EFFECTS OF THE PARTIAL REPLACEMENT OF FINE AGGREGATES WITH QUARRY DUST ON THE STRENGTH AND WORKABILITY OF CONCRETE

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CERTIFICATION

This is to certify that this project titled "Effects Of The Partial Replacement Of Fine Aggregates With Quarry Dust On The Strength And Workability Of Concrete" was undertaken by Achufusi Ejikeme Chinemerem with registration number (NAU/2017224053) in the Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

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APPROVAL

This is to certify that this research work written by Achufusi Ejikeme Chinemerem with registration number "2017224053" has been assessed and approved by the Department of Civil Engineering, Nnamdi Azikiwe University, Awka.

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DEDICATION

I dedicate this project report to the Almighty God whose grace and guidance made it possible for me to reach this phase of my academic pursuit, to my dear parents and siblings whose support in my life have been greatly overwhelming.

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ABSTRACT

The current study focuses on determining the suitability of using quarry dust as fine aggregates in traditional concrete. It presents the feasibility of the usage of quarry dust in an increasing order of 10%, 20%, 30%, 40% and 50% as substitutes for sharp sand in concrete. Portland cement known as Dangote 3x cement was used for the study. During the tenure of the study, some physical and engineering properties of quarry dust and sand were determined and compared. Specific gravity tests and sieve analysis tests were also carried out where applicable. The compressive strength of concrete was determined after replacing sand with quarry dust in various ratios. Strength results of the concrete cubes used were taken at 7, 14 and 28 days of curing. The study showed encouraging results for the replacement of 50% of sand with quarry dust. From the results of the experimental investigations conducted, it is found that 50% replacement of fine aggregate by quarry dust gives maximum result in strength than normal concrete. The workability of plastic concrete at each phase of fine sand replacement was also obtained. With a constant water-cement ratio of 0.6, it was observed that the workability of concrete reduces as more quarry dust is used as replacement for sharp sand in a concrete mixture. Therefore, trial casting with the quarry dust should be carried out to achieve the most suitable water content and mix proportions to achieve a desired workability levels and strength requirements.

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Concrete is the most widely used construction material in the world and this can be attributed to two aspects of application. Firstly, concrete is used for many different structures such as pavements, building frames or bridges and dams much more than any other construction material. Secondly, the amount of concrete used in volume is much more than any other material in construction. Its worldwide production exceeds that of steel by a factor of 10 in tonnage and by more than a factor of 30 in volume. The applications of concrete in the fields of infrastructure, habitation, and transportation have greatly promoted the development of civilization, economic progress, stability, and quality of life, (Li, 2011). Conventional materials that are used in the concrete manufacture are; the coarse aggregates, fine aggregates, cement and water. Building materials often constitute the single largest input to housing construction in most developing countries and cities particularly in Africa. It is estimated that the cost of building materials alone can take up to 70 per cent of a standard low-income formal housing unit (Erguden, 2001). The consumption of fine aggregate in concrete production is very high throughout the world and several developing countries are facing difficulties in meeting the supply of natural fine aggregate in order to satisfy the increasing needs of infrastructural development in recent years. Sustainability is a global concern and methods are being employed to minimise wastage to ensure adequate reserves are left for future generations. Sharp sand is the most popular choice for the fine aggregate component of concrete with its consumption in concrete generation at about 1 billion tons per year (Krishnamoorthi and Mohankumar, 2012) but overuse of the material has led to environmental concerns, depleting securable sand deposits and a concomitant price increase of the material. The rapid extraction of sand from the river beds causes problems like erosion, lowering of the water table, sinking of bridge piers, change in river courses leading to floods, deepening of the river beds, loss of vegetation on the bank of rivers, disturbance to the aquatic life eto (Anzar, 2015). Therefore, it is considered necessary to obtain environmentally friendly substitutes for sharp sand that are preferably by-products. Rising construction costs and the need to reduce environmental degradation through the depletion of aggregate deposits to make construction sustainable, has necessitated research into the use of alternative materials, especially locally available ones which can be used as conventional ones in concrete production.

There have been investigations about the use of steel slag, a waste product of blast furnace, in the process of iron extraction used as fine aggregates. Other investigations on suitable components of concrete apart from conventional one includes; partial replacements of cement with Class-F fly ash, this study was done in India. Richer mix and higher compressive strength has been obtained from the experimented partial replacement of cement with fly ash, (Tensing, 2010). In Tanzania, a study on alternative components for lightweight concrete was conducted using waste materials as coarse aggregates. The study was conducted in Kilwa and the waste materials used were coconut shell, sisal fibres, and PET plastic due to their abundance in the area. In preparation for mixing, coconut shells were crushed into aggregate no larger than 19mm, sisal fibres were cut into pieces no longer than 9.4mm, and PET plastic was shredded into 6.25mm inch-wide strips no longer than 6 inches. Replicate samples were mixed and then cured for 28 days before they were tested for compressive strength, unit weight, and absorption. The resulting data were compared to ASTM Standards for lightweight concrete masonry units to determine their adequacy. Based on these results, there is potential for coconut shells to be used as coarse aggregate in lightweight concrete. However, Sisal fibre was unsuccessful in producing the appropriate compressive strength. Concrete mixes using PET plastic as aggregate resulted in adequate compressive strengths, but were too dense to be considered 'lightweight' concrete, (Rust, 2014). According to past research, quarrying of limestone and dolomite typically produces 20-25% fines and sandstone/grit stone up to 35% fines (University of Leeds as cited in (Wilson, 2007)). This means for every 100m3 of aggregates produced daily; there are 35m3 of quarry dust produced and will only be left idle. This situation has prompted a desire to carry out a research on suitability of quarry dust to be used as fine aggregates in concrete. This is because currently, the ability of quarries to sell fines into the construction market is hampered by lack of product specifications.

Quarry dust is a byproduct of the crushing process in quarries which is a concentrated material to use as aggregates for concreting purposes, especially as fine aggregates. In quarrying activities, the rock has been crushed into various sizes; during the process the dust generated is called quarry dust and it is formed as a waste material. It results in air pollution and may be considered a useless material. Utilisation of quarry dust will conveniently decrease the demand of natural sand hence help in reducing the rate of depletion of resources and also provide some time for the resources to be replenished. Utilisation of quarry dust not only relieves the pressure on sand but also reduces the need for dumping of quarry dust which was considered a waste product in the quarries. Most of the developing countries are under pressure to replace fine aggregate in concrete by an alternate material also to some extent or totally without compromising the quality of concrete. The attempt for the replacement of sharp sand with quarry dust has also been made in Nigeria.

Quarry dust is obtained during the crushing of large rock boulders into coarse aggregates about 20-25% of the total material crushed in a crusher unit for extraction of aggregates is left as fine dust and is considered to be waste (Sakthivel et al, 2013). They are sieved aggregates usually less than 5mm in size with a particle size distribution close to that of sand and are usually produced in large volumes daily. Only a little fraction is used in the highway department as the binding material between the bitumen and coarse aggregate and also in the manufacturing of hollow and autoclave blocks, tiles and bricks. Quarry dust has been used for different activities in the construction industry, such as building materials, road development materials, aggregates, bricks, and tiles. Quarry dust has been proposed as an alternative to sharp sand that gives additional benefit to concrete. It is known to cause an increase in the strength of concrete over that made with equal amounts of sharp sand (Hameed and Sekar, 2009). Utilisation of quarry dust not only relieves pressure on sand but also reduces the need for its dumping as quarry dust is considered a waste product in the quarries. It is also found that utilisation of quarry dust as fine aggregates in concrete provides sufficient workability and also the required strength. This can prove to be an effective alternative for replacement of sand if found convenient. Quarry dust has been accepted as a building material in industrially advanced countries for the past three decades (Mahzuz et al. 2011). As a result of sustained research and developmental works undertaken with respect to increasing application of this industrial waste, the level of utilisation of quarry dust in industrialised nations like Australia, France, Germany and UK has reached more than 70% of its total production (Gowrisanker et al, 2016).

1.2 Problem Statement

The world around us is rapidly evolving and so is the world infrastructure. The infrastructure industry has witnessed a rapid and enormous growth in the last decade. For years, the use of sand and gravel as aggregates in the construction of roads and buildings has been conventional. Today, demand for sand and gravel continues to increase. Mining operations, in conjunction with cognizant resource agencies, must work to ensure that sand mining is conducted in a responsible manner. Excessive in-stream sand and gravel mining causes the degradation of rivers and lowers the stream bottom, which may lead to bank erosion. This decade has proven to be a golden era for the infrastructure industry & the construction community. But with this rapid growth, the resources were also rapidly utilised. Our main focus as engineers should be towards maintaining the balance between construction and a sustainable environment. One of the ways to achieve that can be using alternative material and material sources. In such a case, quarry dust can be an economical alternative to sharp sand. The availability of the dust and its effects to the environment when left to accumulate leads to the need for usage as sand replacement material. However, the lack of clear guidance and assurance on its suitability to be incorporated in concrete manufacture has been the problem. To overcome this problem, this study will focus on testing the suitability of quarry dust as fine aggregates in the concrete manufacture by identifying an optimal mix proportion between sand and quarry dust in concrete, assessing workability properties of quarry dust as fine aggregates and testing compressive strength properties of concrete containing quarry dust as fine aggregates.

1.3 Aim and Objectives of the Study

The aim of the study is to investigate the possible replacement of sharp sand with quarry dust as fine aggregates in concrete production. The major objectives of the study are as follows:

i. To determine the significant properties of quarry dust and compare it with the properties of conventional sand.

ii. To determine the best suitable ratio of Sand: Quarry Dust in concrete to obtain the desired design compressive strength.

iii. To determine the workability and compressive strength in the replacement of various samples of sharp sand with quarry dust as fine aggregates in concrete production.

iv. To make adequate recommendations with regards to the use of quarry dust in concrete production.

1.4 Scope of Study

The present research work mainly deals with the influence of different replacement proportions of sand with quarry dust on the properties of concrete. The present report is planned to study the effects of quarry dust addition in normal concrete and to assess the rate of compressive strength development. Strength results will be taken after seven, fourteen and twenty- eight days of curing. The study is limited to the effects of quarry dust on the compressive strength and workability of concrete. However, conventional concrete constituent materials and their properties will be investigated, this includes the grading of aggregates.

1.5 Significance of the Study

The importance of studying quarry dust as possible replacement of fine aggregate in concrete are as follows:

i To aid civil engineers to have better understanding and appreciate the use of quarry dust as fine aggregate in concrete constructions.

ii. To reduce the high cost of sand as resulted from high demand in concrete works.

iii. To provide a readily available alternative product for fine aggregates in the market.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Numerous attempts have been made to investigate the ability of quarry dust to serve as a replacement for sand in concrete. Below are some of these investigations and their outcomes; Gowrisanker et al (2016) carried out an experimental study on the variation in strength of concrete when replacing sand with quarry dust and cement with lime powder with replacement from 0%-30%. From the test results, it was found that the maximum compressive strength and tensile strength was obtained at 30% replacement. They reported that quarry dust can be utilised as a good substitute for sharp sand. Mohankumar and Sudharsan (2017) carried out an investigation into the replacement of cement and fine aggregate with quarry dust. The sharp sand was totally replaced with quarry dust while the cement was partially replaced at 0, 2, 4, 6, 8 and 10% by weight. It was observed that the optimum replacement level of cement with quarry dust was at 6%. Krishnamoorthi and Mohankumar (2012) made preliminary studies on the strength properties of quarry dust based concrete. A trial mix design for M30 grade concrete and sand replaced at different percentages with quarry dust. They recommended a total replacement of sand with quarry dust. Allam et al (2016) studied the behaviour of M35 grade concrete having partial replacement of cement or sand with granite waste. It concluded that the optimum percentage of cement with granite fine powder was 5%. Nanda et al (2010) studied the replacement of stone crusher dust as fine aggregate in concrete for paving blocks in various percentages. The test results showed that the replacement of stone dust more than 50% by weight had a negligible effect on any physical or mechanical properties of the concrete paving blocks. Anzar (2015) made a study on the suitability of quarry dust as sand replacement material and discovered that it improves the mechanical properties of concrete as well as its elastic modulus. The optimum compressive strength was achieved at a proportion of fine to coarse aggregates of 60:40. Agrawal et al (2017) made a study focusing on determining the suitability of using quarry dust as fine aggregate in traditional concrete. The compressive strength of concrete was determined after replacing sand with quarry dust at several ratios. The results of the study showed encouraging results for replacement of 50% of sand with quarry dust. Ukpata et al (2012) studied the compressive strength of concrete using lateritic sand and quarry dust at various combinations as fine aggregates. The results compared favourably with those conventional concrete. The concrete was found to be suitable for use as structural members where lateritic sand did not exceed 50%. Sakthivel et al (2013) studied the partial replacement of quarry dust with sand for M35 grade concrete. It was found that the partial replacement of sand with 10% of quarry dust gave optimum results and its usage can help in effective waste management for the quarries. Kumar et al (2017) studied the strength and durability of concrete using quarry dust as fine aggregate and comparing it with that of a conventional mix. A large range of curing period of 28 days was considered for a M20 grade design concrete mix with replacement at various percentages of quarry dust. The results showed that workability increased with the increase in quarry dust and compressive strength increased up until 10% after which it started decreasing. Dhivya et al (2017) carried out tests on the strength behaviour of concrete by partial replacement of coarse aggregates with river pebbles and fine aggregates with quarry dust. Concrete was mixed with various percentages of river pebbles and quarry dust and it was observed that the concrete produced was of adequate strength. Sureshchandra et al (2014) also conducted a study on the effect of quarry dust in hollow concrete blocks for different mix proportions. Both partial (50%) and complete replacement were tested with and without admixtures. It was discovered that blocks replaced with 50% of quarry dust performed better than those made using natural sand. Admixtures also helped to produce a better performance. Sukesh et al (2013) studied the replacement of sand with quarry dust and fly ash in concrete. They noted an increase in the compressive strength of concrete when sand was replaced with quarry dust. They also noticed a decrease in the workability of concrete when the percentage of quarry dust increased. They noted the ideal percentage of the replacement of sand with quarry dust to be between 55% -75% for optimum compressive strength. Fly ash also helped improve the workability of concrete. Bala et al (2014) looked into an experiment on the effect of partial replacement of sand with quarry dust in the production of sandcrete blocks using a mix ratio of 1:6 at various replacement percentages. Compressive strength tests were carried out after curing and it was found that the optimum strength was achieved at 45% corresponding to 2.6 N/mm^2. Manguriu et al (2013) studied the partial replacement of natural river sand with crushed rock sand in concrete production. After experimentation, they concluded that the mechanical properties of crushed rock depends on the source of its raw material hence the selection of the quarry is important in obtaining quality fine aggregate. An increase in the compressive strength was observed at 20% replacement with a value of 23.6 N/mm^2, Mahzuz et al (2011) investigated the use of stone powder in concrete as an alternative to sand using three concrete mix proportions, 1:1.5:3, 1:2:4 and 1:2.5:5. The results of the compressive strength were compared for these mixes for both that of sand and stone powder, the latter gave a higher value by about 14.7%, 4% and 10.44% respectively. In another study, Wakchaure et al (2012) used artificial sand in place of river sand and ran tests for a M30 grade mix. The compressive strength and split tensile strength increased by 3.98% and flexural strength also increased by 2.8%. Raman et al (2011) studied the effect of quarry dust and found that the partial replacement of river sand with quarry dust without the inclusion of fly ash resulted in a reduction in the compressive strength of concrete paving block specimens. It was also reported that the reduction in the compressive strength of quarry dust concrete was compensated by the inclusion of fly ash into the concrete mix. Ilangovana et al (2008) carried out an investigation on the strength and durability of concrete containing quarry dust as the fine aggregate. It was reported that the physical and chemical properties of quarry dust as well as the durability of quarry dust concrete was better than that of conventional concrete. Devi and Kannan (2011) carried out an investigation on strength and corrosion resistance behaviour of inhibitors in concrete containing quarry dust as fine aggregate. The incorporation of inhibitors as admixtures did not show any adverse effects on the strength properties and there was an increase in strength up to a certain percentage. The addition of inhibitors as admixtures to concrete was found to lower the permeability and water absorption. Sivakumar and Prakash (2011) carried out an investigation on the mechanical properties of concrete with quarry dust. They reported that the quarry dust may be used as effective replacement material for natural river sand to increase the strength of the concrete produced. The experiment results showed that the addition of quarry dust for a fine to coarse aggregate ratio of 0.6 was found to enhance the compressive properties as well as the elastic modulus. Amit et al (2015) carried out an experiment to study the workability and compressive strength of concrete made using stone dust as partial replacement of fine aggregate in the range of 10% - 100%. M25 grade of concrete was designed using Portland pozzolana cement (PPC) for referral concrete. Workability and Compressive strength were determined at different replacement levels of fine aggregate vis-à-vis referral concrete and optimum replacement level was determined based on compressive strength. Results showed that by replacing 60% of fine aggregate with stone dust concrete of maximum compressive strength can be made as compared to all other replacement levels. Balamurugan and Perumal (2013) conducted an experimental study on the variation in the strength of concrete when replacing sand by quarry dust from 0% to 100% in steps of 10%. M20 and M25 grades of concrete are taken for the study keeping a constant slump of 60mm. The compressive strength of concrete cubes at age of 7 and 28 days is obtained at room temperature. Split tensile strength and flexural strength of concrete are found at the age of 28 days. From the test results it is found that the maximum compressive strength, tensile strength and flexural strength are obtained only at 50% replacement. This result gives a clear picture that quarry dust can be utilised in concrete mixtures as a good substitute for natural river sand at 50% replacement with additional strength than control concrete. Anil et al (2015) carried out an experiment on the compressive strength of various grades of concrete with the replacement of sand by manufactured sand and with the addition of chemical admixture is discussed. Concrete plays a very important role in the construction industry and is being utilised on a large scale. River sand, which is one of the constituents used in the production of conventional concrete, has become expensive and also a scarce material. In view of this there is a need to find an alternative source for the replacement of this river sand, which will be having the same properties of the river sand thus a alternative quarry dust is being selected and is made used in a concrete as an alternative for river sand in addition with the chemical admixtures Polycarboxylic ethers (PCE) and sulfo naphthalene formaldehyde (SNF), Concrete traditionally comprises of cement, fine aggregate, coarse aggregate and water. An attempt here has been made to replace the fine aggregate with quarry dust with an objective of utilising the waste material. It is found that quarry dust improves the mechanical properties of concrete when used along with super plasticizers. In fact we need high strength concrete to withstand the heavy loads in a building. The sand is replaced by manufactured sand by 100% and various chemical admixtures are added to increase the workability of the concrete. Divarkar et al (2012) experimented on the behaviour of M20 grade concrete with the use of granite fines as a partial replacement for sand at 5%, 15%, 25%, 35% and 50% and based on the results obtained from the compressive, split tensile and flexural tests, concluded that 35% of sand should be replaced with granite fines. Hameed and Sekar (2009) studied the effect of crushed stone dust as fine aggregates and found that the flexural strength was higher than that of concrete made with natural sand but recorded that the strength reduced when the percentage of stone dust increased. The idea of using quarry dust as an alternative aggregate was developed because granite which is the parent material is hard and dense and therefore can serve as an excellent aggregate material (Sureshchandra et al, 2014). Its use as a fine aggregate in concrete is expected to improve certain properties, such as the compressive strength, durability, strength development, workability and economy. The importance of the compressive strength in concrete is such that for structural design purposes, it is the criterion for quality.

2.2 Concrete

Concrete is an artificial material comparable in appearance and properties to some natural limestone rock. Concrete is a composite material consisting of a binding medium in which a relatively inert filler material (sand and gravel aggregate) is embedded. The most commonly used binding medium is the product formed by a chemical reaction between cement and water. It is a man-made composite, the major constituent being natural aggregate such as gravel, or crushed rock, sand and fine particles of cement powder all mixed with water. The concrete as time goes on, through a process of hydration of the cement paste, produces a required strength to endure load (Maninder and Manpreet, 2012). Concrete is defined in student Encarta as a mixture of sand, cement, aggregate and water in specific proportions that hardens to a strong stony consistency over varying length of time. The aggregate in this context refers to rock particles of size above $5mm^2$. The American Concrete Institute also sees concrete as an engineering material made from a mixture of Portland cement, water, fine and coarse aggregate and small amounts of air. Olanipekun (2006) defines concrete as a composite material consisting of a binding medium within which the particles are embedded. Other scholars also define concrete as a combination of aggregates and a paste composed of Portland cement and water. The aggregate refers to sand and gravels or crushed stones (Mannan and Ganapathy, 2002). Concrete is a widely used construction material in civil engineering projects throughout the world for the following reasons: It has great resistance to water, structural concrete elements can be formed into a variety of shapes and sizes and it is usually the cheapest and most readily available material for the job (Olanipekun, 2006).

The standard mix of approximately 1:2:4 (ratio of cement to fine and to coarse aggregate) is expected to give a compressive strength of 20 N/mm^2 at 28 days, but Olanitori and Olotunh (2005) could not achieve these using aggregates available in Akure metropolis, rather they achieved a concrete of compressive strength between 8 N/mm2 and 12 N/mm^2 instead. In the light of the shortcomings that may be associated with aggregates, it has become imperative to research into these aggregates that are readily available in our environment and know at what optimum mix ratio a minimum concrete strength is obtained. The research into the characteristics and behaviour of locally available aggregates is expected to improve the knowledge of structural engineers and general concrete users. Concrete begins as a plastic mixture and gradually hardens into a stone-like mass. In its hardened state, concrete is a rock-like material with a high compressive strength. The aggregates occupy roughly three- quarter of the available space within a given mass of concrete. Particles less than 5mm in diameter are designated as fine aggregate, which is represented by sand in normal concrete. The space that is not occupied by the aggregates, which is roughly one-quarter of the entire volume of a given mass of concrete, is filled up with cement paste and air voids (Kumar et al. 2017). In a freshly made and well compacted concrete of suitable proportions, the volume of unavoidable entrapped air is not more than one or two percent of the entire volume. The impact strength, as well as the tensile strength, of normal concrete is low and this can be improved by the introduction of fibres into the concrete mix. Steel, polypropylene, asbestos and glass fibres have all been used with some success (Divarkar et al, 2012). Considerable care and knowledge are required to produce quality concrete before it is even placed.

2.3 Components of Concrete

Concrete is a composite material composed mainly of cement, aggregates (fine and coarse), and water. When these ingredients are mixed together, they form a fluid mass that is easily moulded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredient together into a durable stone-like material with many uses. The properties of these constituent components are discussed below:

2.3.1 Cement

Cement is one of the most important components of concrete. The volume of cement in concrete greatly affects its strength. Cement is a combination of compounds which includes lime, silica and alumina. Cement is made of finely grounded powders that when mixed with water, a chemical reaction (i.e. hydration) takes place, which produces a very hard and strong binding medium for the aggregate. The most generally used cement is ordinary Portland cement (OPC), but other additional materials such as pozzolana, silica fume and fly ash can also be included as long as their acceptance has been proven. The manufacture of Portland cement consists of ingredients mainly lime, silica, alumina and iron oxide from limestone and clay/shale which react together on firing to form a series of more complex products. The relative proportions of these oxide compositions are responsible for influencing the various properties of particular cements; in addition to the rate of cooling and fineness of grading which affects the strength of the cement. In many structural applications, the choice of cement has a lesser influence on the long-term performance of concrete than the practical aspects of mix control, cement content, water content, aggregate quality, and compaction, finishing and curing (Newman and Choo, 2003).

2.3.1.1 Types of Portland Cement

According to (BS EN 197-1, 2000), cements are classified into five main types depending on its constituents. They include:

• Portland cement (PC)

• Portland composite cement.

• Blast furnace cement.

• Pozzolanic cement.

• Composite cement.

Portland cement (PC) is by far the most important type of cement. Prior to 1987, there was only one grade of Portland cement which was governed by IS 269-1976. Portland cement was classified into three grades namely 33 grade, 43 grade and 53 grade depending upon the strength of the cement after 28 days when tested as per IS 4031-1988. If the 28-day strength is not less than 33 N/mm^2, it is called 33- grade cement, if the strength is not less than 43 N/mm^2, it is called 43-grade cement, and if the strength is not less than 53 N/mm^2, it is called 53-grade cement. In the construction works, higher grades cement have become so popular that 33-grade cement is out of the market. Portland cement is classified in Table 2.1 under the ASTM (American Society of Testing Materials) into five categories, Type I – V

Table 2.1: Types of Portland Cement (Manguriu et al, 2013)

ASTM Type and name	composition				Characteristics	Applications
	C_3S	C_2S	C_4A	C_4A_8		
I(Ordinary)	42-65	10	0-17	6-18	No special requirement	General construction (e.g sidewalks)
II(Ordinary)	35-60	15-35	0-8	6-18	Moderate sulphate resistance. Moderate heat of hydration.	Drainage systems, sea walls, floors, slabs, foundations
III (High-Early Strength)	45-70	10-30	0-15	6-18	High strength after pouring	Cold weather constructions
IV (Low-Heat)	20-30	50-55	3-6	8-15	Low heat hydration	Massive structures(eg. dams)
V (Sulphatic-resistant)	40-60	15-40	0-5	10-18	High sulphate resistance	Foundations in high sulphate soils

2.3.1.2 Chemical Compounds of Cement

Portland Cement is distinguished from one another by its chemical composition. Four main compounds are considered as the major constituents of cement and these compounds are presented in Table 2.2. The composition of Portland cement is based on the 'Bogue composition' which is given in the equations below:

$C_3S = 4.07(CaO) - 7.60(SiO_2) - 6.72(Al_2O_3) - 1.43(Fe_2O_3) - 2.85 (SO_3)$

$C_2S = 2.87 (SiO_2) - 0.754(3CaO.SiO_2)$

$C3A = 2.65 (Al_2O3) - 1.69(Fe_2O_3)$

$C_4AF = 3.04 (Fe_2O_3)$

ASTM C 150 and AASHTO M 85 present the standard chemical requirements for each type. The phase compositions in Portland cement are denoted by ASTM as Tricalcium silicate (C_3S), Dicalcium silicate (C_2S), Tricalcium aluminate (C_4Al), and Tetracalcium alumina-ferrite (C_4AF). However, the actual components are often complex chemical crystalline and amorphous structures, denoted by cement chemists as "elite" (C_3S), "belite" (C_2S), and various forms of aluminates (Tilak, 2013).

Table 2.2 Compound Composition And Its Contribution To Hydration Of Portland Cement (Nawy, 2008)

Chemical formula	Shorthand notation	Weight percent	Reaction Rate	Contribution to strength
$3CaO.SiO_2$	C_3S	50	Moderate	High
$2CaO.SiO_2$	C_2S	25	Slow	Low initially and high later
$3CaO. Al_2O_3$	C_3A	12	Fast	Low
$4CaO.Al_2O_3.Fe_2O_3$	C_4AF	8	Moderate	Low

It is seen that the major products of the hydration reactions, which primarily account for the strength of concrete, are the calcium silicate hydrates (C_3S and C_2S) that make up most of the hydrated cement (Nawy, 2008). These silicates are the most vital compounds responsible for the strength of hydrated cement paste and are formed from the reactions between the two calcium silicates and water.

2.3.2 Water

Water is a very vital component of concrete as it readily participates in the chemical reaction with cement. In general, potable water is safe for use in concrete. Water containing harmful substances such as salts, silts, suspended particles, organic matter, oil, or sugar can unfavourably affect the strength and setting properties of cement and disturb the affinity between aggregate and cement paste (Nawy, 2008). Some specifications state that water for making concrete should have a ph value between 6 and 8 and should be free from organic matter. Therefore, the suitability of water should be examined before use. As a rule, any water with silt content below 2000 mg/L is suitable for use in concrete (Shetty, 2005).

2.3.2.1 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 and has an important influence on the quality of concrete produced. A lower water-cement ratio leads to higher strength and durability, but may make the mix more difficult to place. According to Rakennustekniikan koulutusohjelma (2010), water-cement ratio is a very important factor in concrete production, and it has crucial effects to both, fresh and hardened concrete properties. A difference in water amount as small as 5 kg/m^3 can cause tremendous effects to workability of fresh concrete. The main variation in water amount comes from the aggregates, and aggregate moisture contents may vary due to the fact that aggregates from a new delivery with different moisture content are used. Also during wintertime when the aggregates are heated in order to get warm concrete, the aggregate mass can locally differ in temperature and moisture content affecting the workability of the concrete.

2.3.3 Aggregates

Aggregates are mainly divided into two categories from consideration of size; coarse aggregate and fine aggregate. Aggregates greater than 4.75mm are considered as coarse aggregates and aggregates less than 4.75mm are considered as fine aggregates. Usually aggregates compose the greatest possible volume of mix. The mere fact that the aggregates consist of 70-80% of the volume of the concrete means that they have an immense impact on various characteristics and properties of concrete. To know more about concrete, it is very essential that one should know more about aggregates which constitute a major volume in concrete. Without the study of the aggregate in depth and range, the study of the concrete is incomplete. The aggregates used for concrete and mortar can be conveniently divided into heavy and light weight types. The heavy class includes all the aggregates normally used in mass and reinforced concrete, such as sand, gravel, crushed rock and slag. The light weight class include pumice, clinkers, foamed slag, expanded clay, shale and slate, exfoliated vermiculite and expanded volcanic such as perlite (Agrawal et al, 2017). It is important that fine aggregates have an adequate proportion of very small particles called fines. Concrete made with this type of fine aggregate is easier to finish than concrete made with coarse sand. The latter requires more paste to produce an equally acceptable surface finish. Aggregates for construction works should be clear and free from dust or salt deposits. For durability, washing of both coarse and fine is very desirable. Beach sand in particular should be washed with fresh water to remove the salt (Mohankumar and Sudharsan, 2017). The maximum size of aggregate practicable to be used in concrete production is 80mm.

2.3.3.1 Coarse Aggregate

Aggregates were originally viewed by Troxell et al. (1968) as being inert and dispersed all through the cement paste in concrete, largely due to economic reasons, that is, as a fill material. Studies have shown that fine and coarse aggregates are very important in concrete because aggregates occupy 60% to 75% of the concrete volume and strongly influence the concrete's freshly mixed and hardened properties, mix proportions, and economy (Quiroga and Fowler, 2004). The vital requirement of an aggregate for concrete is that it remains constant within the concrete (both in the fresh and hardened states) and in any given environment, throughout the design life span of the concrete (Smith and Collis, 2001). Coarse aggregates are materials retained on 5mm (3/16 inches) test sieve and containing only as much finer material as allowed from the various sizes.

Table 2.3: Type of Coarse Aggregate and Source

TYPES	SOURCE
Uncrushed gravel	From natural disintegration of rock
Crushed stone	From crushing of gravel or hard stone
Partially crushed gravel	Product of the blending uncrushed and crushed gravel

2.3.3.2 Fine Aggregates

Sand may be described into three major parts, which are natural sand,crushed stone and crushing gravel sand. Table 2.4 shows the different types of coarse aggregate and their source which all of the fine aggregate are from rock. According to Suryakanta, (2014), commonly, fine aggregate passes 4.75mm sieve and contains only as much coarser as is permitted by specification. Normally, river sand and crushed sandstone with fineness modulus of 1.78 were passed through a 2.36 mm sieve analysis. Commonly, materials used have a maximum particle size with 2.36 mm diameter.

Table 2.4: Type of Fine Aggregate and Source

Types	Source

Natural sand	From natural disintegration of rock
Crushed stone sand	From crushing of hard stone
Crushed gravel sand	From crushing of natural gravel

2.3.3.3 Properties Of Aggregates

Aggregates possess certain properties, which directly influences the strength of concrete. Some of these properties cannot be measured qualitatively and some indirect measures are taken sometimes. The main properties of aggregates, which may influence the concrete properties, are:

- Shape
- Texture
- Size gradation
- Moisture content
- Specific gravity
- Bulk unit weight
- Strength of aggregate
- Soundness
- Wear resistance

• Alkali-aggregate reaction

• Impurities

• Unsound particles

2.4 Properties of Concrete

The properties of concrete in its fresh and hardened state can show large variation depending on the type, quality and the proportion of the constituent materials. The properties are discussed under two headings: namely, the plastic (fresh) state and the hardened state.

2.4.1 The Plastic State

The properties of concrete in its plastic state, or the stage during which it is to be handled, placed and compacted in its final form, should be sufficiently workable for the required properties in its hardened state to be achieved (Balamurugan and Perumal, 2013). This means that:

a) The concrete should be sufficiently fluid for it to be able to flow into and fill all parts of the formwork or mould, into which it is placed.

b) It should do so without any segregation or separation of the constituent materials.

c) It must be possible to fully compact the concrete when placed in position.

d) It must be possible to obtain the required surface finish.

2.4.2 The Hardened State

In its hardened state, concrete should have adequate durability, the required strength and also the desired surface finish. The behaviour of concrete is also affected by some properties namely, thermal properties, the mix proportion and hardness of the concrete, permeability and shrinkage, the definitions of some of the terms listed above are discussed below;

a. Durability

Durability of concrete refers to its ability to endure weathering action, attack by various chemical substances, and many other conditions to which it may be exposed over the years. Many of the conditions that cause concrete to lack durability are not immediately apparent. Some of them are harmful materials in the aggregate that cause cracking and surface blemishes, shrinkage of various aggregates that causes large deflections and cracking, use of highly absorptive aggregate that expands when moist and exerts sufficient force to disrupt concrete when frozen and impure mixing water (Pomeroy, 1989). Adequate durability of exposed concrete can be obtained by ensuring that suitable materials are used, also the use of good mix proportioning, careful batching, mixing, handling and placing, adequate consolidation and sufficient curing. The choice of aggregate is also important particularly for concrete wearing surfaces and where improved fire resistance is required.

b. Thermal Properties of Concrete

The thermal expansion of concrete varies with the proportion of aggregate present, richness of the mix and the type of aggregate. Dry and wet specimens show almost the same value at an intermediate condition of dryness and the values are 20% higher. The temperature at which concrete is used has an important bearing on the development of its strength. Concrete made with ordinary Portland cement increases with increased temperature at early ages, although at later ages, the concrete made and cured at lower temperature shows high strength (Pomeroy, 1989).

c. Shrinkage

Shrinkage of concrete is caused by the settlement of solids and loss of free water from the plastic concrete (Plastic shrinkage), by the chemical combination of cement with water (autogenous Shrinkage) and by drying of concrete (drying shrinkage). Where movement of the concrete is restrained, shrinkage will produce tensile stresses within the concrete which may cause cracking. Most concrete structures experience a gradual drying out and the effect of drying shrinkage should be minimised by the provision of movement joints and careful attention to detail at the design stage. A good quality concrete should have the good quality of reducing or minimising shrinkage of any sort to its minimum. Several factors influence the overall drying shrinkage of concrete. These include the type, content and proportion of the constituent materials of concrete, the size and shape of the concrete structure, the amount and environment (Jackson, 1984).

2.5 Curing Process

Curing is the name given to the procedures used for promoting the hydration of the cement, and consists of a control of temperature and of moisture movement from and into the concrete. Curing allows continuous hydration of cement and subsequently continuous increase in the strength. Once curing stops, the strength increase of the concrete also stops. Proper moisture conditions are critical because the hydration of the cement virtually stops when the relative humidity within the capillaries drops below 80%. With insufficient water, the hydration will not continue and the resulting concrete may not possess the necessary strength and impermeability. The continuous pore structure formed on the near surface may allow the entrance of harmful agents and would cause various durability problems. Moreover due to early drying of the concrete, micro-cracks or shrinkage cracks would develop on the surface of the concrete. When concrete is exposed to the environment, evaporation of water takes place and loss of moisture will reduce the initial water cement ratio which will result in the partial hydration of the cement and hence lowering the quality of the concrete. Various factors such as wind velocity, relative humidity, atmospheric temperature, water cement ratio of the mix and type of the cement used in the mix will affect the curing of concrete.

Evaporation in the initial stage leads to plastic shrinkage cracking and at the final stage of setting it leads to drying shrinkage cracking (Yash Nahata et al., 2013). Curing of the concrete is also governed by the moist-curing period, longer the moist-curing period, higher the strength of the concrete assuming that the hydration of the cement particles will go on. Curing has a strong effect on the properties of hardened concrete; appropriate curing will increase the durability, strength, volume stability, abrasion, resistance, impermeability and resistance to freezing and thawing (Yash Nahata et al. 2013).According to Yash Nahata et al. (2013), there are three method of curing which includes; air curing, water curing and saturated wet covering. Air curing is a curing method where the concrete cubes are left in open air to be cured at room temperature. Water curing is a curing method where the concrete cubes were cured in a water tank at room temperature. Saturated wet covering is a curing method where moisture retaining fabrics such as burlap cotton mats, gunny bags and rugs are used as wet covering to keep the concrete in a wet condition during the curing period.

2.6 Setting Time of Concrete

Setting time is defined as a specific time required for concrete to change from liquid state to plastic state (initial setting time) and plastic state to solid state (final setting time) so that the surface becomes sufficiently rigid to withstand a definite amount of pressure (Tanvi Lad, 2016). It is necessary to place and consolidate the concrete before the initial setting starts and do not disturb till the final setting has taken place. Concrete will hold its shape and withstand minimum pressure after the initial set time. It may take several hours or weeks before the final set is reached. Setting time of concrete usually depends on various factors such as the type of cement, fineness of cement, chemicals, sand, temperature, percentage of water etc (Allam et al, 2016). Temperature is the main contributing factor for variability in setting time. Setting time increases as temperature drops. For example, setting time is longer in cold regions due to low temperature. Concrete will not set at temperatures less than 20° F (Raman et al, 2011).

2.7 Compressive Strength of Concrete

The compressive strength of concrete is taken as the maximum compressive load it can carry per unit area. The compressive strength of concrete is important and can easily be determined. A standard concrete strength can be achieved by the selective use of the type of cement, mix proportions, method of compaction and curing conditions (Ilangovana et al, 2008). The compressive strength is frequently used as a measure of these properties. Similarly, the compressive strength is used as an indication of other properties relating to deformation or durability.

The compressive strength of the concrete is determined from the following formula;

$$F_c = \frac{F}{A_c}$$

Where;

F_c = Compressive strength in N/mm^2

F = Maximum load at failure in Newton

A_c = Cross-sectional area of the specimen on which the compressive force acts.

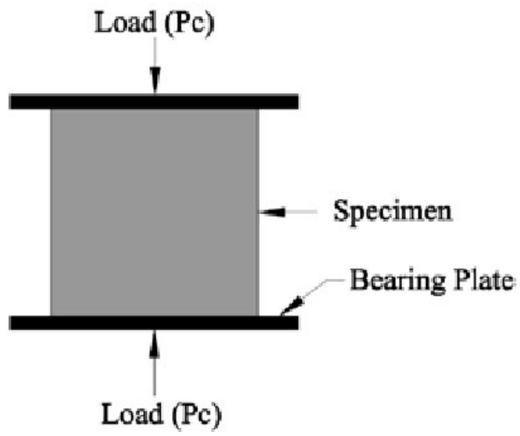

Figure 2.1: Compressive Test Setup

The crushing strength is influenced by a number of factors in addition to the water/cement ratio and degree of compaction. These are;

i. The type of cement and its quality. Both the rate of strength gain and ultimate strength may be affected.

ii. Type and surface of aggregate. Affects the bond strength.

iii. Efficiency of curing. Loss in strength of up to 40% may result from premature drying out.

iv. Temperature. In general, the initial rate of hardening of concrete is increased by a rise in temperature but may lead to lower ultimate strength. At lower temperatures, the crushing strength may remain low for some time, particularly when cement of slow rate strength gain are employed but may lead to higher ultimate strength provided frost damage does not occur.

v. Age. When moisture is available, concrete will increase in strength with age, the rate being greatest initially and progressively decreasing with time. The rate will be influenced by the cement type, cement content and internal concrete temperature.

vi. Moisture condition. Concrete allowed to dry will immediately exhibit a higher strength due to the dry process but will not gain strength thereafter unless returned to and maintained in moist conditions. Dry concrete will exhibit a reduced strength when moistened.

2.8 Workability of Fresh Concrete

Workability is one of the physical parameters of concrete which affects its strength and durability as well as the appearance of the finished surface. The workability of concrete depends on the water-cement ratio and the water absorption capacity of the aggregates. Fresh concrete is a freshly mixed material which can be moulded into any shape. The relative quantities of cement aggregates and water mixed together control the properties of concrete in the wet state as well as in the hardened state. Workability of concrete can be defined as the ability of concrete to be mixed, transported, placed and finished without loss of homogeneity (Ukpata et al, 2012). Three main characteristics of the property of workability are consistency, mobility and compatibility. Consistency is a measure of wetness or fluidity. Mobility defines the case with which a mix can flow into and completely fill the formwork. Compatibility is the case with which a given mix can be totally compacted, all the trapped air being removed (Devi and Kannan, 2011). Workability also depends on:

i. The method employed for conveyance and compaction.

ii. The size, shape, surface and roughness of formwork or moulds

iii. The quality and spacing of reinforcement.

The test commonly used for measuring workability does not measure the individual characteristic (consistency, mobility, and compatibility) of workability. However, they provide useful and practical guidance on the workability of a mix. Three tests widely used for measuring workability are the slump test, compacting factor, and V-B consistency test. Workable concrete is one that exhibits very little internal friction between particles and that can overcome the frictional resistance offered by the formwork or reinforcement. The factors that affect the workability of concrete include the water content, mix proportions, size of aggregates, shape of aggregates, surface texture of aggregates, grading of aggregate, use of admixtures etc (Anzar, 2015).

2.9 Quarry Dust

Quarry dust, stone dust or crusher dust as it is variably called, is a by-product of the cutting and crushing process of stones which generally refer to undersized materials typically finer than 4mm. Quarry dusts are produced as a result of mostly controlled blasting operations. They receive no further processing and are generally considered of no economic value thus accumulated as unwanted waste. The primary object of quarrying is to obtain coarse aggregate of various sizes to be used for various construction purposes. The proportions of fines vary according to the rock material used in the crushing process. Fine aggregates used in asphalt are defined as materials passing the 2mm BS test sieve (BS EN 13043:BS12002b) and fine aggregates for other uses including concrete, as materials passing 4mm sieve. Therefore from (BS 134043:2002,BS12002a) quarry dust are defined as fraction passing 4mm and materials passing 0.075mm.In this project quarry fine is a term referring to fine aggregates, fines and filler materials of less than 0.3mm which will be used as portion replacement of natural sand of same sizes. Crushing of quarry rock is carried out in different stages. First stage is known as the primary stage, second stage being the secondary stage and third stage refers to the tertiary stage. Different types of crusher are employed in different stages of crushing to reduce rocks sizes from blocks as big as 1.5m to successively smaller sizes ultimately finer than 20mm.In general, the greater the number of crushing stages the higher the proportions of dust produced (Hudson et al, 1997). Quarry dust has been identified over the years as a substitute material for fine aggregate in concrete. In Nigeria, quarry dust materials are produced as a result of rocks crushed in various quarries sites. Required aggregates are sieve from the total crushed materials and from which finer materials are treated as waste. These finer materials cause environmental concern on how to dispose of it. Each quarry produces fines with particular qualities, depending on the rock type and crushing plant that is used. Quarry dust has been used for different activities in the construction industries such as road construction and manufacture of building materials such as lightweight aggregates, bricks, tiles and autoclave blocks. The use of quarry dust in concrete is desirable because of its benefits such as the useful disposal of a by-product, reduction of coarse aggregate usage as well as increasing the strength parameters and workability of concrete (Jain et al, 1999). For this investigation, the physical (mechanical) and Chemical properties of quarry dust and sharp sand are listed in Table 2.5 and Table 2.6 respectively according to Chandana Sukesh, K. B. Krishna, P. S. Teja, S. K. Rao (2013).

Table 2.5: Mechanical Properties of Quarry Dust and Sharp Sand

Properties	Quarry Dust	Sharp Sand
Specific gravity	2.54-2.86	2.60
Bulk unit weight (kg/m3)	1590	1880
Aggregate crushing value (%)	49.38	18
Fineness modulus	3.4	2.56
24-h water absorption (%)	0.70-1.5	-
PH Value	8.38	6.2

Table 2.6: Chemical Composition of Quarry Dust and Sharp Sand

Constituents	Quarry Dust	Sharp Sand	Test Method
Magnesium (MgO)	2.56	0.77	IS 4032- 1968
Sodium (Na_2O)	Nil	1.37	IS 4032- 1968
Potassium (K_2O)	3.18	1.23	IS 4032- 1968
Aluminium (Al_2O_3)	18.72	10.52	IS 4032- 1968
Iron (Fe_2O_3)	6.54	1.74	IS 4032- 1968
Silica (SiO_2)	62.48	80.78	IS 4032- 1968
Calcium (CaO)	4.83	3.21	IS 4032- 1968
Titanium (TiO_2)	1.21	Nil	IS 4032- 1968
Loss on ignition	0.48	0.37	IS 4032- 1968

2.91 Summary of Literature Review

Considering previous research and investigations, properties of concrete, cement, aggregates, and quarry dust and water, it can be encouraged to carry on with the experiments into the "Effects of the Partial Replacement of Fine Aggregates with Quarry Dust on the Strength and Workability of Concrete".

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Preamble

The details of the materials and procedures carried out in this project are presented here. Highlights on materials source to be used, equipment and apparatus to be used, with the set standards of operations are discussed as well.

3.2 Research Materials

Materials to be used in this project work were found to be in accordance with the required standards. The experiments were carried out in the Unizik Concrete and Soil Laboratories, Awka. The materials used include the following;

3.2.1 Portland Cement

The Dangote 3x brand of Ordinary Portland Cement (OPC) Grade 42.5 according to the Standard Organization of Nigeria (SON) was used in the course of this project. It has a specific gravity of 3.07 and normal consistency of 30.5%. Bags were carefully kept away from dampness to avoid lumps.

3.2.2 Coarse Aggregates

Natural crushed granite was used as the coarse aggregate with a maximum diameter of 20 mm. It was bought in Awka but was originally obtained from Ebonyi State.

3.2.3 Sharp Sand

Sharp sand was used as the fine aggregate and was found suitable for the purpose of these experiments. The aggregate sample used was obtained from Amansea River, Awka, Anambra State. Sufficient quantities were obtained and spread out for a few days before use to dry, removing dampness in order to maintain consistent weights when batching. Pebbles and other odd particles were cleared from the pile during shovelling and spreading.

3.2.4 Quarry Dust

Quarry dust was also used as fine aggregate in this project and the sample was sourced from a quarry in Ebonyi State in bags and transported to the laboratory. The basic tests on quarry dust were conducted as per IS-383-1987 and its specific gravity was around 2.75. These sample results were found suitable for the purpose of this experiment.

3.2.5 Water

Water is an important ingredient of concrete as it initiates the chemical reaction with cement, and the mix water was completely free from chlorides and sulphates. Ordinary potable water was used throughout the investigation as well as for curing concrete specimens. The water was colourless, odourless and generally satisfactory for the work to be carried out. The water conformed to BS31480 requirements.

3.3 Test Apparatus

The following apparatus were used in the course of this study for the experiments.

i. Weighing Balance

ii. B.S Sieves

iii. Moulds

iv. Rammer/Tamping Rod

v. Slump Cone

vi. Universal Testing Machine

3.3.1 Weighing Balance

This has a range of 0-50 kg and it is used in weighing the required proportion of constituent materials for the concrete, as batching is by weight. It is also used for weighing the cubes after curing.

Figure 3.1: Weighing Balance

3.3.2 B.S Sieves

These are to be used in the sieve analysis of fine aggregates, coarse aggregate and quarry dust and are also used in getting the required sizes of granite for the purpose of the experiment. They are circular vessels with a bottom of woven wire to separate different sizes of aggregate.

Figure 3.2: Set of B.S sieves.

3.3.3 Steel Moulds

An open cast-iron or steel square comprising four sides and a base plate to which the mould is clamped. They are of size 150mm by 150mm by 150mm. They were properly oiled and tightened before usage.

Figure 3.3: Steel Mould

3.3.4 Rammer/ Tamping Rod

This is a steel bar about 400mm long. 1.8kg mass and a bottom ramming face 25 mm, which is used to tap the concrete during casting to achieve good compaction.

3.3.5 Other Instruments

This includes the trowel, shovels, scrappers, head pans, wheelbarrow, measuring tape etc.

3.4 Laboratory Testing of the Properties of Aggregates

3.4.1 Determination of Specific Gravity

3.4.1.1 Apparatus

1. Density bottle of approximately 50 ml capacity
2. Vacuum desiccator or water bath
3. Drying oven
4. Weighing balance accurate to 0.001gm
5. Vacuum pump
6. Glass rod
7. Wash bottle

3.4.1.2 Procedure

1. Weigh the oven dried bottle to the nearest 0.001 grams (W_1).
2. Take about 15 grams of oven dried sample sieved through BS sieve No 7. Put it in the density bottle and weigh to the nearest 0.001 grams (W_2).

3. Add air free distilled water and use paraffin just to cover the sample. Place it in the water bath or vacuum desiccator to evacuate the air. The bottle shall remain in the desiccator until no further air is released from the sample.
4. The bottle and contents shall then be removed from the desiccators and air free liquid added until the bottle is full. Insert the stopper and weigh the battle with contents to the nearest 0.001 grams (W_3).
5. The bottle shall then be completely cleaned and filled with air free liquid and stopper inserted. Wipe dry the bottle and weigh it to the nearest 0.001 grams (W_4).

3.4.1.3 Calculations

The specific gravity of the sample (G,) shall be calculated from the following formula:

$$Gs = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

Where;

W_1 = weight of the pycnometer

W_2 = weight of pycnometer + dry sample

W_3 = weight of pycnometer + dry sample + distilled water

W_4 = weight of pycnometer + distilled water

Based on this formula, the specific gravity of quarry dust and sharp sand was calculated.

3.4.2 Particle Size Distribution

Prior to testing, the materials were sieved so as to assess their gradation properties. This test consists of dividing up and separating by means of a series of test sieves, a material into several particle size classifications of decreasing sizes. The standard sieves used for sand and quarry dust were 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm, 0.15mm and 0.075mm. Whereas for coarse aggregates were 35.7mm, 19mm, 9.5mm, 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm, 0.15mm and 0.075mm. The sieves were arranged in ascending order with the smallest sieve at the bottom and the largest at the top. The percentage retained in each sieve was calculated using the ratio between cumulative weights retained in the sieve and total weight of a sample. The mass of the particles retained on the various sieves is related to the initial mass of the material. The cumulative percentages pausing each sieve are reported in numerical and graphical form. For a soil sample to be well graded, the Coefficient of Uniformity, Cu should be greater than 6 ($Cu > 6$). The Coefficient of Curvature Cc should be less than or equal to 1 and greater than or equal to 3($1 \leq Cc \leq 3$).

3.4.2.1 Objective

i. To determine the particle size distribution of specified aggregates.

ii. To draw grading curves for the aggregates specified.

3.4.2.2 Procedure

1. The test sieves are arranged from top to bottom in order of decreasing aperture sizes with pan and lid to form a sieving column.

2. The aggregate sample was then poured into the sieving column and shaken thoroughly.

3. The sieves were removed one by one starting with the largest aperture sizes (top most) and each sieve shaken ensuring no material was lost. All the material which passed each sieve was returned to the column before continuing with the operation with that sieve.

4. The retained material was weighed for the sieve with the largest aperture size and its weight recorded.

5. The same operation was carried out for all the sieves in the column and their weights recorded.

6. The screened material that remained in the pan was weighed and its weight recorded.

3.4.2.3 Calculations

1. Various masses were recorded on a test data sheet.

2. Mass retained on each sieve was calculated as a percentage of the original dry mass

3. The cumulative percentage of the original dry mass passing each sieve down to the smallest aperture was calculated.

3.5 The Properties of Fresh Concrete

3.5.1 Mix Proportioning

The concrete material was batched in weight. The ratio of the mix was 1:2:4 with the water cement ratio of 0.6. Each test will consist of 3 samples for the compressive strength to be taken after 7 days, 14 days and 28 days.

3.5.2 Mixing

The batching of the materials was done by weight and the mixing was carried out by hand on a bowl to avoid loss of water, clean hard surface using shovels. The appropriate size of granite and sand was then measured and added to the cement. The mix was then being spread out and a hole was made in the centre where water was added bit by bit (until the 0.65 water cement ratio was achieved). Further mixing was then done without allowing the water to seep away, until a uniform colour and acceptable workability was achieved.

3.5.3 Slump Test

3.5.3.1 Apparatus

i. Truncated conical mould 100 mm diameters at the top, 200 mm diameter at the bottom and 300 mm high.

ii. Steel tamping rod 16 mm diameter and 600 mm long with ends hemispherical.

Figure 3.4: Slump Test Apparatus

3.5.3.2 Procedure

The slump test was carried out on the design mixes in order to characterise the workability of the fresh concrete. The standard slump cone with a base plate was used. The workability test was conducted with a water-cement ratio of 0.6 for the various tests immediately after mixing. Firstly, the internal surface of the mould was cleaned and oiled for the test. The mould was then filled in three layers of equal sizes. For each layer, 25 Strokes were applied using the tamping rod and the strokes being uniformly distributed over the surface area of the layer. The top filled surface of the cone was smoothened and the cone gradually lifted vertically. The base plate was firmly held as the mould was being lifted gently in the vertical direction. The unsupported concrete slumped and the decrease in height at the centre point was measured using the standard measuring rule.

3.6 The Properties of Hardened Concrete

3.6.1 Determination of the Compressive Strength

A. Casting of Cubes

The specimens were cast in iron moulds, generally 150mm x 150mm x 150mm cubes. This conforms to the specifications of BS 1881. The mould surfaces were first cleaned and oiled on the inside surfaces to prevent development of bond between the mould and concrete. The moulds were then assembled and bolts and nuts tightened to prevent leakage of cement paste. After preparing trial mixes, the moulds were filled with concrete in three layers, each layer being compacted to remove as much entrapped air as possible and to produce full compaction of concrete without segregation. The moulds were made to overflow and excess concrete removed by the sawing action of a steel rule. Surface finishing was then done using a trowel. The test specimens were then left in the moulds undisturbed for 24 hours and protected against shock, vibration and dehydration at a temperature of 30°C.

B. Curing of Cubes

Caring may be defined as the procedure used for promoting hydration of cement and consists of a control temperature and the moisture movement from and into the concrete. The objective of curing is to keep concrete as nearly saturated as possible until the originally water filled space in the fresh cement is filled to the desired extent by the products of hydration. The temperature during curing also controls the rate of progress of hydration and consequently affects the development of the concrete strength. Before placing cubes into a curing task, they must be labelled. Details to be marked on the cubes are mainly, type of mix, date of casting, duration of curing and crushing day.

C. Compressive Test

Concrete cubes were cured for a maximum period of 28 days. After curing the cubes for the specified period, they were removed and wiped to remove surface moisture in readiness for compressive test. The cubes were then placed with the cast faces in contact with the plates of the testing machine, that is the position of the cube when tested should be at right angles to that of the cast. The load applied was applied at a constant rate of stress of approximately 15 N/mm^2 to failure. The readings on the dial gauge were then recorded for each cube.

3.7 Proportioning of the Constituent Material

The constituent materials used for the concrete were proportioned by weight. The analysis and calculation of the proportioning are shown below:

CALCULATIONS	OUTPUT
Density of concrete = 2400 kg/m³ Volume of cube sample = 0.15 x 0.15 x 0.15=0.003375 m³ Mass = Density x Volume = 2400 kg/m³ x 0.003375 m³ = 8.1 kg Using mix ratio = 1:2:4:0.6 =1+2+4+0.65 = 7.6 Mass constituent of one cube: Cement = $\frac{1}{7.6}$ x 8.1 = 1.07 kg Sand/Quarry dust= $\frac{2}{7.6}$ x 8.1 = 2.13 kg Granite = $\frac{4}{7.6}$ x 8.1 = 4.26 kg Water = $\frac{0.6}{7.6}$ x 8.1 = 0.64 kg To calculate for wastage, 10% of wastage was allowed: For cement = 10/100 x 1.07 = 0.11 kg For sand/quarry dust = 10/100 x 2.13 = 0.21 kg For granite =10/100 x 4.26 = 0.42 kg For water = 10/100 x 0.64 = 0.06 kg Total mass of constituent for one cube:	

Cement = 1.18 kg Sand/Quarry dust = 2.34 kg Granite = 4.68 kg Water = 0.70 kg	Mix ratio in kg 1.18:2.34:4.68

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 Preamble

This comprises the results and analysis of tests done in the process of this project. This includes particle size distribution analysis, workability test, specific gravity and compressive strength test.

4.2 Particle Size Distribution Curves and Analysis

Sieve analysis for fine and the coarse aggregates is based on BS 881:1992. The weight of aggregate percentages passing the sieves is measured and the percentages determined. The values are weighed for aggregates passing the sieves, expressed in percentage and recorded in the corresponding tables. The resultant curves for each aggregate are represented as well.

A. Coarse Aggregates

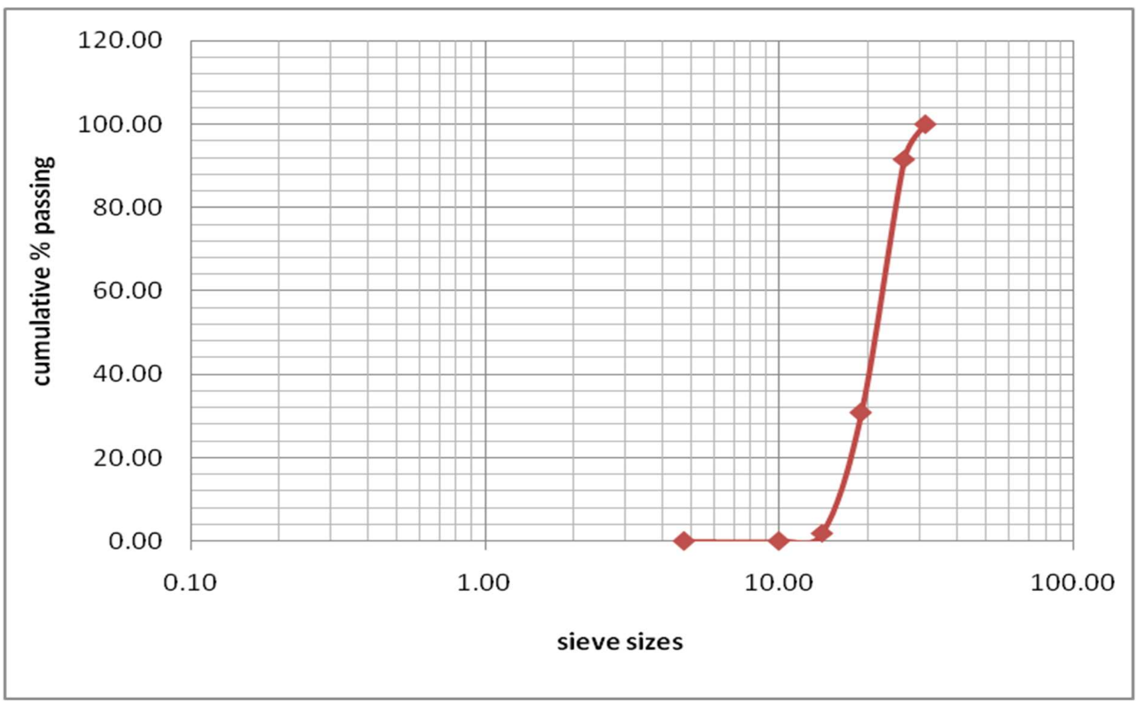

Figure 4.1: Particle Size Distribution Curve for Coarse Aggregate

B. Sharp Sand

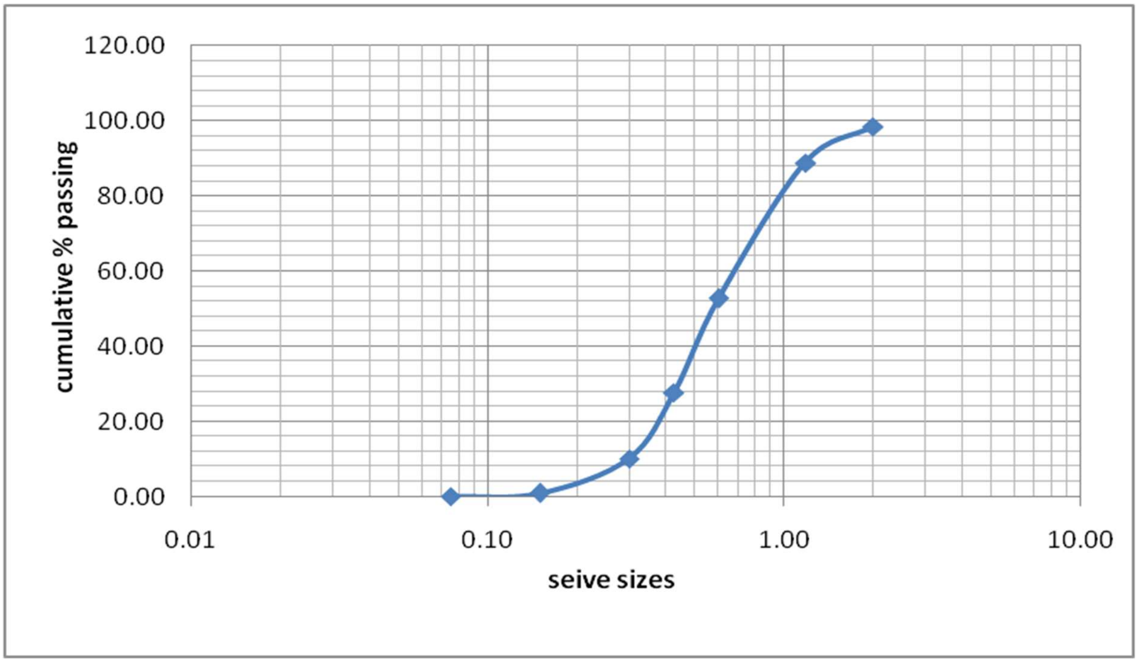

Figure 4.2: Particle Size Distribution Curve for Sharp Sand

C. Quarry Dust

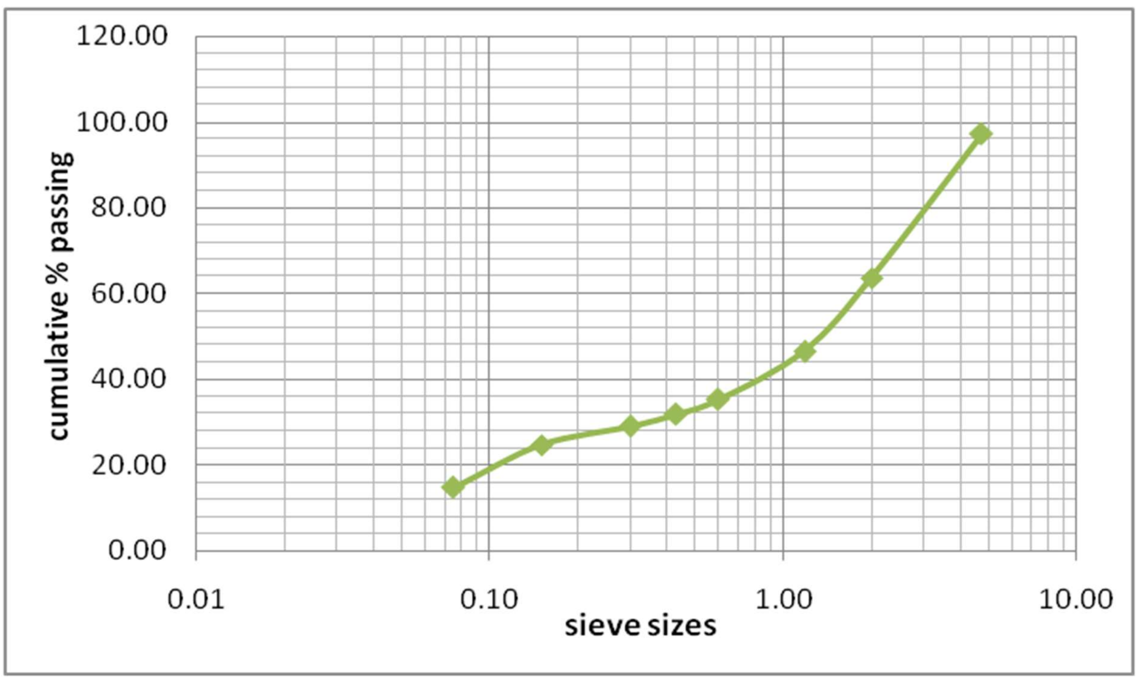

Figure 4.3: Particle Size Distribution Curve for Quarry Dust

In order to determine the grading of the aggregate samples used, equation 4.1 below is employed:

Using uniformity coefficient, Cu = $\frac{D60}{D10}$ ……………………………….(4.1)

Cu >4 for well graded gravel

Cu >6 for well graded sand

Cu <4 for uniformly graded soil containing particles of the same size

For the coarse aggregate, coefficient of uniformity, Cu = $\frac{D60}{D10} = \frac{23.00}{17.00} = 1.35$

For the sharp sand, coefficient of uniformity, Cu = $\frac{D60}{D10} = \frac{0.69}{0.28} = 2.46$

For the quarry dust, coefficient of uniformity, Cu = $\frac{D60}{D10} = \frac{1.85}{0.075} = 24.67$

Also, Coefficient of Curvature, Cc = $\frac{(D30)2}{D60\ X\ D10}$

For the coarse aggregate, coefficient of curvature, Cc = $\frac{(19)2}{23\times17}$ = 0.92

For the sharp sand, coefficient of curvature, Cc = $\frac{(0.45)2}{0.69\times0.28}$ = 1.05

For the quarry dust, coefficient of curvature, Cc = $\frac{(0.42)2}{1.85\times0.075}$ = 1.27

The above results indicate that coarse aggregate is well graded and fine aggregate is a uniformly graded sample containing particles of the same size. The quarry dust is well graded, having a range of particle sizes that allows for good compaction and production of a concrete mix with higher strength. Hence, there was no need for grading as the samples lie within the appropriate limits and are suitable for the use in concrete.

4.3 Workability Test

The workability test was conducted with a water-cement ratio of 0.6 for the various tests immediately after mixing. The height of the slump after removing the mould was measured using the standard tamping rod and measuring rule.

Height of Cone=300mm

Table 4.1: Table for Slump Values for Various Tests

Test Number	Test	Height of Collapsed Mix (mm)	Slump(mm)	Degree of Workability
1	A_{10}	250	50	Medium
2	B_{10}	249	51	
3	A_{20}	254	46	Low
4	B_{20}	258	42	
5	A_{30}	263	37	Low
6	B_{30}	262	38	
7	A_{40}	266	34	Low
8	B_{40}	267	33	
9	A_{50}	270	30	Low
10	B_{50}	271	29	
11	A_{00}	245	55	Medium

Table 4.2: Average Slump and Water absorption values for every mix

Percentage Replacement		Slump(mm)
Sharp Sand	Quarry Dust	
100	0	55
90	10	51
80	20	44
70	30	38
60	40	34
50	50	30

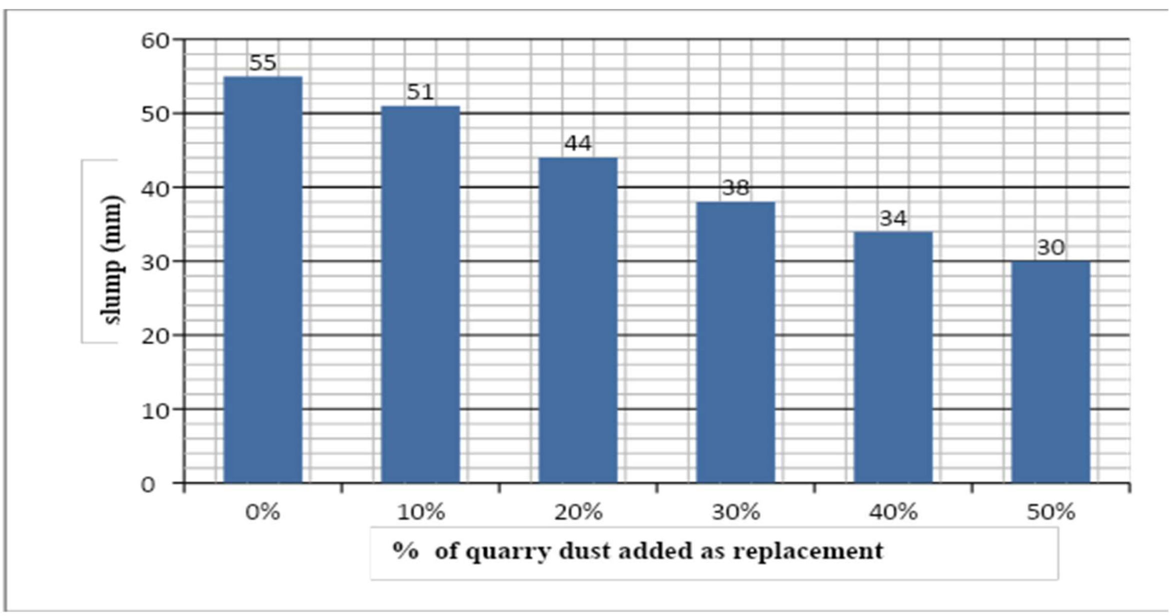

Figure 4.4: Slump Test Results for the Replacement of Sharp Sand at Various Percentages

Based on the results of the slump test, it is observed that quarry dust causes a reduction in the workability of concrete. Quarry dust requires a considerably higher amount of water as compared with sharp sand.

The samples containing quarry dust had a generally low workability as compared to the sample with 100% sand as fine aggregate alone. This shows that the high proportion of fine particles in concrete made with quarry dust reduces the water effect; so much of the water is first used to wet the fine aggregates before bonding them together. This leaves the amount of water available for bonding inadequate to create a workable mix. However, the reduction in flow ability is not detrimental as the slump falls were still within the limits of medium workability of 30-60mm if replacement of sand with quarry dust is to be suspended at 50%. Also, the test results have shown that the workability/fluidity of the concrete is decreasing when the replacement percentage of the quarry dust is increasing gradually, showing that quarry dust has slightly higher water absorption properties.

4.4 Specific Gravity Test

Tables 4.3 reveal the specific gravity of the aggregates used in this research in accordance with the specification of American Standard for Testing and Materials ASTM (C127 AND C128, 2012).

Table 4.3: Properties of Materials used.

Materials	**Properties**	**Values**
Sharp Sand	Specific gravity Coefficient of curvature(Cc) Uniformity Coefficient (Cu)	2.51 1.05 2.46
Quarry Dust	Specific gravity Coefficient of curvature(Cc) Uniformity Coefficient (Cu)	2.75 1.27 24.67
Coarse Aggregate	Specific gravity Coefficient of curvature(Cc) Uniformity Coefficient (Cu)	2.86 0.92 1.35

The coarse aggregate, sharp sand and quarry dust displayed specific gravity values of 2.86, 2.51 and 2.75 respectively. The porosity and the weight of the coarse aggregate account for its high specific gravity.

4.5 Compressive Strength Test

Cube crushing or compressive strength of the concrete cubes are calculated as the ratio of the compressive strength axial load failure to the supporting area of the cube faces.

Area of cube face = 150mm x 150mm = 22,500mm^2

4.5.1 Compressive Strength Test Result For Cubes Having 100% Sharp Sand As Aggregate (0% Quarry Dust)

This table indicates 0% replacement of sharp sand with quarry dust

Mix Ratio=1:2:4

Cube Dimension=150x150x150 mm

Table 4.4: Test Result For Cubes Having 100% Sharp Sand As Aggregate

	Parameters	7 days	14 days	28 days
1	Weight of the Cubes(kg)	8.3 8.2	8.3 8.2	8.2 8.1
2	Applied Load for Cube 1 & Cube 2 (KN)	251.1 253.1	348.8 353.3	448.9 455.0
3	Compressive strength of Cube 1 & Cube 2 (N/mm^2)	11.16 11.25	15.50 15.70	19.95 20.22
4	Mean Compressive Strength(N/mm^2)	11.21	15.60	20.08

4.5.2 Compressive Strength Test Result For 10%, 20%, 30%, 40% And 50% Replacement Of Sharp Sand With Quarry Dust In 7, 14, 28 Days.

Table 4.5: The Result of Compressive Strength for 10% Quarry Dust in 7, 14 and 28 days.

	Parameters	7 Days	14 Days	28 Days
1	Percentage Replacement	10.00%	10.00%	10.00%
2	Size of Cube (mm)	150 x 150 x 150	150 x 150 x 150	150 x 150 x 150
3	Mix Ratio	1:2:4	1:2:4	1:2:4
4	Weight of the Cubes(kg)	8.1 8.2	8.1 8.1	8.0 8.1
5	Applied Load for Cube 1 & Cube 2(KN)	254.25 261.00	353.25 357.75	463.50 445.50
6	Compressive strength of Cube 1 & Cube 2 (N/mm^2)	11.3 11.6	15.7 15.9	20.6 19.8
7	Mean Compressive Strength(N/mm^2)	11.45	15.80	20.20

Table 4.6: The Result of Compressive Strength for 20% Quarry Dust in 7, 14 and 28 days.

	Parameters	7 Days	14 Days	28 Days
1	Percentage Replacement	20.00%	20.00%	20.00%
2	Size of Cube (mm)	150 x 150 x 150	150 x 150 x 150	150 x 150 x 150
3	Mix Ratio	1:2:4	1:2:4	1:2:4
4	Weight of the Cubes(kg)	8.2 8.3	8.1 8.2	8.1 8.1
5	Applied Load for Cube 1 & Cube 2(KN)	267.75 263.25	366.75 371.25	488.25 499.5
6	Compressive strength of Cube 1 & Cube 2 (N/mm^2)	11.9 11.7	16.3 16.5	21.7 22.2
7	Mean Compressive Strength(N/mm^2)	11.80	16.40	21.95

Table 4.7: The Result of Compressive Strength for 30% Quarry Dust in 7, 14 and 28 days.

	Parameters	7 Days	14 Days	28 Days
1	Percentage Replacement	30.00%	30.00%	30.00%
2	Size of Cube (mm)	150 x 150 x 150	150 x 150 x 150	150 x 150 x 150
3	Mix Ratio	1:2:4	1:2:4	1:2:4
4	Weight of the Cubes(kg)	8.2 8.3	8.2 8.2	8.1 8.1
5	Applied Load for Cube 1 & Cube 2(KN)	272.25 279.00	380.25 391.50	546.75 537.75
6	Compressive strength of Cube 1 & Cube 2 (N/mm^2)	12.1 12.4	16.9 17.4	24.3 23.9
7	Mean Compressive Strength(N/mm^2)	12.25	17.15	24.10

Table 4.8: The Result of Compressive Strength for 40% Quarry Dust in 7, 14 and 28 days.

	Parameters	7 Days	14 Days	28 Days
1	Percentage Replacement	40.00%	40.00%	40.00%
2	Size of Cube (mm)	150 x 150 x 150	150 x 150 x 150	150 x 150 x 150
3	Mix Ratio	1:2:4	1:2:4	1:2:4
4	Weight of the Cubes(kg)	8.2 8.1	8.1 8.1	8.0 8.0
5	Applied Load for Cube 1 & Cube 2(KN)	288.00 292.50	405.00 400.50	576.00 571.50
6	Compressive strength of Cube 1 & Cube 2 (N/mm^2)	12.8 13.0	18.0 17.8	25.6 25.4
7	Mean Compressive Strength(N/mm^2)	12.90	17.90	25.50

Table 4.9: The Result of Compressive Strength for 50% Quarry Dust in 7, 14 and 28 days.

	Parameters	7 Days	14 Days	28 Days
1	Percentage Replacement	50.00%	50.00%	50.00%
2	Size of Cube (mm)	150 x 150 x 150	150 x 150 x 150	150 x 150 x 150
3	Mix Ratio	1:2:4	1:2:4	1:2:4
4	Weight of the Cubes(kg)	8.3 8.3	8.3 8.2	8.2 8.2
5	Applied Load for Cube 1 & Cube 2(KN)	306.00 310.50	409.50 423.00	605.25 596.25
6	Compressive strength of Cube 1 & Cube 2 (N/mm^2)	13.6 13.8	18.2 18.8	26.9 26.5
7	Mean Compressive Strength(N/mm^2)	13.70	18.50	26.70

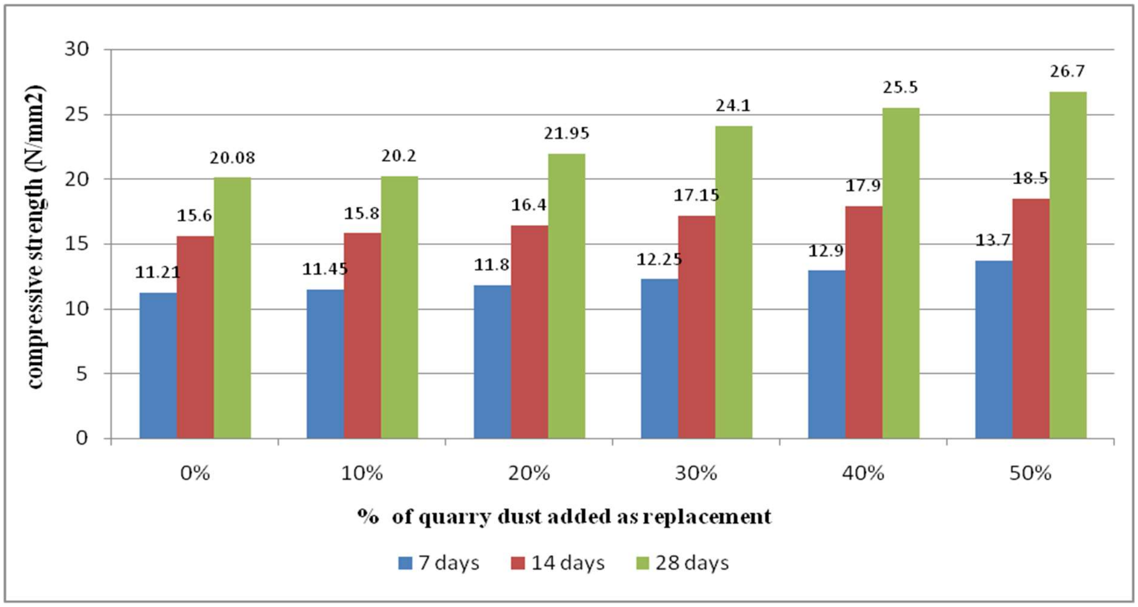

Figure 4.5: Compressive Strength Results for the Replacement of Sharp Sand at Various Percentages

From Figure 4.5, it is evident that at 50% replacement of sharp sand with quarry dust, the highest value is obtained to be 26.7 N/mm^2 after 28 days of curing, while the lowest was obtained at 10% replacement with a compressive strength of 11.45 N/mm^2 after 7 days of curing. This still gives a slightly higher compressive strength value than the conventional concrete mixture with sharp sand as the only fine aggregate.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the results of this investigation on the technical feasibility of using a by-product (quarry dust) as partial replacement of sharp sand in concrete production, the following conclusion can be drawn:

The quarry dust should be used as a replacement material for sharp sand. Quarry dust has been used for different activities in the construction industry such as for road construction and manufacture of building materials such as light weight aggregates, bricks, tiles and auto clave blocks. However, its use as rigid concrete is very much limited. As the strength properties are almost the same as sand, quarry dust should be used as fine aggregate in concrete.

Quarry dust provides fine aggregates which can be used to produce good quality concrete of high strength. At 28 days, The maximum achieved compressive strength results for conventional concrete mix averaged at 20.1 N/mm^2 for M20 grade concrete. However, the 50% partial replacement of sharp sand with quarry dust gave higher compressive strength results ranging from 13.7-26.7 N/mm^2 for M20 grade concrete during the 7 - 28 days of curing.

Concrete made with quarry dust achieved a maximum result of 26.7 N/mm^2 while that made with only sharp sand achieved a maximum result of 20.1 N/mm^2. This proves that quarry dust can act as a suitable replacement for sharp sand in concrete.

The specific gravity is almost the same both for sharp sand and quarry dust. The variation of the physical properties like particle size distribution may affect the mix design of the concrete.

Quarry dust has a higher number of finer particles than sharp sand. Hence, it requires more water in the mixture to wet the particle surfaces adequately (higher water absorption). As the replacement of the sand with quarry dust increases, the workability of the concrete is decreasing due to the absorption of the water by the quarry dust. Obviously increasing the water content in the mixture will adversely affect the quality of the concrete.

The use of the quarry fines will reduce environmental degradation in two aspects, firstly, reduction of overdependence on natural sources of aggregates i.e, river sand. Secondly, quarry dust can be put into a more useful use as fine aggregates in concrete, other than only for dumping and landfilling. Use of the aggregates will promote environmental sustainability and sustainable development.

5.2 Recommendations

From the laboratory test results and analysis, I would like to recommend that quarry dust be used as a replacement for sharp sand in concrete production by contractors in the industry. Results from this project and other works indicate that partial replacement of sand with quarry dust is possible as shown by the strength tests. However, trial casting with the proposed quarry dust should be carried out to achieve the most suitable water content and mix proportions to suit the required workability levels and strength requirements as there may be challenges working with such concrete.

Also there should be further investigations on;

1. The effect of quarry dust on the tensile strength on concrete when totally or completely replaced by sharp sand as fine aggregate

2. The behaviour of quarry dust in reinforced concrete ie. Its suitability in RC beams, slabs, columns etc. Also, its use in precast elements.
3. The physical and chemical properties of the samples of quarry dust and sharp sand from different locations so as to deduce why they and their combinations gave relatively different values.
4. The use of fly ash and admixtures like super plasticizers with quarry dust in concrete production should also be looked into to determine if significant properties can be attained most especially the increase in its workability.
5. Long term behaviour of quarry fines concrete under moderate weather conditions that is external exposure.

REFERENCES

Allam M. E., Bakhoum E. S., Ezz H. And Garas G. L., (2016). Influence of using granite waste on the mechanical properties of green concrete. *ARPN Journal of Engineering and Applied Sciences*, 11(5), pp. 2805-2811.

Anzar H. M., (2015). Improved Concrete Properties Using Quarry Dust as Replacement for Natural Sand. *International Journal of Engineering Research and Development*, *Vol. 11, issue 03*, pp. 46-52.

Balamurugan G. and Perumal P., (2013). Behavior of concrete on the use of quarry dust to replace sand – an experimental study. *IRACST Engineering Science and Technology: An International Journal (ESTIJ), Vol. 3, No. 6.*

Bye G. L., (1999). *Portland Cement*, 2nd Edition: pp. 205-206.

Devi M. And Kannan K., (2011). Analysis of strength and corrosion resistance behavior of inhibitors in concrete containing quarry dust as fine aggregate, *ARPN Journal of Engineering and Applied Sciences, Vol. 6,* pp.124-135.

Divakar Y., Manjunath S., and Aswath M. U., (2012). Experimental Investigation on Behaviour of Concrete with the use of Granite Fines, *International Journal of Advanced Engineering Research and Studies, Vol. 1, Issue 4,* pp. 84-87.

Ezeagu CA, Agusi MS. Effects of The Total and Partial Replacement of Sharp Sand with Quarry Dust on Concrete. J *Adv Res Const Urban Arch* 2018; 3(4): 1-6.

Gowrisanker D., Aslam S., Kumar R. S., Jaganathan M. And Mohan E. K., (2016). Partial Replacement of Sand with Quarry Dust and Cement with

Lime Powder. *International Journal of Engineering Science and Computing, Volume 6,* Issue No. 3, pp. 2321-3361.

Hameed M. S. And Sekar A. S., (2009). Properties of green concrete containing quarry rock dust and marble sludge powder as fine aggregates. *ARPN Journal of Engineering and Applied Science, Vol.4 (4),* pp.83-89.

Ilangovan R., Mahendran N. And Nagamani K., (2008). Strength and durability properties of concrete containing quarry rock dust as fine aggregates. *ARPN Journal of Engineering and Applied Science, Vol.3 (5)*, pp.20-26.

Krishnamoorthi A. And Mohankumar G., (2012). Preliminary studies on the Three Dimensional Characteristics of Quarry Dust Concrete. *International Journal of Applied Engineering Research*, 7(13), pp. 1479-1492.

Lohani T. K., Padhi M., Dash K. P. And Jena S., (2012). Optimum utilization of Quarry dust as partial replacement of sand in Concrete. *International Journal of Applied Sciences and Engineering Research,* 1(2):391-404.

Mahzuz H. M., Ahmed A. M. And Yusuf M. A., (2011). Use of stone powder in concrete and mortar as an alternative to sand. *African Journal of Environmental Science and Technology, Vol. 5 Issue 5*, pp. 381-388.

Mohankumar G., and Sudharsan S., (2017). Study on the Replacement of Cement and Fine Aggregate with Quarry Dust. *International Journal of Engineering Sciences & Research Technology* 6.7, pp. 460-467.

Nanda P., Das K. And Moharana N., (2010). Stone crusher dust as a fine aggregate in concrete for paving blocks. *International Journal of Civil and Structural engineering, Volume 1.*

Olanitori M. And Olotuah H., (2005). Optimum Mix Design for Minimum Concrete Strength Requirement. *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS)* 3(4): pp. 718-724.

Raman S. N., Ngo T., Mendis P. And Mahmud H. B., (2011). *High-Strength Rice Husk Ash Concrete Incorporating Quarry Dust as a Partial Substitute for Sand, Construction and Building Materials*.

Sakthivel P. B., Ramya C. And Raja M., (2013). An Innovative Method of Replacing River Sand by Quarry Dust Waste in Concrete for Sustainability. *International Journal of Scientific & Engineering Research Volume 4,* Issue 5.

Singh A., Kumar A. And Singh H., (2015). Study of Partial Replacement of Fine Aggregate by Iron Slag. *International Journal of Advanced Research, Volume 4.* Issue 7, 687-702.

SivakumarA.and Prakash M., (2011). Characteristic studies on the mechanical properties of quarry dust addition in conventional concrete. *Journal of Civil Engineering and Construction Technology,* 2(10):218-235. 20.

Sukesh, C., Krishna, K.C., Teja, P.S., & Rao, S.K. (2013). *Partial Replacement of Sand with Quarry Dust in Concrete.*

Sureshchandra H. S., (2014). Experimental Investigation on the Effect of Replacement of Sand by Quarry Dust in Hollow Concrete Block for Different Mix Proportions. *International Journal of Environmental Science and Development.*

Tanvi Lad, (2016). *What is Setting Time of Cement?* Gharpedia. https://gharpedia.com/blog/setting-time-cement.

Ukpata J. O., Ephraim M. E. And Akeke G. A., (2012). Compressive strength of concrete using lateritic sand and quarry dust as fine aggregate. *ARPN Journal of Engineering and Applied Sciences Vol 7* No. 1, pp. 81-92.

Wakchaure M. R., Shaikh A. P. And Gite B. E., (2012). Effect of Types of Fine Aggregate on Mechanical Properties of Cement Concrete. *International Journal of Modern Engineering Research (IJMER), Vol. 2,* Issue 5, pp. 3723-3726.

APPENDIX

Table A: Particle Size Distribution for Coarse Aggregate

Initial Weight of passing = 800g

Sieve size (mm)	Weight retained (kg)	Cumulative retained	Cumulative (%) retained	Cumulative (%) passing
31.50	0.03	0.03	0.00	100.00
26.50	67.00	67.03	8.38	91.62
19.00	487.25	554.28	69.29	30.72
14.00	229.98	784.26	98.03	1.97
10.00	15.27	799.53	99.94	0.06
4.75	0.05	799.58	99.95	0.05
TRAY	0.42	800.00	100.00	0.00

Table B: Particle Size Distribution for Sharp Sand

Initial Weight of passing = 300g

Sieve size (mm)	Weight retained (kg)	Cumulative retained	Cumulative (%) retained	Cumulative (%) passing
2.00	4.73	4.73	1.58	98.42
1.18	28.63	33.36	11.12	88.88

0.60	108.62	141.98	47.33	52.68
0.425	75.08	217.06	72.35	27.65
0.30	52.86	269.92	89.97	10.03
0.15	27.28	297.19	99.06	0.94
0.075	2.39	299.58	99.86	0.14
TRAY	0.42	300.00	100.00	0.00

Table C: Particle Size Distribution for Quarry Dust

Initial Weight of passing = 300g

Sieve size (mm)	Weight retained (kg)	Cumulative retained	Cumulative (%) retained	Cumulative (%) passing
4.75	8.46	2.82	2.82	97.18
2.00	100.83	109.29	36.43	63.57
1.18	51.21	160.50	53.50	46.50
0.60	33.59	194.09	64.70	35.30
0.425	10.46	204.55	68.18	31.82
0.30	8.33	212.88	70.96	29.04
0.15	13.36	226.24	75.41	24.59
0.075	29.81	256.05	85.35	14.65
TRAY	43.95	300.00	100.00	0.00

Table D: Specific Gravity for Coarse Aggregate

Density bottle	Weight of density bottle	Density bottle + dry granite	Weight of bottle + granite +water	Weight of bottle + Water	Specific gravity (GS)	Mean specific gravity (GS)
A	445.62	750	1550	1350	2.92	2.86
B	438.68	750	1550	1350	2.80	

Table E: Specific Gravity for Sharp Sand.

Density bottle	Weight of density bottle	Density bottle + dry sand	Weight of bottle + sand +water	Weight of bottle + Water	Specific gravity (GS)	Mean specific gravity (GS)
B_1	25.18	57.39	98.94	79.24	2.57	2.51
B_2	23.77	58.25	97.28	76.59	2.50	
B_3	24.32	58.70	100.38	80.00	2.46	

Table F: Specific Gravity for Quarry Dust

Density bottle	Weight of density bottle	Density bottle + dry quarry dust	Weight of bottle + quarry dust +water	Weight of bottle + Water	Specific gravity (GS)	Mean specific gravity (GS)
A_1	26.21	51.97	94.44	77.71	2.86	2.75
A_2	25.30	54.64	97.67	79.22	2.69	
A_3	25.31	53.20	94.16	76.51	2.72	