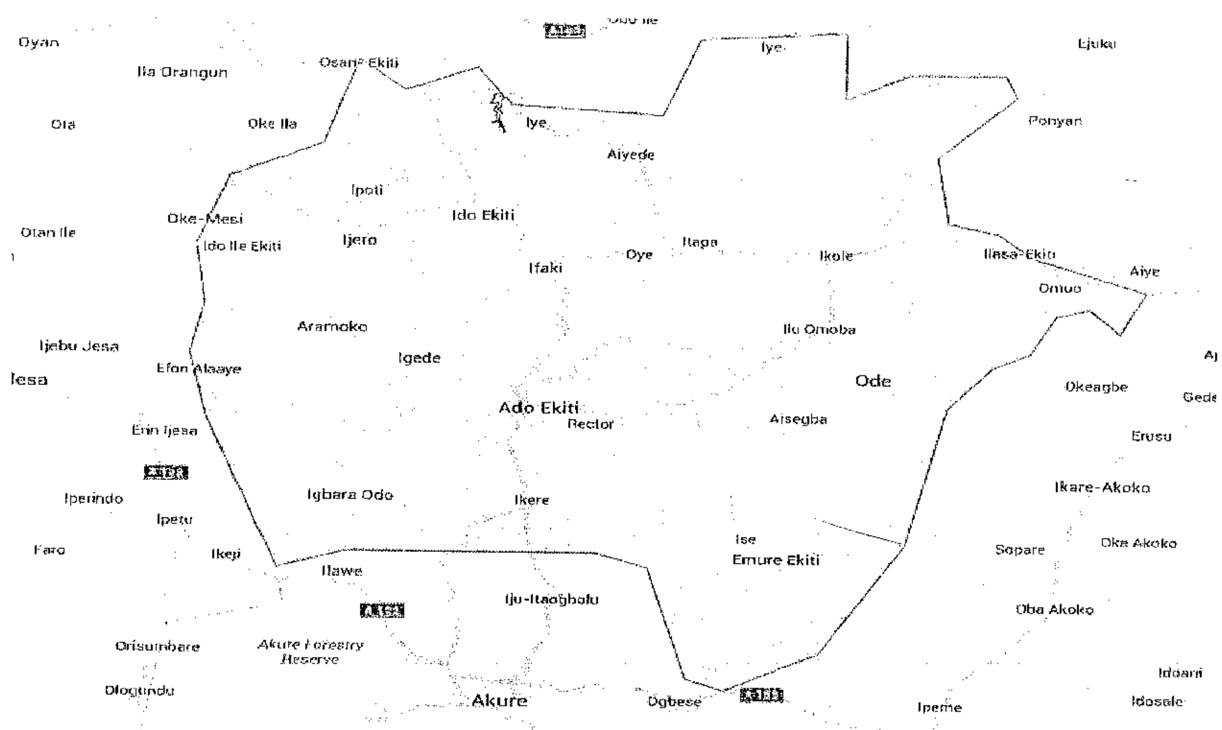


Figure 1.1; Map of Ekiti State Showing My Study Area

1.4 Scope of Study

This study will focus on the characterization of washed and unwashed quarry dust to sand ratio in other to achieve a good workable concrete strength. This covers a selected quarry sites in Ekiti state namely: Kopek Quarry.

The study involves the collection of samples from Kopek quarry site replacing the sand with the dust at varying percentages varying from 0%-100% (0, 25, 50, 75, and 100). The tests to be carried out includes;

i. Fine aggregate (sand and dust): *sieve analysis*
ii. Concrete: *workability, compressive test, water absorption.*

1.5 SIGNIFICANCE OF STUDY

Quarry dust have been used for different activities in the construction industry such as for road construction and manufacture of building materials such as lightweight aggregates, bricks, tiles and autoclave blocks. Sand collected from aeolian deposit is expensive due to unwanted cost of transportation from natural sources. Large scale exploitation of natural sand creates environmental impact on society. River sand is most commonly used fine aggregate in concrete but due to acute shortage in many areas, availability, cost & environmental impact are the major concern (Ahmed et.al., 1989). To overcome this crisis, partial or total replacement of sand with quarry dust can be an economic alternative.

This study involves the use of quarry dust as a replacement of fine aggregate in the production of concrete at varying percentages and comparing the compressive strength of the varying mix ratio of the quarry dust to sand.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Concrete

Concrete is a construction material comprising of cement (commonly Portland cement), aggregates (coarse aggregate such as gravel, limestone or granite and fine aggregate such as sand), water and chemical admixtures. The compressive strength of concrete is commonly considered its most valuable property although in many practical cases other characteristics such as durability and impermeability may be considered more important. Nevertheless, strength usually gives us an overall picture of the quality of concrete because strength is directly related to the structure of the hardened cement paste (Neville, 1981).

Concrete has relatively high compressive strength but significantly low tensile properties, and as such is usually reinforced with materials that are high in tension often steel (Ukpata, 2006). In engineering practice, the strength of concrete at a given age and cured at prescribed temperature is assumed to depend on two factors only; the water-cement ratio and degree of compaction (Kulkarni, 1992).

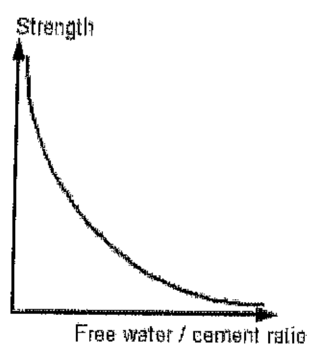
2.2 Factors Affecting the Strength of Concrete

The following are the factors affecting the strength of concrete:

2.2.1 Water Cement Ratio

The **water–cement ratio** is the ratio of the weight of water to the weight of cement used in a concrete mix. A lower ratio leads to higher strength and durability, but may make the mix difficult to work with and form. (Wikipedia, 2016)

The relation between water cement ratio and strength of concrete is shown in the plot as show below:



v. The upturned slump cone was placed on the base to act as a reference, and the difference in level between its top and the top of the concrete was measured and recorded to the nearest 5 mm to give the slump of the concrete.

When the cone is removed, the slump may take one of three forms. In a true slump the concrete simply subsides, keeping more or less to shape. In a shear slump the top portion of the concrete shears off and slips sideways. In a collapse slump the concrete collapses completely. Only a true slump is of any use in the test. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix. Then the same procedure is done with the concrete having the partial replacement of sand with raw quarry dust at various percentages.

3.5 Test on Hardened Concrete

Compressive Strength Test

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. For most of the works cubical moulds of size 10cm x 10cm x 10cm was used.

The test procedure for compressive strength test;

i. Representative samples of concrete was taken and used for casting cubes 10 cm x 10 cm x 10 cm.

ii. The concrete was filled into the moulds in layers approximately 5 cm deep.

iii. It was distributed evenly and compacted by hand tamping. After the top layer has been compacted, the surface of concrete was finished level with the top of the mould using a trowel; and covered with a polythene bag to prevent evaporation.

iv. The specimen was stored at site for 24+ ½ h under damp matting or sack. After that, the samples was stored in clean water at $27+2^0$C; until the time of test (curing).

v. Specimen was tested immediately on removal from water and while they are still in wet condition. The bearing surface of the testing specimen was wiped clean and any loose material removed from the surface.

vi. The specimen (cube) was placed in the compressive testing machine. The load was applied slowly without shock and increased continuously at a rate of approximately 140 kg/sq.cm/min until the resistance of the specimen (cube) to the increased load fails and no

The higher the water/cement ratio, the greater the initial spacing between the cement grains and the greater the volume of residual voids not filled by hydration products. For a given cement content, the workability of the concrete is reduced if the water/cement ratio is reduced. A lower water cement ratio means less water, or more cement and lower workability. However if the workability becomes too low the concrete becomes difficult to compact and the strength reduces. (The constructor, 2015)

i. Effect of High Water/Cement Ratio

No matter how high the water consumption rate of the reaction is, due to the large amount of water present in the mix, some water will still be left when the concrete hardens and is ready for use. This trapped water will gradually evaporate, leaving some voids in the concrete block. The presence of voids results in greatly reduced strength.

ii. Effect OF Low Water/Cement Ratio

The strength of concrete is more when the w/c ratio is low, because; since the water available for hydration is very less, almost all of it is utilized during the reaction. So no water is left to get evaporated later, and hence the strength-reduction due to subsequent void formation is also much lower when the w/c ratio is low. (Anangsha Alammyan, 2015)

2.2.2 Degree of Compaction of Concrete

Compaction is the process which expels entrapped air from freshly placed concrete and packs the aggregate particles together so as to increase the density of concrete. It increases significantly the ultimate strength of concrete and enhances the bond with reinforcement. It also increases the abrasion resistance and general durability of the concrete, decreases the permeability and helps to minimize its shrinkage-and-creep characteristics. Proper compaction also ensures that the formwork is completely filled – i.e. there are no pockets of honeycombed material – and that the required finish is obtained on vertical surfaces (CCAA, 2006).

2.3 Properties of Concrete

Some properties of concrete to be reviewed in this chapter includes the following;

i. Workability
ii. Strength (compression and tensile strength)
iii. Durability

iv. Shrinkage and expansion

v. Water tightness

2.3.1 Workability

Workability of concrete is defined as the property determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity. The term *manipulate* means the mixing, placing, compacting and finishing operations done when casting concrete (Kumar and Paulo, 2006).

The effort required to place a concrete mixture is determined largely by the overall work needed to initiate and maintain flow (*consistency*), which in turn depends on the property of the lubricant (the cement paste) and the internal friction between the aggregate on one hand and the external friction between the concrete and the surface of the formwork (*stability or cohesiveness*) on the other.

i. *Consistency;* an index for mobility or flowability of concrete.

ii. *Cohesiveness;* an index for stability or lack of bleeding and segregation (non-uniform distribution of the particles of aggregate).

The significance of workability in concrete technology cannot be over-emphasized. It is one of the key properties that affect constructability. Regardless of the sophistication of the mix design procedure used and other considerations, such as cost, a concrete mixture that cannot be properly placed or compacted fully is not likely to yield the expected strength and durability characteristics. Concrete judged to be workable when high-frequency vibrators are available, would be unworkable when tamping is used.

No single test can be carried out to measure the workability of a concrete. The most widely used test for is the *slump test* which measured only the consistency of the concrete. The *vebe test* is similar to that of the *slump test* which is used in mixtures of low consistency. The third test is the *compacting factor test*, which attempt to evaluate the compactibility characteristics of a concrete mixture (Kumar and Paulo, 2010).

2.3.2 Strength

The strength of a material is defined as the ability to resist stress without failure (Kulkarni, 1992). In concrete, strength is related to the stress required to cause failure and it is defined as the maximum stress the concrete sample can withstand. In tension, concrete are said to be weak while in compression they are said to be strong Kumar and Paulo, 2010).

2.3.2.1 Compressive strength

The compressive strength of concrete is several times greater than other types of strength, therefore a majority of concrete elements are designed to take advantage of the higher compressive strength of the material. The factors affecting the compressive strength includes the properties and proportioning of the materials used in the making of the concrete mix, degree of compaction, water-cement ratio and conditions of curing.

The test for compressive strength of concrete can be done using the compression testing machine. Although in practice, most concrete are subjected simultaneously to a combination of compressive, shearing, and tensile stresses in two or more directions. The test done is the 28 days compressive strength test determined by a standard uniaxial compression testing machine. (Kumar and Paulo, 2006)

2.3.3 Durability

A long service life is considered synonymous with durability. Durability of a concrete is its ability to resist the forces of deterioration (Kumar 1986).

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposure environment and properties desired. For example, concrete exposed to tidal seawater will have different requirements than an indoor concrete floor. Concrete ingredients, their proportioning, interactions between them, placing and curing practices, and the service environment determine the ultimate durability and life of concrete. (Kumar and Paulo, 2006)

Durability of Concrete depends upon the following factors:

i. **Cement content**

Mix must be designed to ensure cohesion and prevent segregation and bleeding. If cement is reduced, then at fixed w/c ratio the workability will be reduced leading to inadequate compaction. However, if water is added to improve workability, water / cement ratio increases and resulting in highly permeable material.

ii. **Compaction**

Compaction is the process which expels entrapped air from freshly placed concrete and packs the aggregate particles together so as to increase the density of concrete. The concrete as a whole contain voids can be caused by inadequate compaction. Usually it is being governed by the compaction equipment used, type of formworks, and density of the steelwork.

iii. **Curing**

Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. The result of this process is increased strength and decreased permeability. Curing is also a key player in mitigating cracks in the concrete, which severely impacts durability.

iv. **Cover**

Concrete cover, in reinforced concrete, is the least distance between the surface of embedded reinforcement and the outer surface of the concrete. Thickness of concrete cover must follow the limits set in codes.

v. **Permeability**

Permeability is defined as the property that governs the rate of flow of a fluid into a porous solid. The rate of viscous flow of fluids under pressure through the pore structure of concrete. It is considered the most important factor for durability. It can be noticed that higher permeability is usually caused by higher porosity .Therefore, a proper curing, sufficient cement, proper compaction and suitable concrete cover could provide a low permeability concrete

2.3.4 Shrinkage and Expansion

Concrete tend to swell upon wetting and to shrink upon drying. Swelling takes place when moisture enters the gel structure of the hydrated Portland cement. The tiny crystals of the hydrated Portland cement are long and thin and resemble a pole of matches in which the matches of wash layer are at right angles to the matches to be forced apart causing swelling of the cement gel. As concrete dry out, this layered structure becomes more compact, causing shrinkage of the concrete. (Kulkarni, 1992).

Concrete, like most materials, will shrink slightly when it dries out. Common shrinkage is about 1/16th of an inch in a 10-foot length of concrete. The reason contractors place joints in concrete pavements and floors is to allow the concrete to crack in a neat, straight line at the joint, where concrete cracks due to shrinkage are expected to occur. Control or construction joints are also placed in concrete walls and other structures.

An increase in temperature will cause thermal expansion of the concrete due to the increase increased energy in the atomic structure (Kumar, 1986).

2.3.5 Water Absorption

Another property of concrete is water tightness. Sometime, it's called impermeability of concrete. Water tightness of concrete is directly related to the durability of concrete. The lesser the permeability, the more the durability of concrete (Kumar, 1986). A concrete with low permeability resists ingress of water and is not as susceptible to freezing and thawing. Water enters pores in the cement paste and even in the aggregate.

2.3.6 Fire Resistance

Concrete is used extensively to fire proof steel beams because it has a low thermal conductivity. The gel structure of hydrated Portland cement does not break down until a temperature of approximately 200^{0}F (1093^{0}C) is reached, and the point of fusion of most aggregate is reached merely at a high temperature (Kumar, 1986).

2.4 Composition of Concrete

The global concerns of sudden collapses of buildings across the world, and in Nigeria in particular demand that materials used for construction of buildings meet minimum requirement (Ukpata, 2006). In some cases, even though the building has not totally collapsed, the aesthetic value is lost to crack and other defects. The defects are mainly caused by the poor quality of concrete composition used. The main composition of concrete includes; cementitious materials, aggregates, water and sometimes admixtures.

2.4.1 Cementitious Materials

Cementitious material includes; Portland cement, blended cement, ground granulated blast furnace slag, fly ash, silica fume, metakaolins and other materials having cementitious properties. Emphasis will be placed on the usefulness of Portland cement in this section.

Portland cement to a layman, means cement. It refers to the material manufactured from limestone and clay and made available in powder from, which when mixed with water can set to a hard durable mass even under water. They are made from basic compounds, tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A) and tetracalcium aluminoferrite (C_4AF) (Young and Sidney, 2003).

TABLE 2.1: Main Chemical Composition of Portland cement

NAME	OXIDE COMPOSITION	ABBREVIATION
Tricalcium Silicate	**$3CaOSiO_2$**	**C_3S**
Dicalcium silicate	**$2CaOSiO_2$**	**C_2S**
Tricalcium aluminate	**$3CaOAl_2O_3$**	**C_3A**
Tetracalcium aluminoferrite	**$4CaOAl_2O_3Fe_2O_3$**	**C_4AF**

Source: (P.C. Varghese, 2010)

Generally, the content of C_2S is about 25% and that of C_3S about 45% of the cement. The process of manufacturing cement is called the *dry or semi-dry process*. The limestone and shale are crushed to powder form and blended in correct proportions. It is then mixed in the dried form by means of compressed air. This mixture behaves like fluid and is sieved and sent to the calciner which converts it into clinker which is ground to cement. The dry process is preferred to the wet process because it consumes less fuel compared to the wet process (100kg of coal per ton of cement compared to 350kg for the wet process). (Varghese P.C, 2010)

The principal consideration in all operation involving and sorting of cement is to avoid damage or contamination of the product prior to its incorporation in the work (Young and Sidney, 2003). Cement should be stored in dry places at all times, because it is very susceptible to damage by contact with water or exposure to a moist atmosphere. When stored under moist conditions for even short periods, cement takes up moisture and hydrates making it unfit for use.

2.4.2 Aggregate

Aggregate, is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material. Aggregates are also used as base material under foundations, roads, and railroads. In other words, aggregates are used as a stable foundation or road/rail base with predictable, uniform properties (e.g. to help prevent differential settling under the road or building).

Aggregate used in concrete are obtained from either natural gravel deposits or are manufactured by crushing quarried rock. Natural deposits of sand and gravel may contain large amounts of deleterious aggregates such as shale and iron oxides. Therefore, some of these deposits do not meet concrete aggregate specification (Balkrishna, 2012). Beneficiating equipment can sometimes remove these undesirable materials during production. During processing, oversized material is either eliminated or reduced to usable size by crushing. Crushed rock is generally obtained from quarried granite, quartzite, limestone or trap rock.

Aggregates comprise as much as 60% to 80% of a typical concrete mix, so they must be properly selected to be durable, blended for optimum efficiency, and properly controlled to produce consistent concrete strength, workability, finishability, and durability. They are the least expensive of the materials used in concrete. Aggregate are divided into two general group sizes, fine and coarse. In many instances more than two actual sizes of materials are used, due to further subdivision by size of materials within one or both of the groups (Donn and Thomas, 2011). The figure below shows an illustration of aggregate size from fine to coarse.

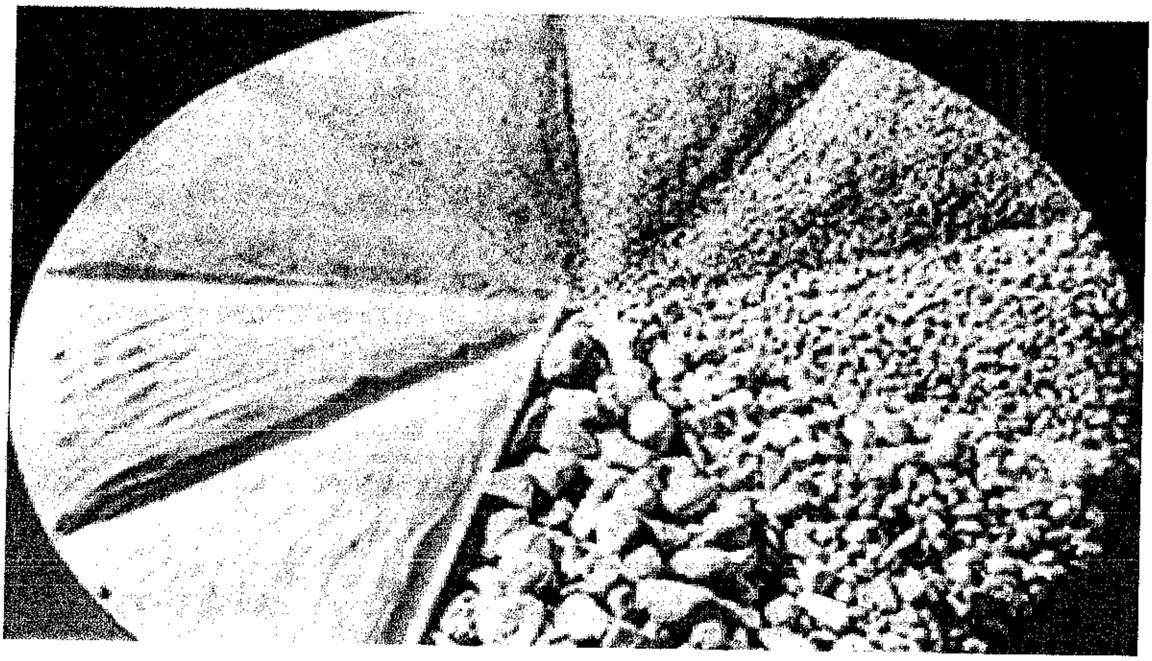


Figure 2.1; Diagram Showing the Various Aggregate Sizes (www.concretenetwork.com)

2.4.2.1 Fine Aggregate

Fine aggregate is normally considered material that will pass through a sieve having 4.75mm (No.4) mesh. Specification require washed, natural sand, unless otherwise provided by the Special Provisions. In some instances, fine aggregate of two or three different sizes or from more than one deposit are used (Chen and Liu, 2004).

2.4.2.2 Coarse Aggregate

Coarse aggregates are used for making concrete. They may be in the form of irregular broken stones or naturally-occurring rounded gravel. It is considered the material that is retained on a 4.75mm (No.4). In maximum size it can be up to 63mm.

1. Classes of Coarse aggregate.

Coarse aggregatevas used in concrete is classified into five groups per specification (Chen and Liu, 2004).

i. Class A is quarried granite, trap rock or quartzite.
ii. Class B is all other quarried rock such as limestone and dolostone.
iii. Class C is natural or partially crushed gravel obtained from natural deposits.
iv. Class D is an approved mixture of two or more of the other classes.

v. Class R is aggregate obtained from crushing and recycling concrete.

2. Aggregate Properties

Determining aggregate properties prior to their use on concrete. The actual test procedures for fine and coarse aggregate may vary slightly, but the purpose is the same.

A. Specific Gravity

Specific gravity is the ratio of the mass of a solid or liquid to the mass of and equal volume of distilled water at 4°C (39°F). For the fine aggregate, the specific gravity is computed by dividing the mass (weight) of the oven-dry sand in grams by the volume of water displaced by the saturated surface dry sand in millimeters. For the coarse aggregate, the specific gravity is computed by dividing the mass (weight) of oven-dry material by the difference in mass (weight) of saturated surface dry aggregate in air and the mass of the same immersed in water.

B. Absorption

All aggregate particles contain small pores that vary in size and number from particle to particle. Oven-dry aggregate particles exposed to water absorb water into the pores. The rate of and extent of absorption into the particles depends on the size of the pores and the amount of water available for absorption (Gupta, 2004). The absorption factor of a test sample of material is determined by dividing the difference in mass between the saturated surface dry material and the oven-dry material by the oven-dry mass.

C. Gradation and Fineness Modulus

The range in size and quantity of an aggregate is referred to as gradation. To produce a uniform quality concrete, limitation are placed on the proportions of aggregate of different sizes (Kulkarni, 1992). The production of aggregate ma require the removal of some material of one size or blending in material of another size so that the combined materials result in a gradation requirements. The gradation is determined by sieving representative samples of the material through a series of different size sieves (in descending order) and recording the amount passing each sieve.

Sieves of selected sizes are designated as standard sieves used in determining a numerical gauge that indicate to some extent the relative gradation of material. The gauge is referred to as "Fineness modulus". The selected sieves are called the Fineness Modulus (F.M.) sieve series and consist of the following coarse aggregate sizes: 75mm, 37.5mm, 19mm, 9.5mm, 4.75mm, 2.36mm, 1.18mm, 600μm, 300μm, and 150μm (3 in, 1-1/2 in, ¾ in, 3/8 in.., No. 4, 8, 16, 30, 50 and 100). (Young and Sidney, 2003).

D. Bulk/Dry Density

Calculating the dry density of a substance allows to know how much a given amount of the substance will weigh (Gupta, 2004). In general, density measures the compactness of a material in kilogram per cubic meter. Dry density is used for materials that are frequently soaked with water to compare with water to compare wet density. Dry density materials include cement, sand (soil) and mulch, among other substances. When the material becomes wet, its density increases because of water content.

E. Aggregate Impact Value

This test is done to determine he aggregate impact value of coarse aggregate as per IS: 2386 (Part IV)-1963. The apparatus used for determining aggregate impact value of coarse aggregate is Impact Testing machine conforming to IS: 2386 (Part IV)-1963. Apparatus needed for the experiment are IS sieves of sizes- 12.5mm, 10mm and 2.36mm, a cylindrical metal measure 75mm dia, and 50mm depth, a tamping rod of 10mm circular cross section and 230mm legth, and oven. (IS 2386, 1963).

F. Aggregate Crushing Value

The Aggregate Crushing Value (ACV) is a measure of aggregate resistance to pulverization. This test helps to determine the aggregate crushing value of coarse aggregate as per IS: 2386 (Part IV)-1963. The apparatus used are cylindrical measure and plunger, compression testing machine, IS sieves of different sizes – 12.5mm, 10mm and 2.36mm.

2.4.3 Water

For production of concrete, water is one of the most important ingredient, as hydration of cement is possible only in the presence of water. The hydration of cement of forms gel, which on hardening gives strength to the concrete (Gupta, 2004). The concrete of any type cannot be prepared without water. The properties of water have been found to influence the properties of concrete to a great extent. For concrete production, water is used for the following purposes.

- Water for preparing concrete, i.e. for mixing concrete ingredients.
- Water for curing concrete.
- Water for washing aggregate.

2.4.3.1 Quality of Water for Preparing Concrete

The common criteria or yard stick to the suitability of water for preparing concrete is that water fit for human consumption (drinking) is fit for concrete making also. But this yard stick is not true for all conditions. Water containing 0.05% sugar by weight of cement is quite fit for drinking, but retards cement initial setting time by 4 hours. (Gupta, 2004). Thus water to be used for concrete production should not contain substances which may have appreciable harmful effect on the initial setting time, strength, and durability of the concrete. Substances like oils, acids, carbonates and bi-carbonate, alkalis, sugar, silt and organic materials have been found to have harmful effect on the properties of fresh and hardened concrete. Hence, concrete mixing water should be free from these impurities. The PH value of concrete mixing water should be between 6.5 and 8.5 which is the WHO standard for drinkable water.

Sea water should not be used for mixing of concrete, because it contains about 3.5% salinity (Gupta, 2004). This salinity contains 78% sodium chloride and 15% chlorides and sulphates of magnesium. Sea water also contains small quantities of sodium and potassium salts. These salts react with reactive aggregate in the same way as alkalis act on cement. It has been reported that the use of sea water for mixing concrete does not reduce the strength of concrete appreciably, but it may lead to corrosion of reinforcement in certain conditions.

2.5 Sand (Fine Aggregate)

Sand is essentially quartz whereas clay is made of many other chemically active minerals like illite, kaolinite, etc. Sand between 4.75mm (about 5mm) and 0.15mm in size is called fine aggregate. It is used for making concrete, mortars and plasters. It is also used for filling under floor, basement. Natural sand occurs from local river beds or pits. An examination should be made on the fineness of the available sands and depending its fineness, it should be then planned to be used for different purposes in construction. Due to increased construction activity, natural sand is becoming more difficult to get and in cost (due to transportation). Hence, search of alternative materials like crushed stone and flyash for use in construction is now a popular subject for research.

Sand which is used in the construction purpose must be clean, free from waste stones and impurities. It is important to know what type of sand is beneficial for construction purpose as sand is also classified into three different forms that make it suitable for specific type of construction. Sand is classified as: Fine Sand (0.075 to 0.425 mm), Medium Sand (0.425 to 2 mm) and Coarse Sand (2.0 to4.75 mm). (Varghese, 2010).

However this classification of sand is further has types of sand in particular and on that basis only they are being incorporated in the construction. The following are different types of sand;

i. **Pit Sand (Coarse sand)**

Pit sand is classified under coarse sand which is also called badarpur in common language. This type of coarse sand is procured from deep pits of abundant supply and it is generally in red-orange color. The coarse grain is sharp, angular and certainly free from salts etc which is mostly employed in concreting.

ii. **River Sand**

River sand is procured from river streams and banks and is fine in quality unlike pit sand. This type of sand has rounded grains generally in white-grey colour. River sand has many uses in the construction purpose such as plastering.

iii. **Sea Sand**

As the name suggest, sea sand is taken from seas shores and it is generally in distinct brown colour with fine circular grains. Sea sand is avoided for the purpose construction of concrete structure and in engineering techniques because it contains salt which tends to absorb moisture from atmosphere and brings dampness. Eventually cement also loses its action when mixed with sea sand that is why it is only used for the local purpose instead of structural construction. There are different standards for the construction purpose which must be checked and considered for the better construction. The requirement according to which sand is chosen should be like:

The extraction of sand from river side is called sad mining. Sand mining on either side of the rivers, upstream and in-stream is one of the causes for environmental degradation and also a threat to the biodiversity. Extraction of alluvial material from within or near a streambed has a direct impact on the stream's physical habitat characteristics, these characteristics includes bed elevation, substrate composition and stability, in-stream roughness elements, depth, velocity, turbidity, sediment transportstream discharge and temperature. This also tends to affect the organism living in the riverbeds, affects fish breeding and migration increases salinity in water etc. (Varghese, 2010).

2.6 QUARRY DUST

Quarry dust is a by-product from the crushing process during quarrying activities. It's also known as Quarry waste. Generally considered as a waste material after the extraction and processing of rocks to form fine particles less than 4.75mm, causes an environmental load due to disposal problem. Hence, the use of quarry dust in concrete mixture will reduce not only the demand for natural sand but also the environmental burden of disposal. (Subramanian and Kannan, 2013).

Quarry dust have been used for different activities in the construction industry such as for road construction and manufacture of building materials such as lightweight aggregates, bricks, tiles and autoclave blocks (Sudhir and Satone 2013). Production of quarry fines is a consequence of extraction and processing in a quarry and collected from the near-by quarry. The amount produced depends on the rock type, amount of fragmentation by blasting and type of crushing used. The product is washed to remove excess fines to get sand of excellent shape, gradation free from silt, clay and unwanted contamination.

2.6.1 Physical Properties of Quarry Dust and Natural Sand

The physical and chemical properties of quarry dust obtained by testing the sample.

Table 2.2: Physical properties of quarry dust and natural sand.

Property	Quarry dust	Natural sand
Specific gravity	2.54 - 2.60	2.60
Bulk density (kg/m^3)	1720-1810	1460
Void ratio	0.55	0.42
Density	1.85	1.63

Source: (Chandana et al, 2013)

2.4.2 Effect of Quarry Dust on Concrete

Quarry dust (QD) is crushed dust obtained from stone boulders in stone crushers during the production of coarse aggregates. The quarry dust consists of excess fines and is dumped in open fields that cause environmental pollution. Quarry dust has been used successfully in concrete, pavement construction, and in controlled low-strength materials (CLSM) (Naga-nathan *et al.*, 2012). From the study of Naganathan *et al.* (2012), the addition of quarry dust does not affect the setting time but it reduces the water demand for constant flow consistency and increase the fresh density and hardened density of concrete. It is concluded that there is potential for the use of industrial waste incineration bottom ash and quarry dust in CLSM. Controlled low strength materials (CLSM) are defined as self-compacting, low strength, cementitious materials used primarily as backfill in lieu of compacted fill (ACI, 1999).Controlled low strength material is characterised by high workability, low density and low strength, which allows for self-compaction. Addition of quarry dust enhances the performance of the mixtures.

Shahul *et al.* (n.d), observed that natural sand is usually not graded properly and has excessive silt, while quarry rock dust does not contain silt or organic impurities and can be produced to meet desired gradation and fineness as per requirement. This consequently contributes to improve the strength of concrete.

Ilangovana *et al.* (n.d), studied the strength and durability properties of concrete containing quarry dust as fine aggregate and found that the compressive, flexural strength and durability studies of concrete made with quarry rock dust were nearly 10% more than the conventional concrete. Their workability results showed slump values ranging between 60 - 90mm and compacting factor 0.87 - 0.90 for grade 20 concrete. The range of 28 - day's compressive and flexural strengths for grade 20 concrete were found to be 23.7 - 34.50 N/mm2 and 3.45 - 6.40 N/mm2 respectively.

CHAPTER THREE

3.0 METHODOLOGY

The study presented in this paper reports an investigation on the behavior of concrete produced from the replacement of sand with quarry dust. The physical and chemical properties of sand and quarry dust were first investigated. The effects of quarry dust on concrete properties will be studied by various test such as; workability, water absorption and compressive strength test.

3.1 Materials and Sampling

The materials used includes cement, sand, gravel, water and quarry dust. The quarry dust used in this project work was be obtained from Kopek quarry site in Ikere-Ekiti, Ekiti state, Nigeria.

A brief on materials used for the study are as follows;

A. Cement

In the present study an ordinary Portland cement (OPC 42.5 grade) was used.

B. Fine aggregate (sand)

The natural fine aggregates are the river sand which is the most commonly used natural material for the fine aggregates was used.

C. Coarse Aggregate

Ordinary granite broken stone aggregates of size greater than 12mm were used for the study.

D. Quarry Dust

Quarry dust (QD) is crushed dust obtained from stone boulders in stone crushers during the production of coarse aggregates.

E. Water

Potable water with pH value 7 is used for mixing and curing throughout the experiment.

3.2 Mix Proportioning of Concrete with Quarry Dust

A grade M20 having a proportion of 1:2:4 was used. For this concrete mix, quarry dust was added for replacement of sand at 0%, 25%, 50%, 75% and 100%.

In this study, six batches of concrete were produced with varying amount of quarry dust substituted for sand in the mix. In 0% replacement, no dust is introduced, then in the 25%, only 25% of quarry dust will replace sand in the mix design ratio by weight, then followed by 50%, 75%, and 100% where it is fully replaced.

3.3 Test on Materials (Aggregates)

Particle Size analysis

The Particle size analysis was done by following the procedure given in IS 2386 (Part I)-1963, the gradation of the aggregate material is important for determining the size and shape of the material. The IS sieves were arranged in the order of (i.e. 4.75mm, 2.36mm,850μm, 425μm, 212μm, 150μm, 75μm) . About 500g of fine aggregate was placed them on the top most sieve and start sieving them for fifteen minutes. The weight retained on each IS sieve was noted and the values of fineness modulus is calculated. A graph is plotted between the particle size and the percentage fineness on a semi log graph sheet. The graph that is plotted is called gradation curve / particle size distribution curve (PSD) this is useful to know whether the sample of the aggregates is well graded or poorly graded.

3.4 Test on Fresh Concrete

Workability (Slump Test)

The workability is one of the physical parameters of concrete which affects the strength and durability and the appearance of the finished surface. The workability of concrete depends on the water cement ratio and the water absorption capacity if the aggregates. In this study, slump cone test was used for measuring the workability of concrete. This involves;

i. The use of a steel slump cone which was placed on a solid, impermeable, level base and filled with the fresh concrete in three equal layers.
ii. Each layer was rodded 25 times to ensure compaction.
iii. The third layer was finished off level with the top of the cone.
iv. The cone will be carefully lifted up, leaving a heap of concrete that settles or 'slumps' slightly.

v. The upturned slump cone was placed on the base to act as a reference, and the difference in level between its top and the top of the concrete was measured and recorded to the nearest 5 mm to give the slump of the concrete.

When the cone is removed, the slump may take one of three forms. In a true slump the concrete simply subsides, keeping more or less to shape. In a shear slump the top portion of the concrete shears off and slips sideways. In a collapse slump the concrete collapses completely. Only a true slump is of any use in the test. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix. Then the same procedure is done with the concrete having the partial replacement of sand with raw quarry dust at various percentages.

3.5 Test on Hardened Concrete

Compressive Strength Test

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. For most of the works cubical moulds of size 10cm x 10cm x 10cm was used.

The test procedure for compressive strength test;

i. Representative samples of concrete was taken and used for casting cubes 10 cm x 10 cm x 10 cm.
ii. The concrete was filled into the moulds in layers approximately 5 cm deep.
iii. It was distributed evenly and compacted by hand tamping. After the top layer has been compacted, the surface of concrete was finished level with the top of the mould using a trowel; and covered with a polythene bag to prevent evaporation.
iv. The specimen was stored at site for 24+ ½ h under damp matting or sack. After that, the samples was stored in clean water at $27{+}2^0$C; until the time of test (curing).
v. Specimen was tested immediately on removal from water and while they are still in wet condition. The bearing surface of the testing specimen was wiped clean and any loose material removed from the surface.
vi. The specimen (cube) was placed in the compressive testing machine. The load was applied slowly without shock and increased continuously at a rate of approximately 140 kg/sq.cm/min until the resistance of the specimen (cube) to the increased load fails and no

greater load can be sustained. The maximum load applied to the specimen was recorded and any unusual features noted at the time of failure brought out in the report.

vii.

3.6 Procedure of Project

The following is the procedure of project using site pictures to illustrate the step followed:

i. Sample were obtained from quarry site. The sample was sieved and a portion was washed to remove dust particle. The figure below shows the author obtaining samples from Kopek quarry site.

Figure 3.1; Author obtaining samples from Kopek quarry site.

ii. Sieve analysis was carried out on the fine aggregate (sand and quarry dust) used in this study to know their properties. The figure below shows the author carrying out the sieve analysis at the University of Ibadan Laboratory.

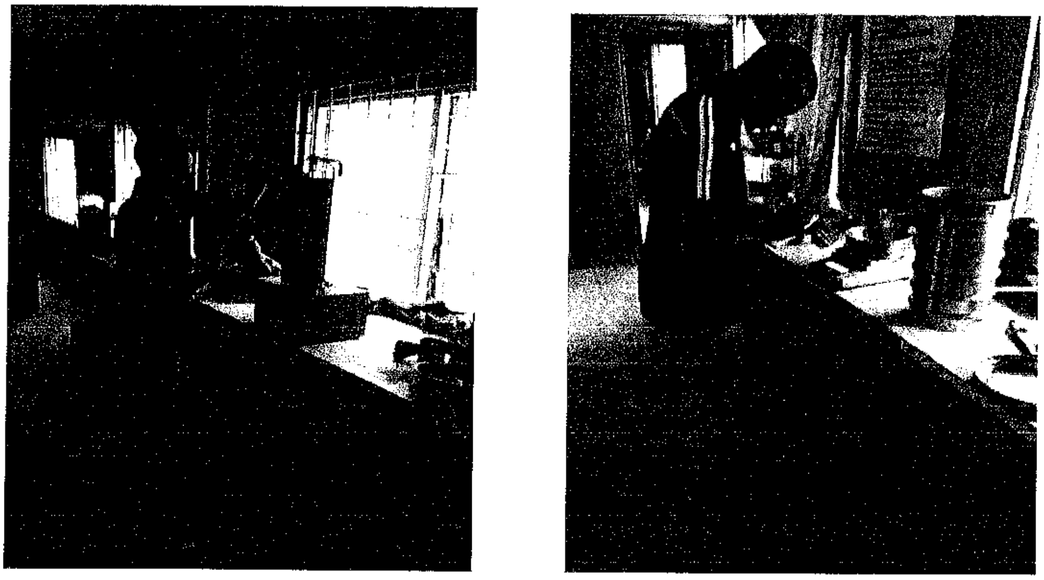


Figure 3.2; Author carrying out the sieve analysis

iii. Prepare mix with the required mix ratio (1:2:4) using sand and quarry dust as the aggregate and also using a water cement ratio of 0.5. The figure below shows the author mixing the concrete using mix ratio 1:2:4.

Figure 3.3; Author mixing concrete

iv. Replace sand with quarry dust at varying percentages (0%, 25%, 50%, 75% and 100%). The figure below shows the author replacing sand with quarry dust at varying percentages.

Figure 3.4; Author replacing sand with quarry dust.

v. Carry out the slump test to determine the workability of the concrete for both trial mix and replaced mix, using a water cement ratio of 0.5. The figure below shows the author carrying out the slump test to determine the workability of the concrete for both trial and replaced mix.

Figure 3.5; Author carrying out the slump test.

vi. Cast twelve moulds for each mix ratio. Three batches for the 7, 14, 28 and 60 days curing. The figure below shows the author casting the concrete in the moulds.

Figure 3.6; Author casting the concrete

vii. Cure for 7, 14, 28 and 60 days. After curing carry out the compressive strength test on all the cubes casted. The figure below shows the author crushing the cubes after curing for days.

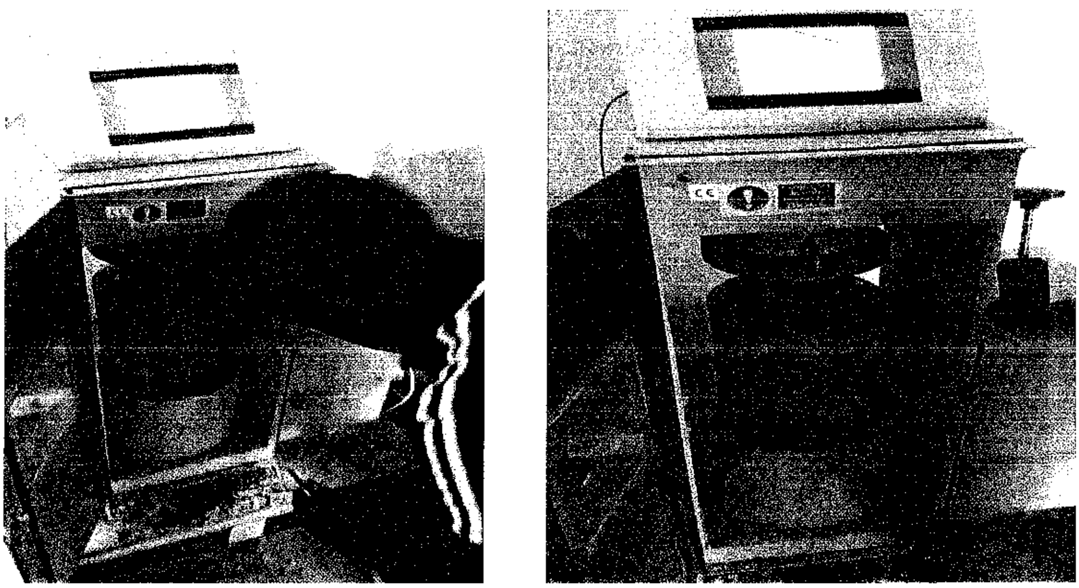


Figure 3.7; Author carrying out a compressive test using the compressive testing machine.

viii. Record my values.

ix. Repeat the same procedure for the unwashed portion of the quarry dust.

3.7 Calculation of the Materials Used

Replacing for 0%, 25%, 50%, 75% and 100%, for every percentage replacement curing was done for 7, 14, 28, and 60 days.

For each curing day, 3 cubes was cast, making it 12 cubes for each percentage replacement.

Washed Sample = 12 cubes x 5 = **60 cubes** Eqn. 4.1

Unwashed Sample = 12cubes x 5 = **60 cubes** Eqn. 4.2

Total cubes to be casted = 60 + 60 = **120 cubes** Eqn. 4.3

3.7.1 Washed Sample

To get the weight of material (concrete) required;

- The volume of the mould is $0.001m^3$ (i.e. $0.1 \times 0.1 \times 0.1$ mould)
- The % Replacement of quarry dust with sharp sand was at $0, 25, 50, 75, 100\%$ replacement. These various replacement were crushed at $7, 14, 28, 60$ $days\ with\ three\ (3\ nos) cubes$ being crushed each testing day. This gives a total of 12 cubes for the different testing days.
- A total of 60 cubes was used for five different percentage replacements **(i.e. 12x5= 60cubes).**
- Volume of concrete mould used $(\mathbf{0.001}\boldsymbol{m})$ x No of cubes cast **(60)** = **total volume of concrete** (0.06m3)
- Mass of concrete required was estimated thus;

*Density of Concrete (2400kg/m³) x Volume of Concrete (0.06m³) = Mass of Concrete **(144kg)***

- Total Mix Proportion of concrete (cement: sand: granite) = $1 + 2 + 4 = 7$ (i.e 1:2:4 mix ratio)

Cement = $\frac{1}{7} \times 144 = 21kg$ Eqn. 4.4

Sand = $2 \times 21 = 42kg$ Eqn. 4.5

Granite = $4 \times 21 = 84kg$ Eqn. 4.6

Water Cement Ratio = 0.5 Eqn. 4.7

W/C = $\frac{weight\ of\ water}{weight\ of\ cement}$

Weight of water = W/C × Wt. of cement

$= 0.5 \times 21 = 10.5kg$ Eqn. 4.8

For Every Percentage Replacement for Cement, Sand and Granite Mixture

CEMENT = $\frac{21}{5}$ = $4.2kg$ (% weight Replacement of cement=$\frac{cement\ weight\ (Eqn.4.4)}{no\ of\ replacement\ (5nos)}$) Eqn. 4.9

GRANITE = $\frac{84}{5}$ = 16.8 (% weight Replacement of granite=$\frac{weight\ of\ granite\ (Eqn.4.5)}{no\ of\ replacement\ (5nos)}$) Eqn. 4.10

WATER = $\frac{10.5}{5}$ = 2.1 (% weight of water=$\frac{weight\ of\ water\ (Eqn.4.8)}{no\ of\ replacement\ (5nos)}$) Eqn. 4.11

SAND = $\frac{42}{5}$ = 8.4 Q.D = 0 Eqn. 4.12

= 6.3 (75% of 8.4kg *(Eqn.4.12)*) Q.D= (25%) =$\frac{25}{100} \times 8.4 = 2.1kg$

(25% of 8.4kg *(Eqn.4.12)*)

= 4.2(50% of 8.4kg *(Eqn.4.12)*) Q.D = (50%) = $\frac{50}{100} \times 8.4 = 4.2kg$

(50% of 8.4kg *(Eqn.4.12)*)

= 2.1(25% of 8.4kg *(Eqn.4.12)*) Q.D = (75%) = $\frac{75}{100} \times 8.4 = 6.3kg$

(75% of 8.4kg *(Eqn.4.12)*)

= 0 Q.D = (100%) = $\frac{100}{100} \times 8.4 = 8.4kg$

Table 3.1; Showing the Proportions of Each Constituent of Concrete

REPLACEMENT %	CEMENT (kg)	SAND (kg)	QUARRY DUST (kg)	GRANITE (kg)	WATER (kg)
0	4.2	8.4	–	16.8	2.1
25	4.2	6.3	2.1	16.8	2.1
50	4.2	4.2	4.2	16.8	2.1
75	4.2	2.1	6.3	16.8	2.1
100	4.2	–	8.4	16.8	2.1

3.7.2 UNWASHED SAMPLE

Same procedure as above for the unwashed sample.

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 Compressive Strength

4.1.1 Washed Sample

The strength result reported from table 4.1 are presented in the form of graphical variation, where the compressive strength is plotted against the age/curing period (Figure 4.1). From the figure, it is clear that as the age advances, the strength of control mix increases. The strength attained at 28 days is 22.96 N/mm^2. There is only about 1N/mm^2 after 28days.

Table 4.1: Load and compressive strength of control mix (0% replacement of sand) at 7, 14, 28 and 60 days

Age (days)	7	14	28	60
Load (kN)	176.8	199.4	229.6	243.6
Compressive Strength (N/mm^2)	17.68	17.94	22.96	24.36

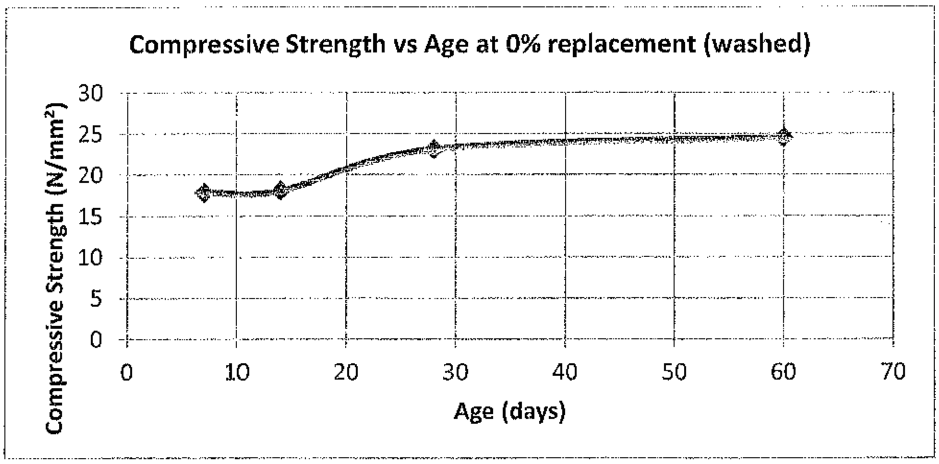


Figure 4.1: Graph Showing Washed Sample At 0% Replacement against their curing age.

Results from table 4.2 – 4.5 also shows that the highest compressive strength of concrete at 28 days is 23.4 N/mm^2 which is derived from sand replaced at 25%. Further replacement up to 100% causes a reduction in the compressive strength of concrete at 28 days. The variation in compressive strength at respective curing days can be clearly seen in figure 4.6. It can also be noted from the table 4.6 that the rate of increase in the compressive strength from day 28 to day 60 was greater at 50%, 75% and 100% respectively. Therefore the highest compressive strength at 60 days was attained at 75% replacement with compressive strength of 25.71 N/mm^2 and then reduces at 100% replacement. At 28 days we have 28% replacement with the highest compressive strength compared to that of the other replacements.

Table 4.2: Load and compressive strength of 25% replacement of sand with quarry dust at 7, 14, 28 and 60 days

Age (days)	7	14	28	60
Load (kN)	166.7	180.0	231.4	251.3
Compressive Strength (N/mm^2)	16.67	18.0	23.14	25.13

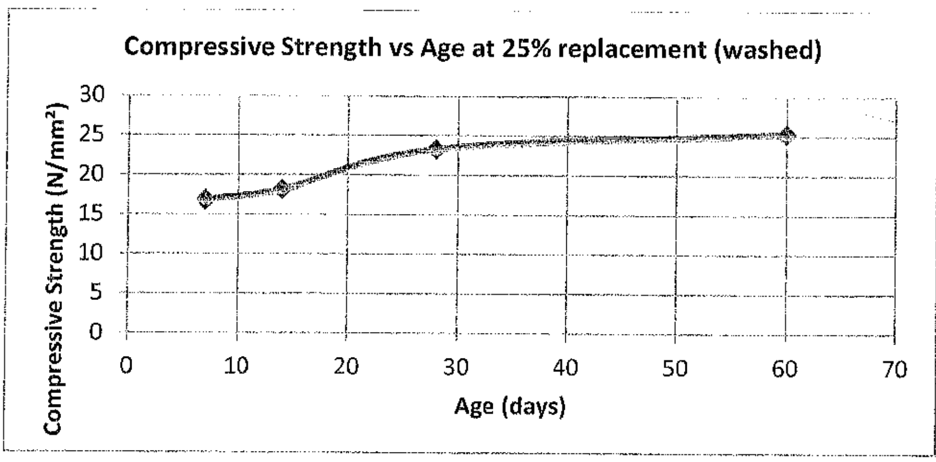


Figure 4.2: Graph Showing Washed Sample At 25% Replacement against their curing age.

From fig 4.2, there is a good consistency in the strength gain. The highest compressive strength at 28 days was obtained here. The gain in strength after 28 days is similar to that of fig. 4.1.

Table 4.3: Load and compressive strength of 50% replacement of sand with quarry dust at 7, 14, 28 and 60 days

Age (days)	7	14	28	60
Load (kN)	161.0	182.0	158.4	254.8
Compressive Strength (N/mm²)	16.10	18.20	15.84	25.48

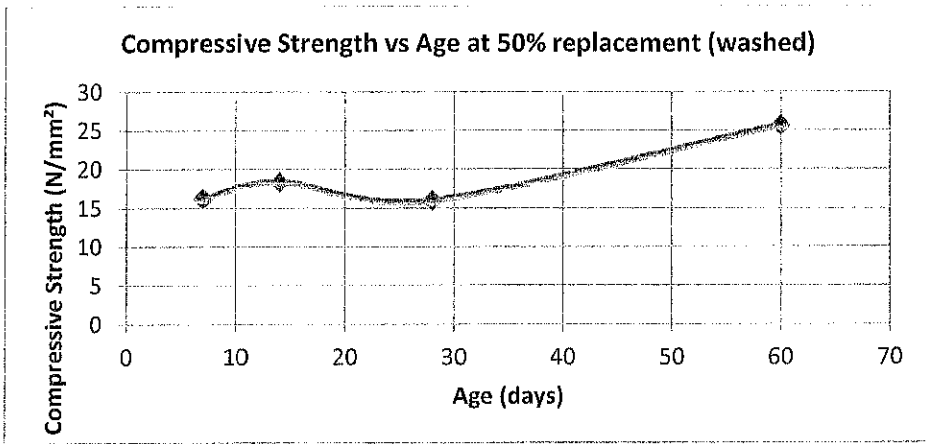


Figure 4.3: Graph Showing Washed Sample At 50% Replacement against their curing age.

Fig 4.3, indicates inconsistency in the rise in strength since 28 days is lower than the 14 days strength. There is a significant rise in strength after 28 days.

Table 4.4: Load and compressive strength of 75% replacement of sand with quarry dust at 7, 14, 28 and 60 days

Age (days)	7	14	28	60
Load (kN)	136.0	140.0	168.7	257.1
Compressive Strength (N/mm²)	13.60	14.0	16.87	25.71

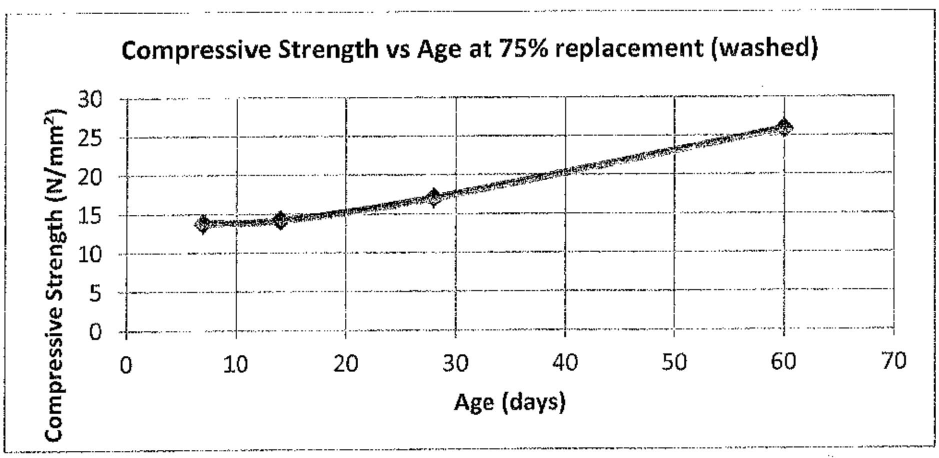


Figure 4.4: Graph Showing Washed Sample At 75% Replacement against their curing age.

Table 4.5: Load and compressive strength of 100% replacement of sand with quarry dust at 7, 14, 28 and 60 days

Age (days)	7	14	28	60
Load (kN)	158.5	185.3	171.8	246.9
Compressive Strength (N/mm^2)	15.85	18.53	17.18	24.69

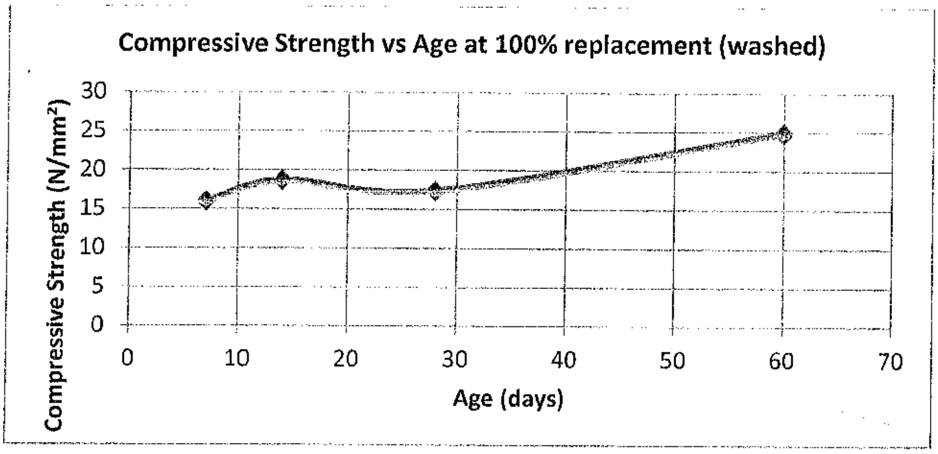


Figure 4.5: Graph Showing Washed Sample At 100% Replacement against their curing age.

Table 4.6; Percentage Replacement Vs Age (Washed)

	Percentage Replacement				
Age (days)	**0**	**25**	**50**	**75**	**100**
7	17.68	16.67	16.1	13.6	15.85
14	17.94	18.0	18.2	14.0	18.53
28	22.96	23.14	15.84	16.87	17.18
60	24.36	25.13	25.48	25.71	24.69

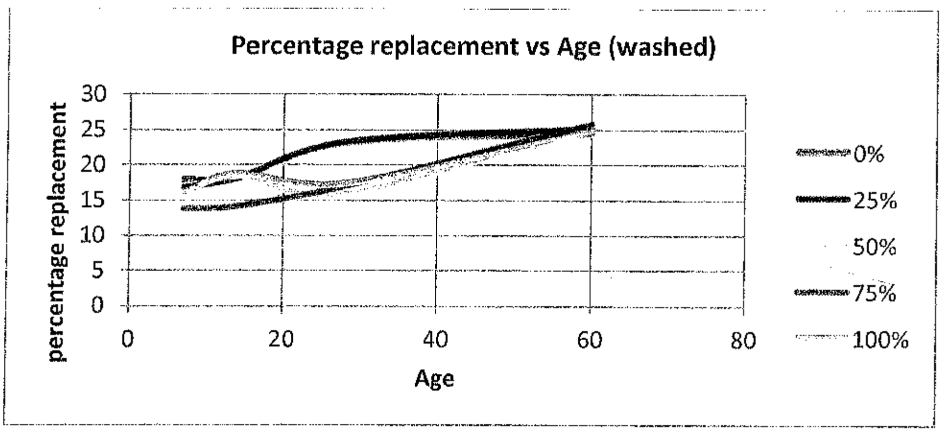


Figure 4.6: Graph Showing Washed Sample At different % Replacement against their curing age.

4.1.2 Unwashed Sample

The strength result reported from table 4.7 are presented in the form of graphical variation, where the compressive strength is plotted against the age/curing period (Figure 4.7). From the figure, it is clear that as the age advances, the strength of control mix increases. The strength attained at 28 days is 16.21 N/mm^2.

Table 4.7: Load and compressive strength of control mix (0% replacement of unwashed sand) at 7, 14, 28 and 60 days

Age (days)	7	14	28	60
Load (kN)	125.0	140.4	162.1	173.3
Compressive Strength (N/mm^2)	12.50	14.04	16.21	17.33

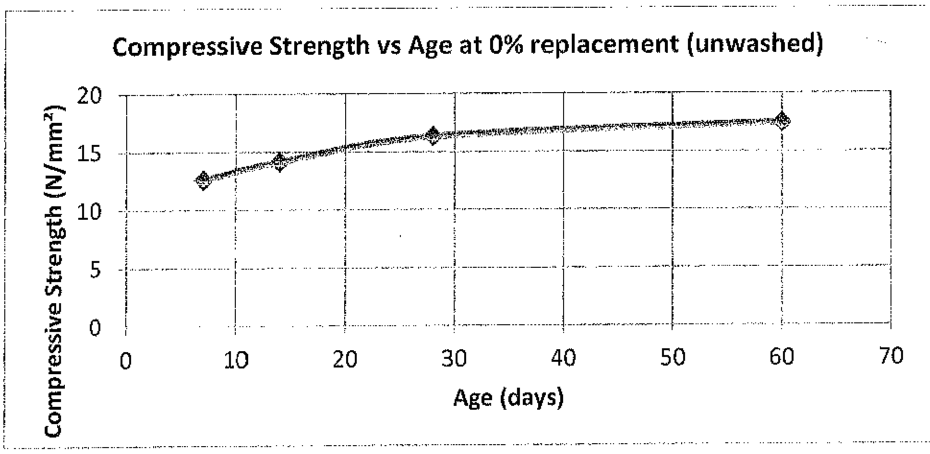


Figure 4.7: Graph Showing Unwashed Sample At 0% Replacement against their curing age.

Results from table 4.8 – 4.11 also shows that the highest compressive strength of concrete at 28 days is 22.03 N/mm^2 which is derived from sand replaced at 100%. The variation in compressive strength at respective curing days can be clearly seen in figure 4.12. It can also be noted from the table 4.6 that there is a gradual increase in the compressive strength of concrete at 60 days from 0%-75% respectively, but then reduces at 100% replacement. Therefore the highest compressive strength at 60 days was attained at 75% replacement with compressive strength of 25.03 N/mm^2 and then reduces at 100% replacement.

Table 4.8: Load and compressive strength of 25% replacement of unwashed sand with unwashed quarry dust at 7, 14, 28 and 60 days

Age (days)	7	14	28	60
Load (kN)	160.7	160.2	215.2	181.5
Compressive Strength (N/mm²)	16.07	16.02	18.15	21.52

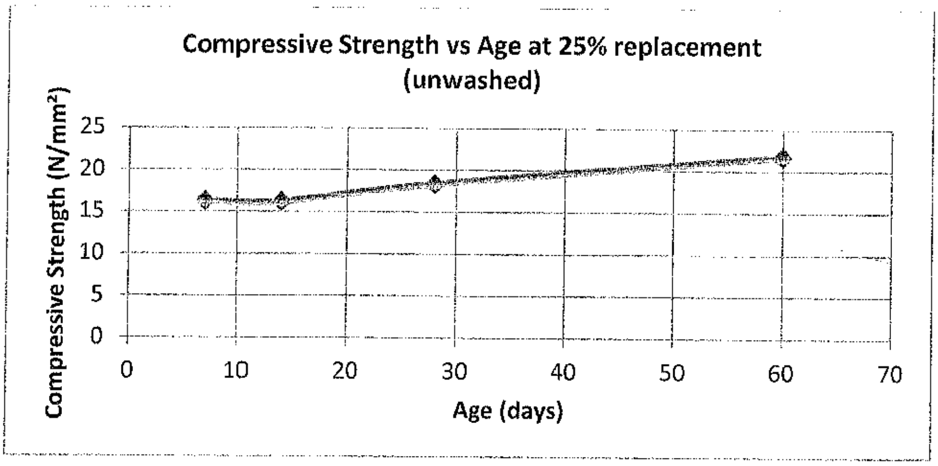


Figure 4.8: Graph Showing Washed Sample At 25% Replacement against their curing age.

Table 4.9; Load and compressive strength of 50% replacement of unwashed sand with unwashed quarry dust at 7, 14, 28 and 60 days

Age (days)	7	14	28	60
Load (kN)	141.7	128.5	189.0	220.5
Compressive Strength (N/mm²)	14.17	12.85	18.9	22.05

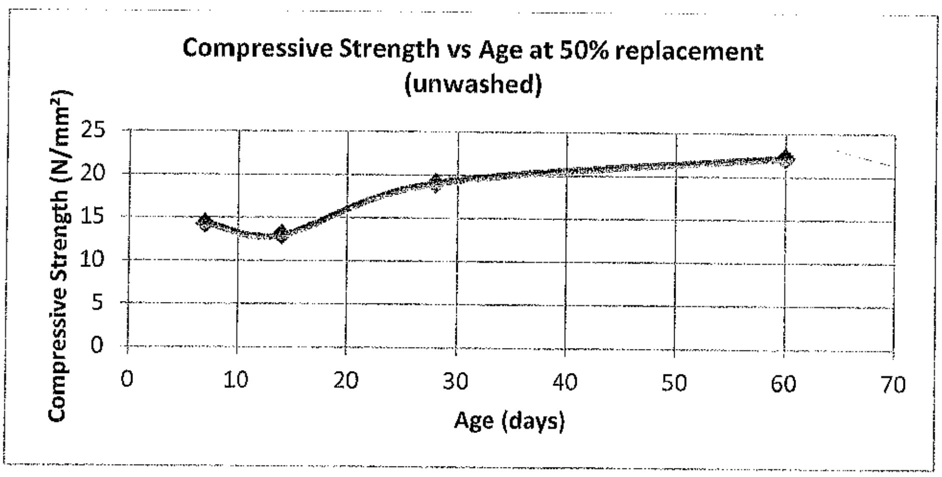


Figure 4.9; Graph Showing Washed Sample At 50% Replacement against their curing age.

Table 4.10: Load and compressive strength of 75% replacement of unwashed sand with unwashed quarry dust at 7, 14, 28 and 60 days

Age (days)	7	14	28	60
Load (kN)	158.8	219.3	194.7	250.2
Compressive Strength (N/mm²)	15.88	21.93	19.47	25.02

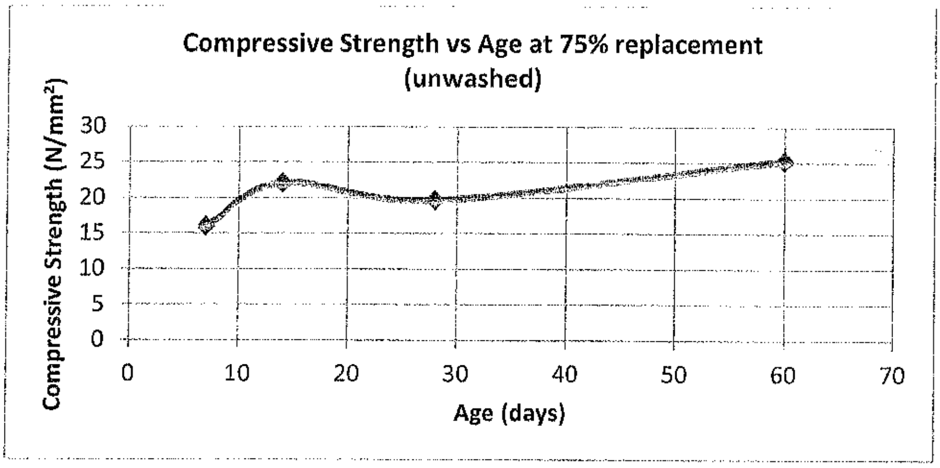


Figure 4.10: Graph Showing Washed Sample At 75% Replacement against their curing age.

Table 4.11; Load and compressive strength of 100% replacement of unwashed sand with unwashed quarry dust at 7, 14, 28 and 60 days

Age (days)	7	14	28	60
Load (kN)	184.8	237.9	220.3	241.4
Compressive Strength (N/mm²)	18.48	23.79	22.03	24.14

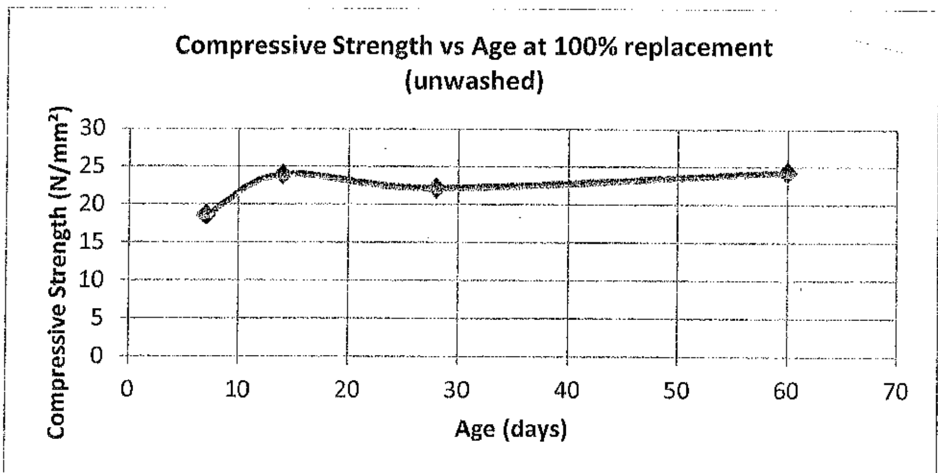


Figure 4.11; Graph Showing Washed Sample At 100% Replacement against their curing age.

Table 4.12; Percentage Replacement Vs Age (Washed)

	Percentage Replacement				
Age (days)	**0**	**25**	**50**	**75**	**100**
7	12.5	16.07	14.17	15.88	18.48
14	14.04	16.02	12.85	21.93	23.79
28	16.21	18.15	18.9	19.47	22.03
60	17.33	21.52	22.05	25.02	24.14

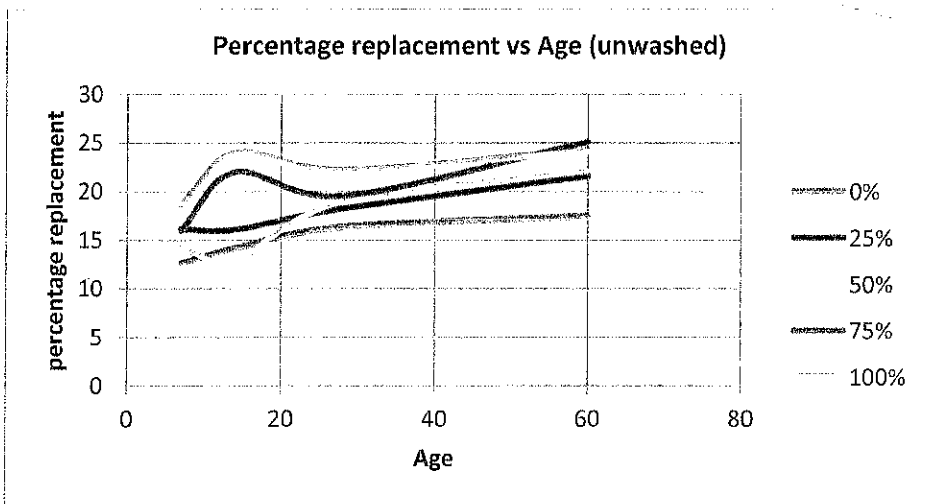


Figure 4.12; Graph Showing Washed Sample At different % Replacement against their curing age.

4.2 Sieve Analysis

4.2.1 Fine Aggregate (Washed Sample)

Table 4.13: Sieve analysis of washed sample

S/N	SIEVE SIZE	MAT. RETAINED	%RETAINED	%PASSING
1	4.75mm	12.3	2.5	97.5
2	2.36mm	25.3	5.1	92.4
3	850μm	129.0	25.8	66.6
4	425μm	171.7	34.4	32.2
5	212μm	115.9	23.2	9
6	150μm	24.0	4.8	4.2
7	75μm	16.4	3.3	0.9
8	Pan	4.6	0.9	-
	Total	**499.2**		

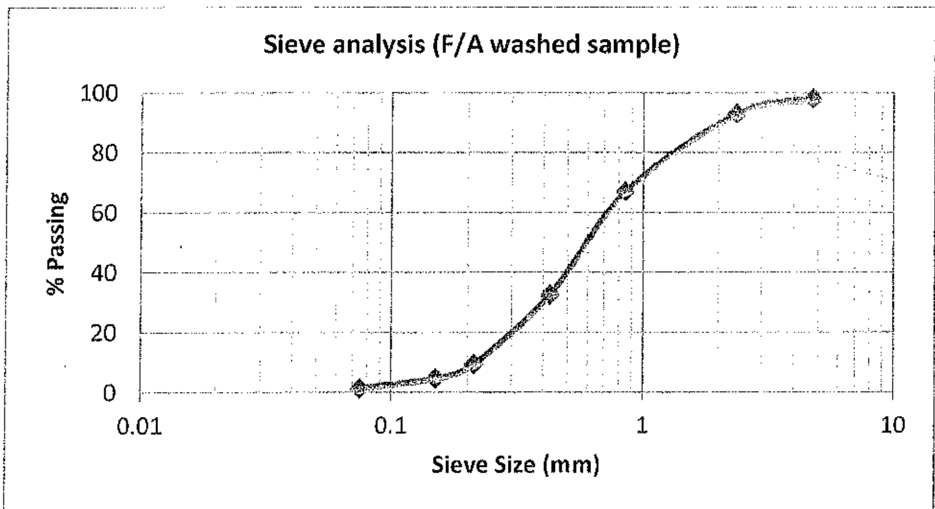


Figure 4.13: Graph of sieve analysis

Cu = Coefficient of Uniformity = $\frac{D_{60}}{D_{10}} = \frac{0.74}{0.22} = 3.36$

Cc = Coefficient of Gradation= $(D30)^2/(D60xD10)=(0.41)^2/(0.74x0.22)=1.03$

Since the percentage passing through the 425μm sieve is less than 35% the soil used is considered cohesionless, also since the coefficient of uniformity is less than 4% the silt content is not very high and the particle distribution in this soil is somewhat similar judging from the value of the coefficient of gradation and we can classify the soil a well graded soil.

4.2.2 Fine Aggregate (Unwashed Sample)

Table 4.14: Sieve analysis of unwashed sample

S/N	SIEVE SIZE	MAT. RETAINED	%RETAINED	%PASSING
1	4.75mm	29.1	6.1	93.9
2	2.36mm	52.7	11.0	82.9
3	850μm	160	33.4	49.5
4	425μm	113.7	23.8	25.7
5	212μm	73.2	15.3	10.4
6	150μm	22	4.6	5.8
7	75μm	22.7	4.7	1.1
8	Pan	5.2	1.1	-
	Total	**478.6**		

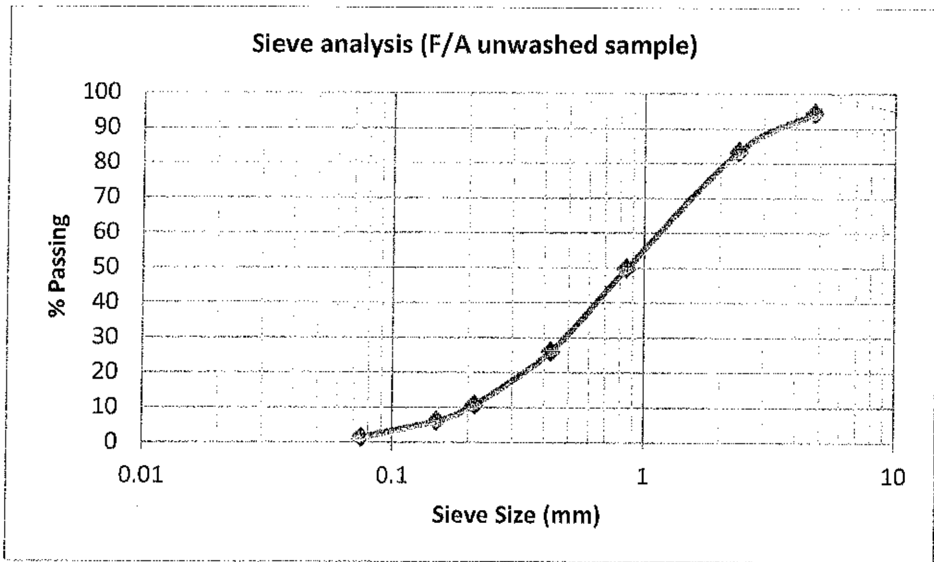


Figure 4.14: Graph of sieve analysis

Cu = Coefficient of Uniformity = D60/D10=1.3/0.21=6.19
Cc = Coefficient of Gradation= $(D30)^2/(D60xD10)=(0.5)^2/(1.3x0.21)=0.92$

Since the percentage passing through the 425μm sieve is less than 35% the soil used is considered cohesionless, also since the coefficient of uniformity is greater than 4% the silt content is very high which is normal since the sand sample used here was not washed and the particle distribution in this soil is similar judging from the value of the coefficient of gradation.

4.2.3 Fine Aggregate (Quarry Dust)

Table 4.15: Sieve analysis of quarry dust sample

S/N	SIEVE SIZE	MAT. RETAINED	%RETAINED	%PASSING
1	4.75mm	7.1	1.4	98.6
2	2.36mm	118.5	23.7	74.9
3	850μm	115.4	23.1	51.8
4	425μm	65.2	13.1	38.7
5	212μm	75.3	15.1	23.6
6	150μm	38	7.6	16.0
7	75μm	45.7	9.2	6.8
8	Pan	34.2	6.8	-
	Total	**499.4**		

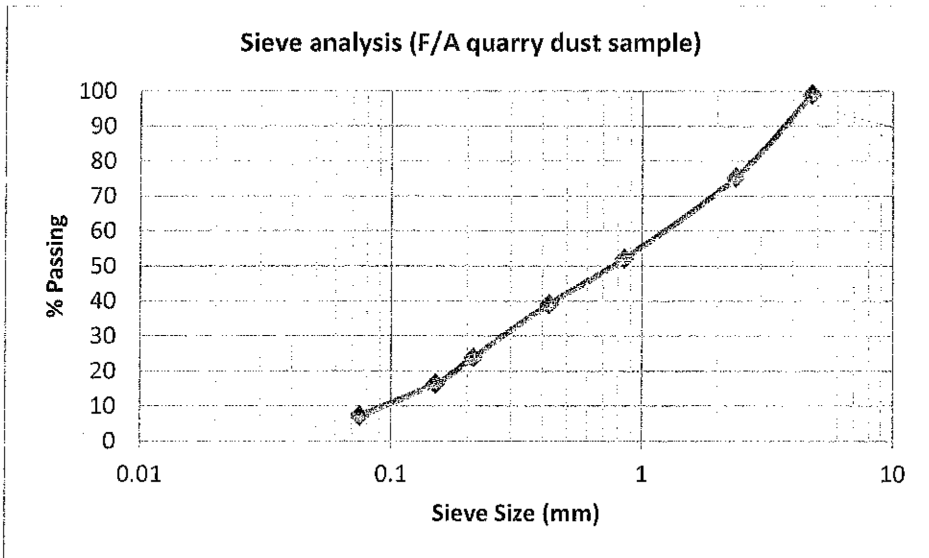


Figure 4.15: Graph of sieve analysis

Cu = Coefficient of Uniformity = D60/D10= 1.4/0.1=14
Cc = Coefficient of Gradation= $(D30)^2/(D60xD10)=(0.3)^2/(1.4x0.1)=0.64$

Since the percentage passing through the 425μm sieve is less than 35% the soil used is considered cohesionless, also since the coefficient of uniformity is greater than 4% the silt content is very high which is normal since the sand sample used here was not washed and the particle distribution in this soil is similar judging from the value of the coefficient of gradation.

4.3 SLUMP RESULT

Washed Sample

Table 4.16: Effect of Quarry Dust on the workability of the concrete (washed sample)

Percentage Replacement (%)	Quarry Dust (0%)	Quarry Dust (25%)	Quarry Dust (50%)	Quarry Dust (75%)	Quarry Dust (100%)
Slump Value(mm)	110	87	78	55	48

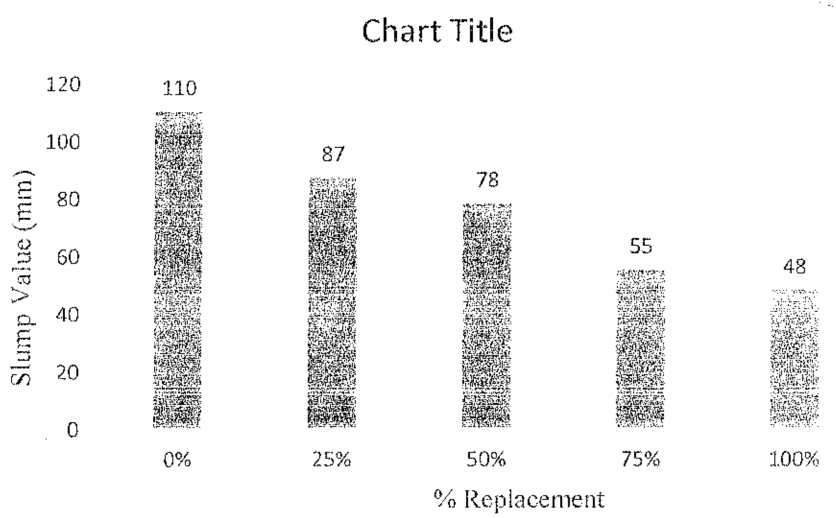


Figure 4.16: Graph showing the effect of Quarry Dust on the workability of the concrete (washed sample)

From table 4.16 above, it can be observed that as the percentage replacement increases from 0% - 100% there is a decrease in slump value which decreases the workability of the concrete. This can also be observed in the bar chart provided (fig. 4.16).

Unwashed Sample

Table 4.17: Effect of Quarry Dust on the workability of the concrete (unwashed sample)

Percentage Replacement (%)	Quarry Dust (0%)	Quarry Dust (25%)	Quarry Dust (50%)	Quarry Dust (75%)	Quarry Dust (100%)
Slump Value(mm)	53	80	72	35	83

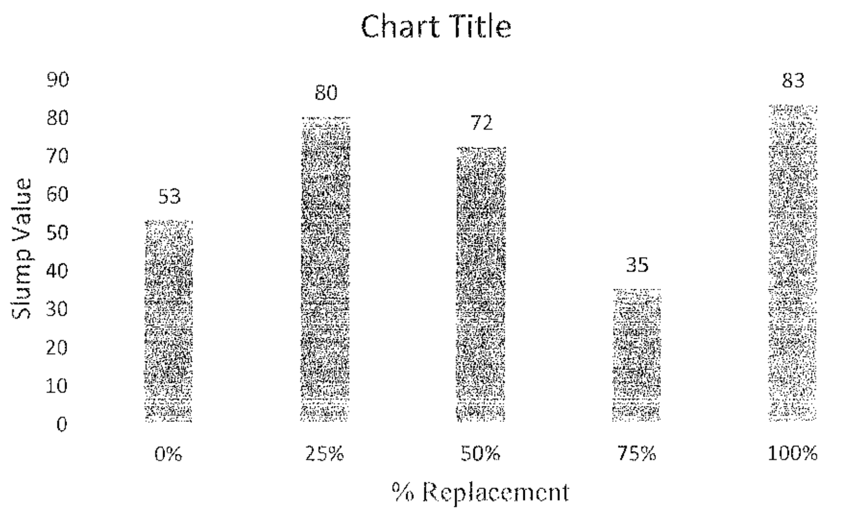


Figure 4.17: Graph showing the effect of Quarry Dust on the workability of the concrete (unwashed sample)

Fig 4.17, indicates inconsistency in the workability of the concrete. With the 25% and 100% replacement having the highest workability of 80 and 83 mm respectively.

Washed Sample

Table 4.17: Percentage Vs Age (washed sample)

% REP.	7 days	14 days	28days	60days
0	17.68	19.94	22.96	24.36
25	16.67	18.00	23.14	25.13
50	16.10	18.20	15.84	25.48
75	13.60	14.00	16.87	25.71
100	15.85	18.53	17.18	24.69

Unwashed Sample

Table 4.18: Percentage Vs Age (unwashed sample)

% REP.	7 days	14 days	28days	60days
0	12.50	14.04	16.21	17.33
25	16.07	16.02	18.15	21.52
50	14.17	12.85	18.9	22.05
75	15.88	21.93	19.47	25.02
100	18.48	23.79	22.03	24.14

From the result derived after curing and crushing for the 7, 14, 28 and 60days. There is a variation in the result obtained for crushing at different days interval, which implies that there is an increase in the strength of the concrete for days being spent in the water for curing.

For 7 days curing of the washed sample, there is an increase in strength within 0%-50% replacement of quarry dust to sand compared to the unwashed sample which is not the same for 75% and 100%.

At 14 days curing of the washed sample and unwashed sample, there is a slight increase in the strength, compared to the 7 days curing. But there was an obvious decrease in strength as the strength at 7 days is greater than the strength at 14 days for the 50% replacement of the unwashed sample.

At 28 days curing of the washed and unwashed sample, there is an increase in the strength compared to that of the 14 days curing. But there was an obvious decrease in strength as the strength at 14 days is greater than the strength at 28 days for the 50% and 100% replacement of the washed sample.

At 60 days curing of the washed and unwashed sample, there is a significant increase in the strength compared to that of the 28 days curing. It was observed that the washed sample has the highest value with the washed sample having a maximum value of 25.7kN and the unwashed having a maximum value of 25.02kN as its highest value.

The result on the table proves that there is a slight difference between the washed and the unwashed in terms of the strength of the concrete.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the study carried out on properties of fresh & hardened concrete the following conclusions are drawn;

i. Concrete with washed fine aggregate has a higher compressive strength compared to that of concrete produced with unwashed fine aggregate at 28 days. The variation in strength of concrete is as a result of the presence of silt in the unwashed material. The silts reduces the strength of concrete.

ii. At the 25% replacement for the washed sample, the strength was found to be higher than that of the control mix as it approaches 14, 28 and 60 days of curing. A partial replacement of 25% gives the highest compressive strength. And according to the result, it meets up with the target strength of the control mix (M15).

iii. The highest compressive strength for washed sample was obtained at 25% replacement.

iv. Further replacement up to 100% causes a reduction in compressive strength at 28 days.

v. The rate of increase in strength from 28 days to 60 days was greatest at 50%, 75% and 100%.

vi. The highest compressive strength at 60 days was attained at 75% replacement with strength $25.21N/mm^2$.

5.2 RECOMMENDATION

After completing my research and testing various samples, it is recommended that quarry dust at 25% partial replacement for fine aggregate in concrete production should be used in areas where river sand are not readily available e.g. Ekiti-State. The scarcity of sand may lead to an increase in transportation cost of sand from the place of extraction to the place of consumption which may in turn lead to the increase construction cost. The use of quarry dust as partial replacement helps to reduce such cost.

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