

**EFFECT OF PARTIAL REPLACEMENT OF SAND WITH QUARRY DUST ON
COMPRESSIVE STRENGTH OF CONCRETE**

BY

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CERTIFICATION

This is to certify that the project topic titled “Effects of Partial Replacement of Sand with Quarry Dust on Compressive Strength of Concrete” was done by Anene Cyprianmichael Onyedikachi with registration number (NAU/2017224060) in the Department of Civil Engineering, Nnamdi Azikiwe University, Awka, Anambra State.

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APPROVAL PAGE

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DEDICATION

This work is dedicated to God Almighty.

ACKNOWLEDGEMENT

Special thanks goes to God Almighty for giving me the strength to complete this work and also for His guidance and protection throughout my stay in Nnamdi Azikiwe University. Also, I will like to express my profound gratitude to my parents; Mr and Mrs Michael Anene for their moral support, constant prayers throughout my stay in school, special thanks goes to my siblings Odinaka Udoh for their encouragement during trying times of my academic pursuit.

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ABSTRACT

The study was done to evaluate the effect of partial replacement of sand with quarry dust on compressive strength of concrete. Quarry dust sample was used to partially replace sand in an increasing order of 5%, 10%, 15%, 20% and 25% by weight of sand. Tests were conducted to evaluate the effect of partial replacement of sand with quarry dust on compressive strength of concrete. The test conducted includes: sieve analysis test, specific gravity test, fineness test, soundness test, aggregate impact and crushing value test, slump test and compressive strength test. Results obtained from sieve analysis test revealed that sand, quarry dust and granite were classified as A-2-6, A-1-b and A-1-b according to AASHTO Soil Classification System, SM, GM and GC according to Unified Soil Classification System, the specific gravity of the samples were 2.55, 2.75 and 2.61, the impact and crushing value of the aggregate were 27.6% and 26.1%, the fineness and soundness of cement was 3% and 0.95%. Results obtained from slump test revealed that the slump of the concrete decreased with consistent addition of quarry dust to the concrete while for the compressive strength test, it was observed that the compressive strength of the concrete increased from 5% addition of quarry dust to 20% addition of quarry dust to the concrete beyond 20% quarry dust content, the compressive strength of the concrete was found to decrease. The study therefore discourages the use of quarry dust beyond 20% in the production of concrete as at 20% quarry dust content, the hardened density and compressive strength of the concrete was undermined.

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LIST OF SYMBOL & ABBREVIATION

QD-Quarry Dust

G_s-Specific Gravity

AASHTO-American Association of State Highway and Transportation Officials

USCS-Unified Soil Classification System

ASTM-American Society for Testing and Material

BSL-British Standard Light

BSH-British Standard Heavy

D₁₀-Particle Size such that 10% is finer than the Size

D₃₀-Particle Size such that 30% is finer than the Size

D₆₀- Particle Size such that 60% is finer than the Size

C_u-Coefficient of Uniformity

C_c.Coefficient of Curvature

SC-Clayey Sand

SM-Silty Sand

GM-Silty Gravel

GC-Clayey Gravel

GW-Well Graded Gravel

GP-Poorly Graded Gravel

SP-Poorly Graded Sand

SW-Well Graded Sand

CL-Inorganic Clay of Low Plasticity (lean clay)

CH-Inorganic Clay of High Plasticity (fat clay)

ML-Silt of low Plasticity

MH- Silt of High Plasticity

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Concrete is one of the most widely used composite materials Ajam, et al., (2020). It is a composite mixture of binding materials (cement), coarse aggregate (gravel), fine aggregate (sand) and water in their correct proportion. The importance of fine aggregate (Natural river sand) in concrete production cannot be over emphasized. As a result of its relative importance in concrete production, the demand for it is very high among the construction industry. Also, Nigeria as one of the developing nations is seriously experiencing excessive excavation and mining of natural river sand which has negative environmental consequences. Among these are erosion and failure of river banks, lowering of river beds and damage of structures situated closer to the rivers, saline water intrusion into the land and coastal erosion are the major adverse effects due to intensive river sand mining.

Globally, there is a growing demand for sustainable development to guarantee a rational use of the earth resources Cavaleri, et al., (2003). Vast demands for mineral resources have led to the proliferation of quarrying industries in Nigeria. These quarrying activities engaged by quarrying industries have substantial impact on the environment and societal wellbeing Cavaleri, et al., (2003). Quarrying of stone intended for construction related and civil engineering application also include the extract of stone for ornamental products, stone to be processed as dimensioned stone or as paving or cladding slab resulting in significant amount of waste rock including coarse and fine materials. The latter (coarse material) is generally the result of cutting machine in quarries. Amit et al. (2015) reported that quarry dust is considered a waste material obtained from crusher plants and has potential to be used as partial replacement of natural river sand in concrete. Owing to these, there is need to investigate the use of quarry dust

as alternative material which can totally or partially replace natural river sand in concrete production.

In other to ensure rational use of earth resources, proffer solutions to problem associated with disposal of quarry dust as waste mineral aggregate, tackle problems related to excessive excavation and mining natural river sand which poses dire environmental consequence, this study will therefore investigate the effect of quarry dust as an alternative material for partial replacement of sand on compressive strength of concrete.

1.2 Statement of Problem

Globally, there is a growing demand for sustainable development to guarantee a rational use of the earth resources Cavaleri, et al., (2003). Vast demands for mineral resources have led to the proliferation of quarrying industries in Nigeria. These quarrying activities engaged by quarrying industries have substantial impact on the environment and societal wellbeing Cavaleri, et al., (2003).Nigeria as one of the developing nations is seriously experiencing excessive excavation and mining of natural river sand which has negative environmental consequences. Among these are erosion and failure of river banks, lowering of river beds and damage of structures situated closer to the rivers, saline water intrusion into the land and coastal erosion are the major adverse effects due to intensive river sand mining.

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1.3 Aim and Objectives of Study

The aim of study is to evaluate the effect of partial replacement of sand with quarry dust on compressive strength of concrete while the objectives are:

- 1 Ascertain the efficacy and feasibility of quarry dust as a partial substitute for sand.
- 2 Characterize the additive (quarry dust), fine aggregate (sand) and coarse aggregate (granite) employed in the study.
- 3 Produce concrete with variation in the quantity of quarry dust.
- 4 Study the effect of partial replacement of sand with quarry dust on mechanical properties of concrete.
- 5 Test the finished concrete for workability, density and compressive strength.
- 6 Determine the maximum amount of quarry dust required for optimum improvement of strength properties of concrete.
- 7 Draw conclusion and make recommendation in the light of the findings obtained from the research.

1.4 Scope of Study

This study is centered on assessing the effect of partial replacement of sand with quarry dust on compressive strength of concrete. Fine aggregate (sand) will be partially replaced with quarry dust in a stepped increase of 5% to 25% by weight of sand. The concrete grade to be used is 1:2:4, all concrete components including additive (quarry dust) will be subjected to laboratory testing. Laboratory testing includes: Sieve analysis test for fine, coarse aggregate and additive (quarry dust), aggregate crushing and impact value test (ACV and AIV), specific gravity of fine, coarse aggregate and additive (quarry dust), soundness and fineness test of cement, slump or workability test of fresh concrete. To evaluate the effect of partial replacement of sand with quarry dust on strength properties of concrete, compressive strength test of the hardened concrete will be conducted.

1.5 Significance of Study

The findings obtained from partial replacement of sand with quarry dust will be significant in the followings ways:

- 1 Ensure rational use of earth materials.
- 2 Proffer solutions to problem associated with disposal of quarry dust as waste mineral aggregate.
- 3 Tackle problems related to excessive excavation and mining natural river sand which poses dire environmental consequence.
- 4 Foster economy in concrete production.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter reviews the relevant literature on the topic of study. It presents the work of other researchers in the field of science and engineering as they relate to this study which focuses on the effect of partial replacement of sand with quarry dust on the strength properties of concrete.

2.2 Concrete

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

Concrete is a widely used construction material in civil engineering projects throughout the world for the following reasons: It has great resistance to water, structural concrete elements can be formed into a variety of shapes and sizes and it is usually the cheapest and most readily available material for the job Olanipekun, (2006). Light Weight Concrete (LWC) can be defined as a concrete with a density of 1840 kg/m^3 (115 lb/ft^3). According to BS 5328 (1997), it is a hardened concrete having an oven dried density greater than 2000 kg/m^3 but not exceeding 2600 kg/m^3 . It has a setting time of 30 - 90

minutes depending upon the moisture in the atmosphere and fineness of cement among others.

According to Stanley and Bond (1999), the oldest concrete discovered dates from around 7000 BC, and was found in 1985 when a bulldozer uncovered a concrete floor during the construction of a road at Yiftah El in southern Galilee, Israel. It was also reported that the Romans also developed the concept of light weight concrete by casting jars into wall arches as well as the use of pumice aggregates. However, though concrete might have existed as early as 7000 BC, the massive use of it might have started around the 19th century.

2.2.1 History of Concrete

The first major concrete users were the Egyptians in around 2,500BC and the Romans from 300BC the Romans found that by mixing pink sand like material which they obtained from Pozzuoli with their normal lime-based concretes they obtained a stronger material. The pink sand turned out to be fine volcanic ash and they had unintentionally produced the first pozzolanic cement. Pozzolanic is any siliceous and aluminous material which possesses little or no cementitious value in itself but will, if finely divided and mixed with water, chemically react with calcium hydroxide to form compounds with cementitious properties.

2.2.2 Structural Benefits of Concrete

Concrete provides so many benefits among which include its low cost when compared to steel. By incorporating waste materials for its production, the cost can significantly reduce hence leading to a significant reduction in the total construction cost. Also, repairing work for concrete is easier and more economical than other construction materials. It is durable and can also be recycled for use in other areas such as a filler material for road construction. Unlike wood, for example, which can rot and decay and is susceptible to natural disaster, concrete requires little or no maintenance and can stand up

to the toughest winds, the harshest of weather conditions and resist fire with ease. Concrete can also have a decorative function. Concrete does not burn and therefore provides comprehensive fire protection including life safety, protection of properties and of the environment. Concrete is one of the more sustainable building materials when both the energy consumed during its manufacture and its inherent properties in-use are considered. Concrete's thermal mass can be used to avoid or reduce temperature swings in the building and to eradicate the need for energy guzzling air conditioning systems. Dense, heavyweight concrete provides the highest amount of thermal mass (European Concrete Platform ASBL, 2009). Another important feature of concrete is that it is environmentally friendly. Concrete is one of the best, most natural building materials to use when considering the environmental impact of construction. The use of waste in the production of concrete helps to reduce environmental pollution and also addresses the problem of waste management. Concrete walls and floors are effective storage heaters, absorbing free heat from the sun during the daytime and releasing heat at night. Concrete stores heat in the winter and cools buildings in the summer, creating optimum comfort conditions for the occupants European Concrete Platform ASBL, (2009). Concrete in buildings provides exceptional levels of security and safety.

2.3 Component of Concrete

Concrete is a composite mixture of several materials and its performance during construction significantly depends on the properties of these materials, this material is highlighted below:

2.3.1 Cement

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. Cement is a substance that is used in construction as a binder for bonding mineral fragments into a compact whole. According to the Energy Technology

Systems Analysis Programme (ETSAP, 2010), global cement production has grown steadily from less than 200 million tonnes in 1950 to more than 2500 million tonnes in 2006. 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, (2013). There are different types of cements with different properties and performance. BS EN 197-1 (2000) stated that the choice of cement, especially the type and/or strength class, based on the requirements for durability largely depends on the exposure and type of construction in which it is incorporated. The most common type of cement used in construction is the Ordinary Portland Cement (OPC) other types of cement include: Portland composite cement, blast furnace cement, pozzolanic cement, composite cement.

2.3.2 Mechanism for Cement Production

The manufacture of OPC involves two stages, notably, clinker production and cement grinding. In the clinker production stage, raw materials are fed to the kiln system to produce clinker. These materials are crushed, grounded and mixed to obtain a homogenous blend. During this process, significant amount of carbon dioxide (CO₂) is released to the atmosphere. Shivaram (2014) stated that producing a tonne of cement will generate approximately a ton of CO₂. This stage ends with the cooling of the clinker in a cooler system. In the second stage, the clinker is grounded with the addition of

other minerals to obtain cement with desired properties such as setting time and strength grade. According to Cement Sustainability Initiative/European Cement Research Academy (CSI/ECRA, 2009), the grinding of clinker with additives to produce cement requires only electricity (no heat) and accounts for about 38% of total electricity used. Table 2.0 shows the physical, chemical, and mechanical properties of Portland cement. As can be seen from the table, Portland cement contains over 60% of lime (calcium oxide) which makes cement sound and also provides strength to the cement. It is the excess of this lime that reacts with pozzolana in the presence of moisture to produce cementitious properties.

Table 2.0 Physical, Chemical and Mechanical Properties of Ordinary Portland Cement Salas et al., (2009).

Chemical Composition	Percentages (%)	Physical Properties	Magnitude or Value	Mineralogical Composition (%)	Percentages (%)
SiO ₂	21.27	Density (kg/m ³)	3,050	C ₃ A	53.29
Al ₂ O ₃	4.63	Blaine Fineness (m ² /kg)	377	C ₂ S	20.79
Fe ₂ O ₃	3.96	Mechanical Properties		C ₄ AF	12.05
CaO	63.05	Compressive Strength (Mpa)		C ₃ A	5.56
MgO	1.56	1 day	10.1	Free CaO	0.54
Na ₂ O	0.16	3 day	23.3		
K ₂ O	0.18	7 day	36.0		
SO ₃	1.75	28 day	46.7		

It is seen that the major products of the hydration reactions, which primarily account for the strength of concrete, are the calcium silicate hydrates (C3S and C2S) 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.

2.3.3 Properties of Portland cement

I. Fineness of cement

As hydration take place at the surface of the cement, it is the surface area of the cement particles which provide the material available for hydration. The rate of hydration is controlled by fineness of the cement. For a rapid rate of hydration, a higher fineness is necessary. (Anna, 1994) Investigated the effect of fineness of cement and eventually came up with the following observation:

- a) Higher fineness require higher grinding (High cost implication)
- b) Finer cement deteriorate faster upon exposure to atmosphere
- c) Finer cement are very sensitive to alkali-aggregate reaction
- d) Finer cement require more gypsum for proper hydration
- e) Finer cement requires more water.

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence fastens the development of strength. Fineness of cement is determined by permeability. For example in the blaine air permeability method, a known volume of air is passed through cement. The time is recorded and the specific surface is calculated by a formula. Fineness is expressed in terms of specific surface of the cement (Cm^2/gr). For OPC specific surface area is 2600-3000 Cm^2/gr . This test is conducted as per BS EN196-6:1995.

II. Setting Time of Cement

Setting time refers to a change from liquid state to solid state. During setting time, cement paste acquire some strength Gartner, et al. (2012). The water content has a marked effect on time of setting. In acceptance test for cement, the water content is regulated by bringing the paste to a standard condition of wetness and this is referred to as “normal consistency”. Normal

consistency of OPC ranges from 20-30% by weight of concrete. Vicat apparatus is used to determine normal consistency. Normal consistency is that condition for which the penetration of a standard weighed plunger into the paste is 10mm in 30sec. In practice, the terms initial set and final set are used to describe arbitrary chosen time of setting. Initial set indicates the beginning of a noticeable stiffening and final set may be regarded as the start of hardening (or complete loss of plasticity). It is the also the period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould. Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression. The setting time test is carried out using the Vicat apparatus as per BS-EN 196 part3 (1995). The results of the test should comply with the requirements of BS-EN 197 part1 (2000), which recommend a minimum of 60 minutes and a maximum of 10 hours as the initial and final setting times of ordinary Portland cement respectively. (Gartener, et al. 1989) summarized the factors affecting setting time as:

- a) Temperature and Humidity.
- b) Amount of water
- c) Chemical composition of cement
- d) Fineness of cement (the finer the cement, the faster the setting)

Marthong, (2012), investigated that the addition of saw dust ash in OPC grade 42.5 had increased the initial and final setting times. This was attributed to the low rate of hydration in the paste containing the saw dust ash.

III. Soundness of Cement.

Soundness is referred to as the volume stability of cement paste. The cement paste should not undergo large changes in volume after it has set. Free CaO and MgO may result in unsound cement Chanadan, (2019). Upon hydration, C and M (calcium and magnesium) will form CH and MH with volume increase thus cracking Gartner, et al. (2012). Since unsoundness is not apparent until several months or years, it is necessary to provide an accelerated method for its determination which include:

- a) Lechatelier Method where only free CaO can be determined.
- b) Autoclave Method where both free CaO and MgO can be determined.

In the soundness test a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is sped up and can be detected. Soundness means the ability to resist volume expansion. For ordinary Portland cement, BS-EN 197 part1 (2000) has specified a maximum expansion of 10mm. The work of Chowdhury et al., (2015) indicated that the soundness of cement was improved with the addition of saw dust ash as partial replacement. In the research, cement was replaced by the ash within the range of 5% to 30% and the soundness was found to increase with an increase in the ash content.

IV. Strength of Cement and it's effect on Concrete.

Strength test are not carried out on neat cement paste because it is very difficult to form this paste due to cohesive property of cement. Strength test are carried out on cement mortar prepared by standard gradation (1 part cement + 3 part sand + $\frac{1}{2}$ part water). The strength of cement is tested through compression, direct tension or flexure tests. According to BS-EN 196 part1 (1995), prisms of size 40mmx40mmx160mm are cast of a cement sand mortar produced using 1:3 mix ratio. The test prisms are tested for compressive strength at 2days and 28 days. According to BS 5826, cement mortar is classified into M4, M6, and M12 with compressive strengths of

4N/mm², 6N/mm², and 12N/mm² respectively at 28 days. BS EN 998 part 2 (2003) had also provided similar compressive strength.

(Chandan, 2019) Investigated on the effect of grade of cement on compressive strength of concrete where it was reported that the compressive strength is largely dependent on the grade of cement as cement grade 52.5 produces comparatively higher compressive strength than cement grade 42.5 and 32.5 respectively. Similar observation was also confirmed by Gideon, et al. (2015).

V. Hydration of Ordinary Portland Cement (OPC).

It is the chemical reaction of cement with water. As the water comes into contact with cement particles, hydration reactions start immediately at the surface of the particles. (Gartener, et al. 1989). Although hydrate such as C-H are formed, process of hydration is a complex one and results in reorganization of the constituents of original compound to form new hydrated compounds. Gartener, et al. (2012) states that at any stage of hydration, the hardened cement paste (HCP) consist of:Hydrate of various compounds referred to collectively as Gel, Crystals of calcium hydroxide (CH), Some minor hydrate compound, Unhydrated cement, Residue of water filled spaces-pores.

Jenings, et al. (2014) opined that upon hydration, C₃S, C₂S and CH are formed which become an integral part of the hydration products. CH does not contribute very much to the strength of Portland cement. According to Jenning, et al. (2014) C₃S having a faster rate of reaction accompanied by greater heat of hydration develops early strength of the paste. On the other hand, C₂S hydrates and hardens slowly so results in less heat generation and develops most of the ultimate strength. Gartener, (et al. 2012) summarized hydration process as:

Immediately after mixing with water

- a. Reaction occurs around particles referred to as early stiffening.
- b. Accompanied by formation of skeletal structure referred to as first hardening
- c. Gel infilling known as later hardening.

2.3.4 Water

Water used in the concrete reacts with cement and causes it to set and harden. It also facilitates mixing, placing and compacting of fresh concrete. Abruckle, (2007), states that mixing water for concrete is required to be fit for drinking or to be taken from an approved source. Findings in previous works (Ezeokoko, 2014: Bert-Okonkwo, 2012: Neil and Ravrinda, 1996) suggest that, to achieve the required workability and strength of concrete in both its fresh and hardened state, the water used for mixing and curing needs to be of appropriate quality, that is, it should be free from impurities such as suspended solids, organic matter and salts which may adversely affect the setting, hardening, strength and durability of the concrete.

Water is used in the production of concrete, washing of aggregates, mortar and bricks formation. Water is also used for construction operations like casting, painting, terrazzo finishing, plastering and other operations. After casting of concrete, water is poured on the concrete to give it strength in a process known as curing. After completion of the building, water is used for cleaning the building in readiness for inspection, handing-over and occupancy. As a result of these facts, it is obvious that water is very important in building construction and related activities. Neil and Ravindra, (1996) further define water to cement ratio (w/c) as the weight of water divided by the weight of cement.

According to (BS8110: Part 1, 1997), the amount of water required in a concrete mix is the minimum for complete hydration of cement. If such concrete is fully compacted without segregation, it would develop the maximum attainable strength at a given age. The BS8110, (1997) further states that the water-cement ratio of approximately 0.25 weight is required

for full hydration of cement. Omuvwie and Mosaku, (2010) suggest that if the water is not properly managed, it can turn around to inflict serious structural damage to the building over time and that such damage can lead to structural failure of the building and eventual collapse aside of the economic drain on client, safety risks as well as aesthetic devaluation.

2.3.5 Aggregate

Aggregate is a collective term for the mineral materials such as sand, gravel and crushed stone that are used with a binding medium to form concrete. Aggregate may be defined as an inert filler material in concrete. It is a granular material, such as sand, gravel, crushed stone, and iron blast-furnace slag, used with a cementing medium to form a hydraulic cement concrete or mortar (ACI 318, 1995). According to Gambhir (2013), the reasons of using aggregate in the construction of concrete are due to the economic reasons, volume stability and durability of concrete. 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 so much finer material as allowed from the various sizes. Table 2.1, classifies aggregate according to the production method, Petrological characteristics, unit weight, and according to the

particle sizes. Depending on the mix design, aggregate may occupy about 70 - 80 percent of the total volume of concrete.

Table 2.1: General Classification of Aggregate Gambhir, (2013).

No	Classification Type	Examples
1.	Natural Aggregates (no change in their natural state except for crushing, grading, or washing)	Sand, gravel, crushed stone, lime rock.
	By-product aggregates	Blast-furnace slags and cinders, fly ash
	Processed aggregates (heat treated) Colored Aggregate	Perlite, burnt clays, shales, processed fly ash Glass, ceramics, manufactured marble
2.	According to Petrological Characteristics	
	Igneous Rocks	Quartz, granite, basalt, obsidian, pumice, tuff
	Sedimentary Rocks	Sandstone, limestone, shale
	Metamorphic Rocks	Marble, slate, schist
3.	According to Unit Weight	
	Normal Weight Aggregates	Sand, gravel and crushed rock
	Light Weight Aggregates	Slag, slate
	Heavy Weight Aggregates	Hematite, barite magnetite, steel and iron punchings
4.	According to Particle Size	
	Fine Aggregate	Sand
	Coarse Aggregate	Gravel

Generally, fine aggregates include particles that pass through 4.75mm sieve and retain on a 0.075mm sieve such as river sand. Their functions include filling the voids between the coarse aggregate while holding them

in suspension, producing workable and uniform concrete mixtures. On the other hand, coarse aggregate are those particles retain on a 4.75mm sieve and use as an inert filler material.

2.3.6 Properties of Aggregate

Aggregate 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:

1. Shape
2. Texture
3. Size gradation
4. Moisture content
5. Specific gravity
7. Bulk unit weight
8. Strength of aggregate
9. Soundness
10. Wear resistance
11. Alkali-aggregate reaction
12. Impurities
13. Unsound particles

2.4 Additive (Quarry Dust)

Quarry dust, also referred to as mechanical sand is defined as residue, tailing or other non-volatile waste material after the extraction and processing of rocks from quarries to form fine particles with less than 4.75mm diameter. Out of the different chipping wastes, chipping dust is produced in abundance; making up about 25% of the output of each crusher unit Sarvade and Nayak,(2014). Quarry dust is a byproduct from the crushing process of stone (blue metal) which is found abundantly from rock quarries at low cost. They are residue left after the extraction and processing of rocks to form fine

particles less than 4.75mm Ilangovan, Mahaendran and Nagamani, (2008). Quarry dust has been proposed as an alternative to river sand that gives additional benefit to concrete as it is known to increase the strength of concrete over concrete made with equal quantities of river sand, though it causes a reduction in the workability of concrete Ukpata, Ephraim and Akeke, (2012). Quarry dust which is considered as a waste material causes an environmental due to disposal problem.

2.4.1 Process of Quarry Dust Production

I. Extraction

With the exception of slag and other manufactured aggregates, most materials for aggregate production come from bedrock or unconsolidated deposits. Some of the methods involved in the production of aggregates are mining and quarrying. Surface mining with either strip mining or open pit; here draglines and large stripping shovels is employed to remove overburdens and expose a relatively horizontal or vertical over-crop. Sometimes it is only a few tens of meters and also the use of hand trucks, excavators and high capacity conveyors to mine the aggregates.

In addition to surface mining, underground mining can take place in coal mine operation as well as aggregate mining; which are room and pillar and long wall mining. The long wall mining involves the use of mechanized shearers to cut and remove the coal or aggregate as the case may be at the face, which can vary in length from 100-250meters. Self-advancing, hydraulic powered supports temporarily hold up the roof while the coal is extracted. The roof over the area behind the face, from which the coal has been removed, is then allowed to collapse.

II. Quarrying

Quarrying could be done in diverse methods such as hard rock mining, using rock drills explosion of dynamite and other sophisticated methods. The process could also be open pit or surface methods, underground and solution mining. The mining method used depends on the particular mineral, the

nature of the deposit and the location of the deposit. Each mining method has its own impact on the environment Ukpong, (2012). The major extraction processes of aggregates are the quarrying methods. Quarrying is an act of exploring and exploiting stone from rock. It is a form of surface mining used when the rock is close to the surface of the land. Quarry is a type of open pit mine from which rocks or minerals are extracted. Quarries are generally used for extracting building materials such as dimension stone, construction aggregate, riprap, sand and gravel. They are often collocated with concrete and asphalt plants due to the requirement for large amounts of aggregate in those materials. Open mines that produce minerals are typically referred to as open pit mines.

Types of rock extracted from quarries include; chalk, china clay, cinder clay, coal, construction aggregate (sand and gravel), coquina, Diabase, Gabbro, Granite, Gritstone, Gypsum, Limestone, Marble, ores, phosphate rock, sandstone, slate etc.

Process of quarrying includes:

1. Face profiling survey: This is a detailed three-dimensional survey of quarry face. It allows the explosives engineers to design the blast and to plot where the shot holes should be drilled so that the blast can be carried out safely and efficiently.

2. Drilling: This is the drilling of the number of shot holes required, at the marked spots corresponding to the hole positions on the blast design, at the angles and depths required. This is done by the drilling contractor, using an air operated drilling rig.

3. Shot holes survey: This is to check that the drilled shot holes correspond to the blast design and the two surveys are combined to allow the blast engineer to work out how each shot hole is filled with explosives.

4. Explosion: The detonator card is placed in each hole. The holes are then loaded with high explosives to within a few meters of the top. The remaining depth is “streamed” with quarry dust or fine aggregate. The detonators are connected to the electric trigger wire and the circuit is checked. After the

site is cleared, sirens are sounded and a final safety check is carried out before the fire is set off the explosive.

5. Inspection of muck-heap: This is to check that all the shot holes are fired correctly. The face shovel or loader then tidies up the shot pile and starts to load the dumper trucks that take the rock to the crusher. Boulders which are too big to go through the crusher are set aside for secondary breaking which is typically done using hydraulic digger fitted with a rock hammer, though crawler cranes with steel drop balls may be used in some quarries.

III. Crushing

The first stage in most operations is the reduction and sizing by crushing. Crushing is used to remove soft and friable particles from coarse aggregates. This process is sometimes the only means of making materials suitable for use. Unfortunately, with any process some acceptable material is always lost, and removal of all harmful particles may be difficult or expensive. Intensive particle-to-particle interaction takes place during crushing operations, particularly when crushers are choke-fed Guimaraes et al., (2007). Crushing can be done in three or four stages: Primary (First stage), Secondary (Second stage), Tertiary (third stage) and in some quarries, a quaternary (fourth stage). Crushed rock, or product, is transported along the process line on conveyor belts or down chutes.

The primary crusher is fed via a chute and vibrating feeder. The base of the feeder is made of steel “grizzly” bars and it is here that the first screening operation is actually done. Fine material and dust produced by the blast, along with any remaining subsoil or weathered rock from the top of the quarry face, drops through the bars onto a separate conveyor belt and onto a stockpile. This screened material is called scalping and is used as rock fill. The scalped product is crushed once to transform the block into broken stone. The process is repeated as many times as necessary to obtain the desired fragment size. The output from the primary crusher is conveyed onto the primary stockpile from which the secondary crusher is fed. The resulting

material is then screened by a screen house just after the secondary crusher to obtain aggregates of the desired grade. The larger pieces that are rejected are returned to the crusher and subsequently re-screened, with the process continued until the desired size is obtained.

Secondary, Tertiary and quaternary crushers are generally gyratory, or cone crushers. These operate on the principle of steel mounted on an eccentric bearing and vertical shaft assembly. Rotation of the eccentric assembly makes the mantle gyrate within a static outer concave. There is a gap between the mantle and the concave. The shape of the gap is tapered towards the base. As the mantle gyrates inside the concave, the gap between it and the concave at any one point opens and closes on each gyration, this produces the required crushing action. Stone is fed in at the top and crushed product falls out from the bottom of the cone. The mantle can be raised or lowered within the concave, allowing the gap, and therefore the size of the crushed product, to be varied to a limited degree. If the crusher is jammed by a stray bit of steel e.g., a digger bucket tooth, the mantle automatically moves down to clear the obstruction.

Each stage of crushing produces progressively smaller sized stones. In order to produce a usable end-product, the crushed rock has to be screened into various size categories. Some categories of aggregates, such as sand and gravel, undergo complementary processing including washing, cycloning and scrubbing, primarily to make them cleaner. Screening is carried out at various stages in the crushing process. Screens which are made to vibrate by a rotating transverse shaft are usually multi-deck i.e. two or more screen meshes are stacked vertically within the screen frame. The whole screen is coupled to its support frame by springs or resilient rubber mountings. Screen decks are mounted at an angle so that the aggregate moves them down. Aggregate is fed onto the high end of the top deck and the vibration causes the aggregate to jiggle down the screen until it either drops through a mesh aperture or falls off the end of a deck. The aggregate is then sorted or

“screened” according to the mesh sizes fitted, from large aperture mesh at the top, to small aperture mesh at the bottom.

Final screens are typically mounted in a screen house over large bins or hoppers into which the different sizes or grades of aggregate are fed. The hoppers are roused on legs so that trucks can drive under them to be loaded. Material is continually drawn from the storage bins for immediate use (e.g. in a coating plant) or for transfer, either by dump truck or conveyor, to storage stockpiles in the quarry to different grading category.

2.4.2 Quarrying Products

A stone quarry typically produces the following products:

1. Large size blocks blasted from the quarry face, from approximately 0.5m³ (approximately 0.36 tonne weight) to 1.25 m³ (approximately 5-6 tonne weight) are called rip rap or rock armour and are used in coastal and river flood defense schemes to shore up sea fronts and river banks.
2. Rubble drawn direct from the shot pile is called face fill and is used as large scale fill on construction sites.
3. Material screened immediately prior to primary crushing is called scalping or grizzly which is again used as fill on construction sites.
4. The direct unscreened output from a crusher contains a complete mix of sizes from dust up to the maximum size that the crusher can pass. Output from the primary and secondary crushers is fed, unscreened, to intermediate or separate stockpiles. Material drawn from these stockpiles is called crusher run and is used for construction fill.
5. Screened out fine material from the secondary crusher is called blinding. Some screens have multiple decks and can screen out several grades of blinding. As with crusher run, blinding materials contain a mix of sizes, from the maximum size that the screen mesh can pass down to dust. Blinding, because it is finer than crusher run, is used for final shaping up of

construction sub bases, particularly in road construction, where the sub base is the last unbound layer before coated materials are laid.

6. Screened aggregate (ballast) for concrete.

7. Screened aggregate is heated and mixed with bitumen, according to certain recipe proportions to make different grades of bituminous macadam or mixed with sand, ground limestone filler and bitumen to make hot rolled asphalt colloquially called bitmac or tarmac. The words tar or tarmac, though very frequently used, is incorrect as tar is no longer available. For coated materials, bitumen, derived from the distillation of petroleum crudes has been in almost universal use as a binder for the last four to five decades.

2.4.3 Machineries used in Quarries

1. Pneumatically operated channelers
2. Gadding machines
3. Wire saws
4. Dump trucks
5. Surface mining vehicles

2.4.4 Crushed Rock Aggregate

Crushed rock aggregate is produced from quarries that are much larger and deeper than sand and gravel pits. Crushed rock aggregate is normally extracted using blasting. The excavated material is delivered to a production plant in a form suitable for processing Mitchell, (2001). Production of crushed rock aggregate involves screening (Scalping) to remove fines and wastes material followed by crushing and screening to produce material with specified site grades. Crushing is carried out to reduce the size of the excavated material from large blocks (up to a metre across) to a size finer than 20 to 50mm.

The stone and aggregate industry creates crushed aggregate using a lengthy process. The stone must be mined in a quarry and then transported to the rock crusher which begins the process of crushing the larger stones into more manageable pieces. As the stones leave the rock crusher, they are sent

to a rock conveyor for transport to the impact crusher, where they will be broken down further. After being processed in the impact crusher, the aggregate is screen for sizing. This process might be handled in a screen shaker or during the washing process in an aggregate washer. If the aggregate is sufficiently crushed, it is transported to the storage area. If the stone is not crushed to the desired size and type, the process is repeated or the stone is transported to other equipment for further processing. So much machinery, time and labour are involved in the creation of crushed aggregate that it can become a very expensive product. Despite the cost, aggregate products are the main component of concrete construction. In the majority of cases, crushed aggregate is used locally to prevent further costs being incurred in transporting the material.

The processes employed in crushed aggregate production include:

1. Drilling
2. Blasting
3. Loading
4. Transporting
5. Crushing
6. Screening
7. Product handling and storage

2.5 Environmental Impact of Quarrying Activities

Several wastes are generated when rocks are extracted from the earth. Environmental disturbance as a result of mining and processing activities constitute a major threat to public health and environment Adepoju, (2008). Severity of the environmental problem depends on the characteristics of the mineral being extracted, the methods of mining, waste materials generated and the site characteristic. The effect is manifested in air, land, plants and water associated with mining process Ukpong, (2012).

Quarries in level areas with shallow groundwater or which are located close to surface water often have engineering problems with drainage. Generally,

the water is removed by pumping while the quarry is operational but for high inflows more complex approaches may be required. For example, the Coquina quarry is excavated to more than 60 feet (18mm) below sea level. To reduce surface leakage, a moat lined with clay was constructed around the entire quarry. Ground water entering the pit is pumped up into the moat. As a quarry becomes deeper water inflows generally increase and it also becomes more expensive to lift the water higher during removal, this can become the limiting factor in quarry depth. Some water-filled quarries are worked from beneath the water by dredging.

Air pollution generally and especially dust from quarry sites are known to be responsible for vegetation injury and crop yield loss and thus become a threat to the survival of plants in industrial areas (Iqbal and Shafiq, 2001). Anand (2006) noted that one of the biggest negative impacts of quarrying on the environment is the damage to biodiversity. Biodiversity essentially refers to the range of living species, including fish, insects, invertebrates, reptiles, birds, mammals, plants, fungi and even micro-organisms. The damage caused to plants by pollution include necrosis (dead areas on leaf structure), chlorosis (loss or reduction of chlorophyll leading to yellowing of leaf), epinasty (downward curvature of the leaf due to higher rate of growth on the upper surface), and abscission of leaves (premature fall) Suresh, (2005). This will no doubt affect the physiological activities of the plants most especially those around the quarry sites such that as in photosynthesis and respiration. The implication of these is that some of the plants may have retarded growth, while others may be eliminated (Lameed and Ayodele, 2010).

Many people and municipalities consider quarries to be eyesores and require various abatement methods to address problems with noise, dust and appearance. One of the more effective and famous examples of successful quarry restoration is Butchart Gardens in Victoria, BC, Canada. Further problem is the pollution of the road from trucks when they are leaving the quarries. To control and eliminate the pollution of public roads wheel washing systems are becoming more common.

Dust from quarry sites is a major source of air pollution, although the severity will depend on factors like the local microclimate conditions, the concentration of dust particles in the ambient air, the size of the dust particles and their chemistry, for example limestone quarries produce highly alkaline (and reactive) dusts, whereas coal mines produce acidic dust. The air pollution is not only a mixture (in terms of deposition on surfaces) and possible effects on health, in particular for those with respiratory problems but dust can also have physical effects on the surrounding plants, such as blocking and damaging their internal structures and abrasion of leaves and cuticles, as well as chemical effects which may affect long-term survival. Unfortunately, quarrying involves several activities that generate significant amounts of noise. The excavation of the mineral itself involves considerable noise, particularly if blasting methods are used. Following this, the use of powered machinery to transport the material as well as possibly processing plants to crush and grade the minerals, all contribute even more noise to the environment. Such extraction of raw materials from their natural habitats by mining, drilling, harvesting and those that relate to large scale water resources development projects, construction, agriculture, energy, industry and development projects, considerably affect the natural environment.

2.6 Review of works on Quarry Dust

Shanker and Ali (1992) studied the engineering properties of quarry dust and reported that quarry dust can be employed as alternative material to river sand in concrete based on grain size analysis. Rao and Anda (1996) discovered improved compaction characteristics of rockcrete consisting of quarry dust and coarse aggregate (rock chips) over river sand moulds (sandcrete).

Soosan et al. (2001) observed that quarry dust exhibit high shear strength which improves the geotechnical properties of moulds in which they are employed. Nisnevich et al. (2003) confirmed the acceptance and utilization of quarry rock dust as building material in industrially advanced countries of the west for the past three decades based on its geotechnical properties. Ilangovan et al. (2008) carried out a comparative study of the physical properties of quarry dust and natural sand in India. His findings revealed that quarry rock dust posses higher relative bulk density as well as fine particles less than 0.075mm which act as filler matrix in moulds. This, he attributed to have resulted in a 10-12% improved strength property of rockcrete over the convectional sandcrete moulds

Hameed and Sekar (2009) demonstrated that rockcrete made from quarry dust are of higher advantage than sandcrete moulds in water logged areas due to lower capillary action and minimal humus content for growth of organics. Research had shown that quarry dust can be advantageously used in reinforced earth retaining walls, reinforced soil beds and reinforced flexible pavements as a fill material due to its stability, free draining nature and good frictional characteristics with synthetic reinforcement (Satyanarayana et al., 2013). The choice of quarry dust as replacement for sand has also been supported by Manassa (2010) showing up to 20% of sand being effectively replaced by quarry dust in traditional concrete.

2.7 Previous Studies on Effect of Partial Replacement of Sand with Quarry Dust on Properties of Concrete.

Celik et al. (1996) reported that increasing the dust content up to 10% improve the compressive strength and flexure strength of concrete. Sahu et al. (2003) concluded that there was significant increase in compressive strength, modulus of rupture and split tensile strength of concrete when sand was partially replaced by stone dust up to 40 percent. Sudhir and Satone, (2013) carried out a study on effect of quarry dust as partial replacement of sand in concrete. They noticed that the increase in dust

content up to 30% increases the compressive strength of concrete, if the dust content was more than 30% the compressive strength decreased gradually. Ilangovan and Nagamani, (2006) reported that Natural Sand with Quarry Dust as full replacement in concrete as possible with proper treatment of Quarry Dust before utilization.

Sandeep et al., (2014), established an experimental investigation to determine the predominant effect of stone dust as a substitute material for fine aggregate in concrete. Compressive strength and flexural strength of concrete produced by replacing the fine aggregate with varying percentage of stone dust such as 30, 40, 50, 60 and 70% was investigated. From the result obtained, it was observed that stone dust has a significant effect and be used effectively in partial replacement of fine aggregate in concrete. They concluded that, compressive strength is not affected much by replacement up to 40%; however, the flexural strength at all ages improved significantly at all the replacement levels.

In another study conducted by Prakash, et al., (2016), the use of quarry dust for normal concrete reporting that a 40% replacement of fine aggregate with quarry dust resulted in highest compressive strength. A similar result was obtained by Aishwaryalakshmi, et al., (2017) where up to 30% replacement of sand with quarry dust was made.

This study will therefore build upon gaps noticed from previous studies on the effect of partial replacement of sand with quarry dust on compressive strength of concrete.

CHAPTER THREE

MATERIALS AND METHODS

This section presents the materials and methods used to accomplish the research aim. Relevant standards were employed to ascertain how the materials collected be analyzed and also the various laboratory tests to be conducted. All Tests such as Sieve analysis test for fine, coarse aggregate and additive (quarry dust), aggregate crushing and impact value test (ACV and AIV), specific gravity of fine, coarse aggregate and additive (quarry dust), soundness and fineness test of cement, slump or workability test of fresh concrete and compressive strength of hardened concrete were carried out at Nnamdi Azikiwe University Civil Engineering Laboratory located inside the school campus.

3.1 Materials

3.1.1 Cement

Ordinary Portland cement (Dangote cement) was used for the experimental study. This cement is designated as OPC. The cement was purchased at Onitsha Market in Anambra State. Upon purchase, the cement was conveyed to school laboratory where it was kept in a cool dry place preparatory for various laboratory testing. The cement sample satisfy the requirement for use as one of the major component of concrete in that, it was not caked or baked through visual inspection and quick setting time. Relevant laboratory test performed on the cement was soundness and fineness test.

3.1.2 Water

The water sample used for this experiment was collected within the school environment. The water sample passed all the necessary requirement for use as ingredient of concrete based on the fact that it is colourless, devoid of suspended solid particles, contains infinitesimal trace of dissolved solid

particles with no trace of turbidity after being subjected to laboratory testing. The water was collected in three gallons (25 litre each).

3.1.3 Additive (Quarry Dust)

The quarry dust sample designated as QD was procured from a road construction company (Popularly known as RCC) at 9th mile in Enugu State. It is relatively small in size (less than 4.75mm) and is a representative of granite (chippings) in colour. The quarry dust was collected in one and half cement bag and was conveyed to the school laboratory via public transport. Upon arrival, the sample was air-dried using corrugated roofing sheet so as to expel any moisture present. Upon drying, the sample were gathered in two empty cement bags and stored in a cool dry place. This quarry dust sample will be used to partially replace cement in a stepped increase of 5% starting from 0% to 30% thereby establishing six different percentage partial replacements.

3.1.4 Fine Aggregate (Sand)

Sand sample used in producing the concrete was provided at a construction site at Nnamdi Azikiwe University Campus. The sand was Sieved through 5.0mm test sieve to remove larger particles and then air-dried to a saturated state of an aggregate. The sample passed the necessary requirement for use as ingredient of concrete based on the fact that it is gritty with particle sizes visible to the naked eyes, physical properties of the sand samples were determined prior to its incorporation into the concrete. The sand sample will be partially replaced with quarry dust in a stepped increase of 5% starting from 0% to 30%.

3.1.5 Coarse Aggregate (Crushed Granite)

Granite samples designated as GT was procured from Reynolds Construction Company (popularly known as RCC) at 9th mile in Enugu State. After procurement, the granite samples were conveyed to the laboratory unit of Department of Civil Engineering Nnamdi Azikiwe University Awka Anambra State where the index properties of the aggregate were determined. The granite sample passed all the necessary physical test in that, it has high crushing strength, it is relatively large in size (within range of 4.75mm to 20mm) and is a representative of granite (chippings) in color.

3.2 Sampling Locality

The cement, sand and water samples used for the production of concrete were collected at Onitsha and Nnamdi Azikiwe University campus Awka Anambra State. Anambra is located within the south eastern region and lies within longitude 6°45'E to 7°30'E and latitude 6°00'N to 6°30'N. The quarry dust and granite samples were collected from Reynold Construction Company (Popularly known as RCC) at 9th mile in Enugu State. Enugu state is located within south east Nigeria and lies within a within longitude 6°65'E to 7°30'E and latitude 6°10'N to 6°30'N.

3.3 Collection and Preparation of Sample

The process involved in the collection of samples entails identifying all the components to be employed in the production of concrete. Water and sand sample were collected at Nnamdi Azikiwe University Campus, Quarry dust and Crushed granite were collected at Reynolds Construction Company (popularly known as RCC) at 9th mile in Enugu State and Cement was purchased at Onitsha Market in Anambra State. These respective materials were stored in a dry place devoid of dust preparatory to various laboratory investigations.

3.4 Laboratory Testing

This section presents the experimental procedure and laboratory tests that were adopted for the project work. The tests conducted was conducted for all the constituents of concrete and this include: Sieve analysis test for fine,

coarse aggregate and additive (quarry dust), aggregate crushing and impact value test (ACV and AIV), specific gravity of fine, coarse aggregate and additive (quarry dust), soundness and fineness test of cement, Slump (workability) test of fresh concrete and compressive strength of hardened concrete. The aforementioned tests were carried out at Nnamdi Azikiwe University Civil Engineering Laboratory located inside the school campus. Below is a detailed description of test procedures and apparatus.

3.4.1 Particle Size Distribution (Sieve Analysis)

Sieve analysis is a procedure used to assess the particle size distribution of a granular material (sand, gravel). The size distribution is often of critical importance to the behaviour of the material during use. Sieve analysis can be performed on any type of non-organic or organic granular material including sand, crushed rock, clay, granite, feldspar and a wide range of manufactured powders, grains and seeds down to minimum size depending on the exact method. The standard grain size analysis test determines the relative proportion of different grain sizes as they are distributed among certain size ranges.

The particle size distribution (PSD) or sieve analysis were performed for coarse aggregate (granite), fine aggregate (sand) and additive (quarry dust) in order to determine the grading of each material in accordance with BS 812-103 (1990).

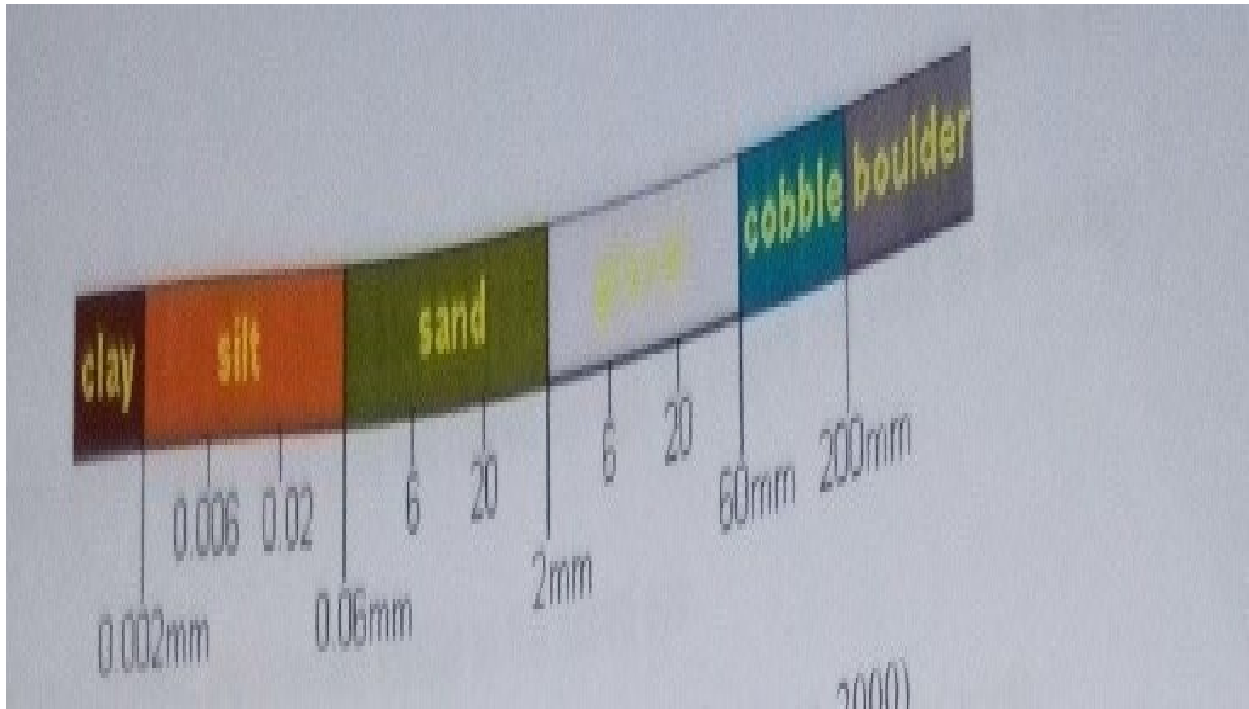


Figure 3.1 Ranges for grain Sizes of different Soil type (Atkinson, 2000).

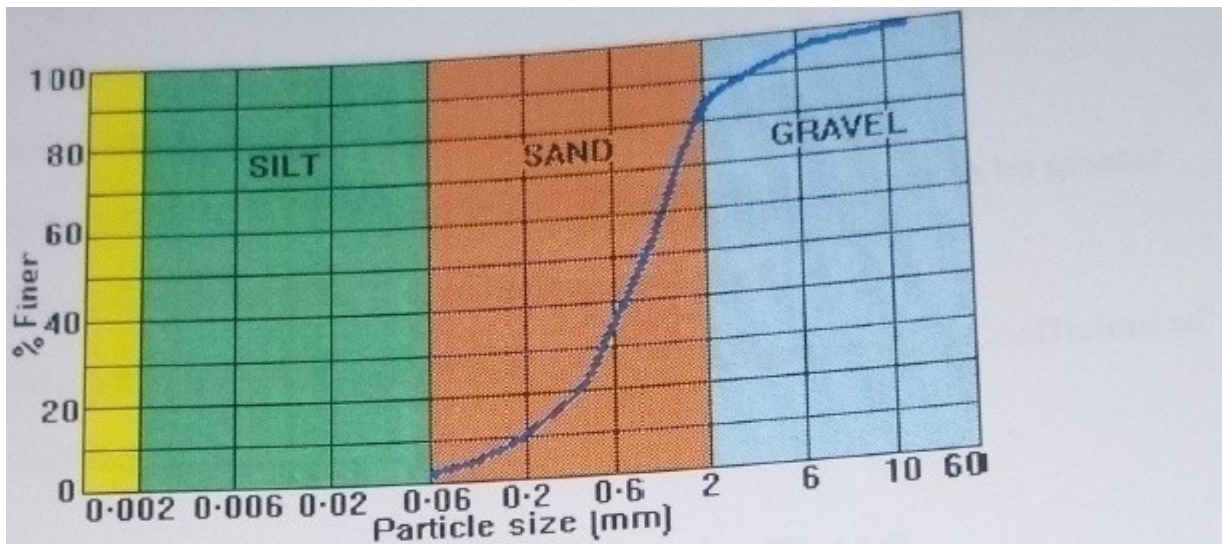


Figure 3.2 Grading Curve Ranges for Different Soil Types (Atkinson, 2000).

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

The apparatus needed for this experiment is listed below:

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

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

$$\text{Cumulative percentage retained} = \sum \text{Percentage retained (\%)}$$

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

$$\text{Coefficient of Curvature} = \frac{D_{60}}{D_{10}^2}$$

$$\text{Coefficient of Uniformity} = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

Where

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

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

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

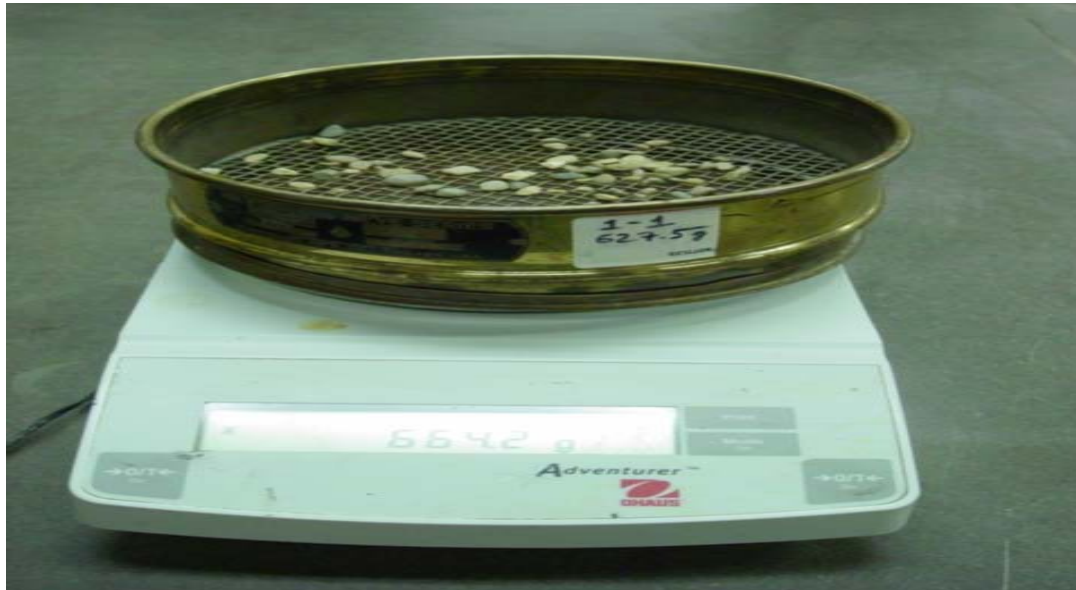


Figure 3.3 Apparatus for Particle Size Distribution Test (Sieve Analysis).



Figure 3.4 Apparatus for Particle Size Distribution Test (Sieve Analysis).

Test Procedure

1. Clean properly the stack of sieves to be used for the experiment using hand brush.
2. Weigh about 500g of air-dried soil sample on a weighing balance.
3. Pour the weighed soil sample into 75um sieve and wash under a steady supply of water until clear water start coming out from the sieve after passing through the soil sample.
4. After washing pour the washed soil sample into a pre-weighed plate and dry it inside the thermostatically controlled oven at a controlled temperature of 80-110°C for 16-24hrs.
5. Remove the sample from the oven and determine it weight (net weight) by deducting the weight of plate from the weight of plate and soil.
6. Arrange the stacks of sieve in the ascending order, place in a mechanical sieve shaker, and thereafter pour the sample and connect the shaker for about 10-15 minute.
7. Disconnect the sieve shaker and determine the mass retained on each of the sieve sizes.
8. Determine the percentage retained, Cumulative percentage retained and Cumulative percentage finer.
9. Plot the graph of sieve Cumulative percentage finer against sieve sizes.
10. Determine D10, D30 and D60 from the plotted graph.
11. Determine the Coefficient of Curvature and Coefficient of Uniformity and classify the soil using the American Association of State Highway and Transportation Official (AASHTO) and Unified Soil Classification System (USCS) respectively.



Plate 3.0: Weighing of Soil Samples for Particle Size Determination



Plate 3.1: Weighing of Mass Retained on the Different Sieve Sizes

3.4.2 Specific Gravity of Fine Aggregate Test

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

The apparatus employed for this experiment includes:

1. Density bottle of 50ml capacity and a stopper.
2. Desiccator containing anhydrous silica gel.
3. Thermostatically controlled oven with temperature of about 80-110°C.
4. Weighing balance of 0.01g sensitivity.
5. Mantle heater.
6. Plastic wash bottle.
7. Distilled water.
8. Funnel
9. Thin glass rod for stirring.
10. 425um Sieve.
11. Dry piece of cloth for cleaning.
12. Masking tape for identification of sample.
13. Exercise book and pen for recording of result.

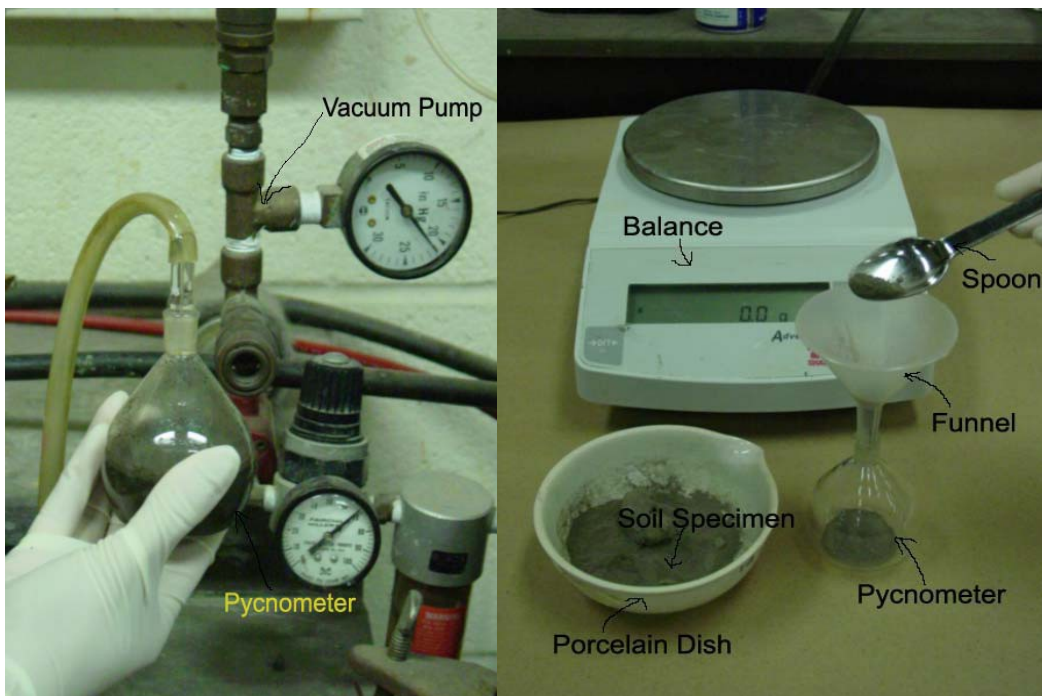


Figure 3.5: Apparatus used for Specific Gravity Test.

Test Procedure

- 1 The density bottle properly cleaned and rinsed with distilled water, thereafter oven-dried and then cooled it in a desiccator so as to remove any moisture present.
- 2 The empty clean and dry density bottle was weighed and recorded as (M_1).
- 3 About 10-15g of soil passing through 425um sieve was placed inside the density bottle, weigh and the weight of density bottle +dry soil + stopper was recorded as (M_2).
- 4 Distilled water was added to fill about half to three-fourth of the density bottle, and then the sample was soaked for 24hrs (The time stated is to enable complete settlement of the soil particle which is evident when clear water appears above the submerged soil).
- 5 The density bottle was gently stirred using thin glass rod and thereafter connected to a mantle heater to de-air the sample, the sample was not allowed to boil over.
- 6 After agitation, the sample was allowed to cool at room temperature and then filled with distilled water up to the specified mark (at lower meniscus level), the exterior surface of the density bottle was cleaned with a clean dry cloth and the weight of the density bottle + stopper +soil filled with water was determined and recorded as (M_3).
- 7 The density bottle was emptied, cleaned and rinsed with distilled water, then filled with distilled water up to the same mark. The exterior surface of the density bottle was cleaned with a clean dry cloth and the weight of the density bottle filled with distilled water + stopper was determined and recorded as (M_4).
- 8 The test procedure was repeated for two more trials and the average specific gravity value was obtained from the total no of trial, the variation in the specific gravity result obtained for each trial must not exceed 2%, otherwise repeat the experiment.

The Procedure for Computation of result obtained are as follows:

$$\text{Specific gravity } (G_s) = \frac{(M_2 - M_1)}{(M_2 - M_1) - (M_3 - M_4)}$$

Where M_1 = weight of density bottle + stopper

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



Plate 3.3: Laboratory Determination of Specific Gravity of Fine Aggregate

3.4.3 Specific Gravity Test of Coarse Aggregate (Granite) Test

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

Apparatus Used

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

Test Procedure

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

3.4.4 Compressive Strength Test of Hardened Concrete Cube

The test method covers determination of compressive strength of cubic concrete specimens. It consists of applying a compressive axial load to molded cubes at a rate which is within a prescribed range until failure occurs.

The Apparatus Used includes:

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

Test Procedure

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

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

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

4. Mixing Concrete - The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other

materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.

5. Mould - Test specimens cubical in shape shall be 150mm × 150mm × 150mm .If the largest nominal size of the aggregate does not exceed 20mm, 100mm cubes may be used as an alternative. Cylindrical test specimens shall have a length equal to twice the diameter.

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

7. Curing - The test specimens shall be stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of $27^{\circ} \pm 2^{\circ}\text{C}$ for 24 hours $\pm \frac{1}{2}$ hour from the time of addition of water to the dry ingredients.

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

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

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

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

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

The compressive strength of concrete cube is computed as follows:

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

Where applied load (N) = Force

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

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

For 220kN = 220 × 1000 = 220,000N

Area of cube = 150mm × 150mm = 22,500mm² (Assumed Load)

Compressive Strength = $\frac{220,000 \text{ N}}{22,500 \text{ mm}^2} = 9.78 \text{ N/mm}^2$ (Assumed Compressive Strength)



Plate 3.4: Universal Testing Machine for Determination of Compression Strength

3.5 Slump (Workability) Test

Slump test is used to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work.

The procedures are as follows:

1. Clean the internal surface of the mold and apply oil.
2. Place the mold on a smooth horizontal non-porous base plate.
3. Fill the mold with the prepared concrete mix in 4 approximately equal layers.
4. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mold. For the subsequent layers, the tamping should penetrate into the underlying layer.
5. Remove the excess concrete and level the surface with a trowel.
6. Clean away the mortar or water leaked out between the mold and the base plate.
7. Raise the mold from the concrete immediately and slowly in vertical direction.
8. Measure the slump as the difference between the height of the mold and that of height point of the specimen being tested.

Calculation

Slump = Height of the slump cone - Height of the unsupported concrete.

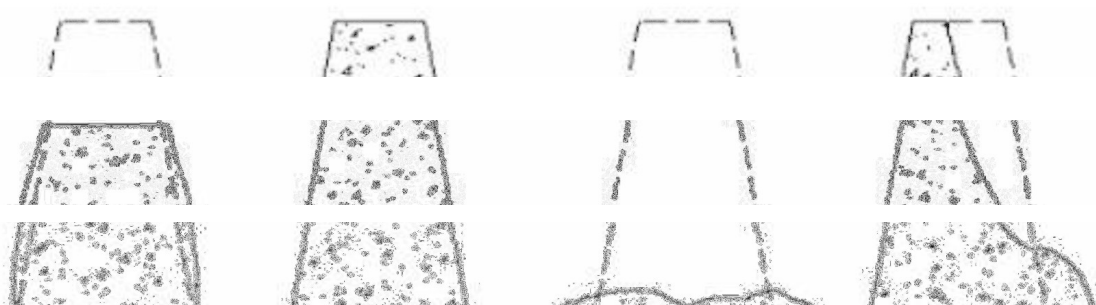




Figure 3.0 Types of Concrete Slump Test Results.

1. True Slump - True slump is the only slump that can be measured in the test. The measurement is taken between the top of the cone and the top of the concrete after the cone has been removed as shown above. In a true concrete just subsides shortly and more or less maintain the mould shape. This type of slump is most desirable and represents the reliable condition to get an idea about the workability of concrete.
2. Zero Slump - Zero slump is the indication of very low water-cement ratio, which results in dry mixes. This type of concrete is generally used for road construction. In this slump, the concrete maintains the actual shape of the mould as it is said to be stiff, consistent and almost non-workable.
3. Collapsed Slump - In the case, fresh concrete collapses completely. This is an indication that the water-cement ratio is too high, i.e. concrete mix is too wet or it is a high workability mix, for which a slump test is not appropriate.
4. Shear Slump - In this case, one-half of the cone slide down in an inclined plane, this slump indicates lack of cohesion in the concrete mix. Shear slump may occur in case of a harsh mix.



Plate 3.10: Apparatus used for Slump Test

3.4.6 Aggregate Impact Value Test (AIV)

The property of a material to resist impact is referred to as toughness (TELM, 2013). Due to movement of vehicles to the road, the aggregate are subjected to impact resulting in their breaking down into small pieces (TELM, 2013). The aggregate should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test. The aggregate impact value test is a measure of its resistance to sudden impact or shock which may differ from its resistance to gradually applied compressive load.

Test Apparatus

- 1 A cylindrical steel cup of internal diameter 102mm, depth 50mm and minimum thickness 6.3mm.
- 2 A metal hammer weighing 13.5 to 14kg with the lower end cylindrical in shape and 50mm long, 100mm in diameter with a 2mm chamfer at the lower edge and case hardened. The hammer should slide freely between vertical guides and be concentric with the cup.
- 3 A cylindrical metal mould having an internal diameter of 75mm and depth 50mm for measuring aggregates.
- 4 Tamping rod 10mm in diameter and 230mm long and rounded at one end.
- 5 A weighing balance of capacity not less than 500g, readable and accurate up to 0.1g.
- 6 A testing weighing machine 45 to 60kg, having a metal base with a plane lower surface not less than 30cm in diameter. It is supported on level and plane concrete floor of minimum 45mm thickness. The machine should have provision for fixing its base.



Plate 3.11: Apparatus Used for Aggregate Impact Value Test

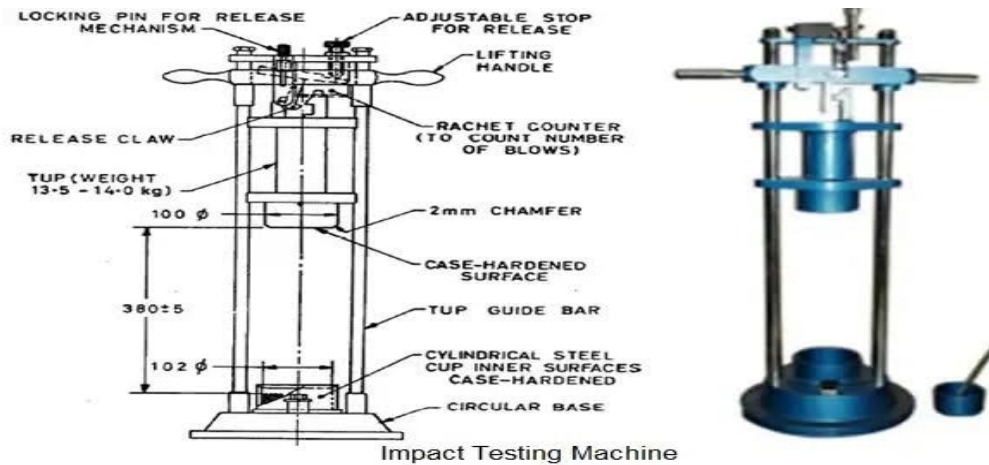


Plate 3.12: Apparatus Used for Aggregate Impact Value Test.

Test Procedure

- 1 The aggregate used for the experimental study was dried by heating at 100°C-110°C for a period of 4 hours and then allowed to cool.
- 2 The material was sieved through 12.5mm and 10mm sieve. The aggregate passing through 12.5mm and retained on 10mm sieve comprises the test material.
- 3 The aggregate passing through the 10mm sieve referred to as the test material was poured in a cylindrical metal mould about one-third the volume of the mould.
- 4 The aggregate was compacted evenly by giving 25 no of blows with the aid of the tamping rod.
- 5 The remaining layers of the test aggregate were added into the mould until full and compacted evenly with 25 no of blows.
- 6 The surplus aggregate was strike off using a spatula or straight edge.
- 7 The net weight of the aggregate was determined to the nearest gram.
- 8 The impact machine was brought to rest without wedging so that it is rigid and the column guides are vertical.

- 9 The cup was fixed firmly to the base of the machine; the test sample was placed and compacted evenly by giving 25 gentle strokes with the aid of a tamping rod.
- 10 The hammer was raised until its lower face is 380mm above the surface of the aggregate sample in the cup and allowed to fall freely on the aggregate sample. The aggregate sample was given 15 blows at an interval not less than one second between successive blows.
- 11 The crushed aggregate was removed from the cup and sieved through 2.36mm sieve until no further significant amount passes in one minute. The fraction passing through the sieve was weighed to an accuracy of 1gm and the fraction retained on the sieve was also weighed.
- 12 The test observation was noted down and the aggregate impact value was computed.

3.4.7 Aggregate Crushing Value Test (ACV)

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

Apparatus Used

- 1 A weighing balance readable to an accuracy of 1gm
- 2 IS Sieve sizes of 2.36mm, 10mm and 12.5mm.
- 3 A compression testing machine capable of applying a load of 40 tonnes and which can be operated to give a uniform rate of loading so that the maximum load is reached in 10 minute.

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



Plate 3.13: Apparatus Used for Aggregate Crushing Value Test.

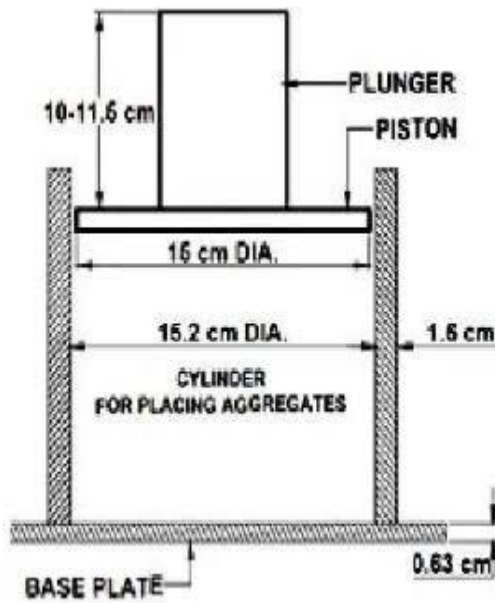


Plate 3.14: Apparatus Used for Aggregate Crushing Value Test.

Test Procedure

- 1 The aggregate used for the experimental study was dried by heating at 100°C-110°C for a period of 4 hours and then allowed to cool.
- 2 The material was sieved through 12.5mm and 10mm sieve. The aggregate passing through 12.5mm and retained on 10mm sieve comprises the test material.
- 3 The cylindrical mould was assembled into position and the test sample was added to about one-third the volume of the mould.
- 4 The test aggregate was subjected to compaction by giving 25 no of blows with the aid of tamping rod.
- 5 The other layers was added and compacted evenly with the surface of the aggregate leveled to flush with the top surface of the mould using a straight edge.
- 6 The plunger was inserted so that it rest horizontally on the surface of the test aggregate, care was exercised to ensure that there was no collision between the plunger and the cylinder.

- 7 The apparatus with the test sample with the plunger in position was placed between the plates of the testing machine.
- 8 The load was applied at a uniform rate as possible so that the total load is reached in 10 minutes.
- 9 The load was released and the whole of the material is removed from the cylinder and sieved on 2.36mm IS sieve.
- 10 The fraction passing through the sieve was weighed and recorded.
- 11 The test observation was noted down and the aggregate crushing value was computed.

3.4.8 Soundness Test of Cement

Soundness is referred to as the volume stability of cement paste. The cement paste should not undergo large changes in volume after it has set. Free CaO and MgO may result in unsound cement (Chanadan, 2019). Upon hydration, C and M (calcium and magnesium) will form CH and MH with volume increase thus cracking.

The apparatus employed for Soundness test include:

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

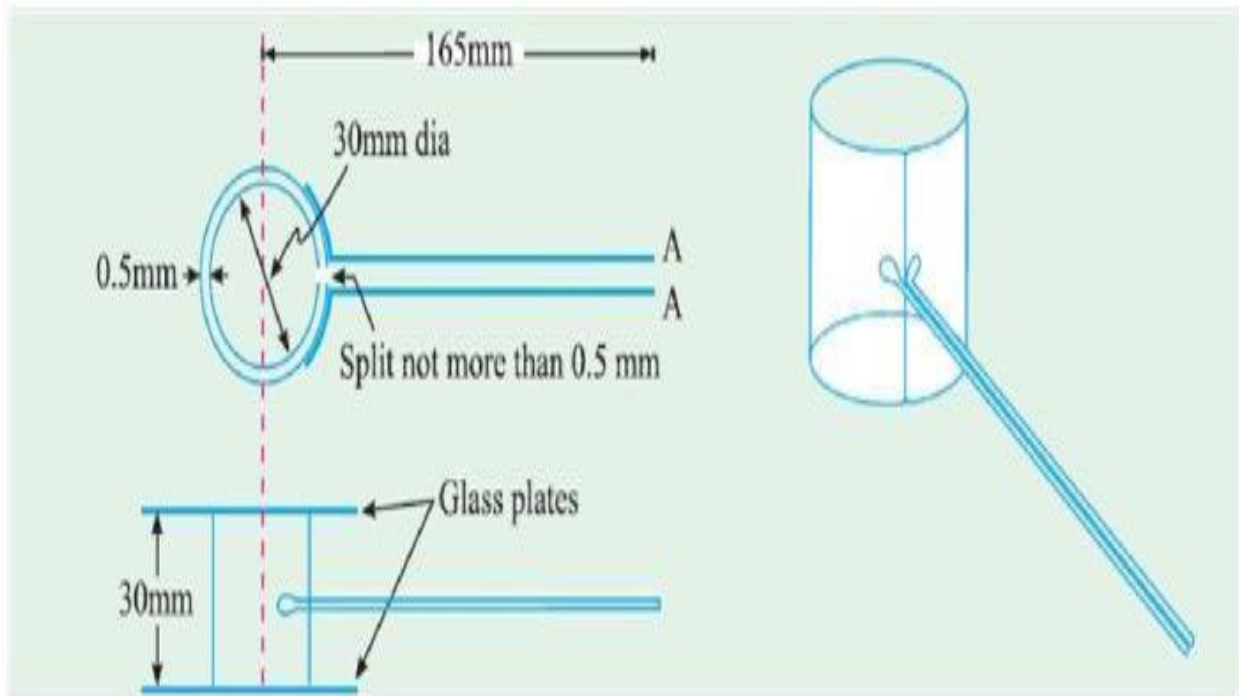


Plate 3.15: Apparatus used for Soundness Test

Test Procedure

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

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

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

3.4.9 Fineness Test of Cement

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

The apparatus employed for fineness test include:

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

Test Procedure

1. Weigh 100 grams of cement and placed in an IS-Sieve no 9
2. Breaking down any air set lumps by fingers.
3. Holding the sieve with both the hands, sieve it continuously for 5-10 minutes until all the fine material is passing through.

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

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

The Fineness is computed as follows:

Weight of cement taken $W_1 =$

Weight of residue after sieving $W_2 =$

Percentage of fineness of cement = $\frac{\text{Weight of residue retained}}{\text{weight of cement}} \times 100$

CHAPTER FOUR

RESULT AND DISCUSSION

During the experimental phase of the study, key findings were obtained which was valuable in ascertaining the index properties of the aggregates used for the production of concrete and also for evaluating the effect of partial replacement of fine aggregates with quarry dust on compressive strength of concrete. These results are presented in Table 4.0 below:

4.1 Results

Table 4.0: Physical Properties of Concrete Components Employed in the Research

Concrete Components/ Properties	Sand	Quarry Dust	Granite	Dangote 3x Cement
Specific Gravity	2.55	2.76	2.61	----
Aggregate Impact Value (%)	-----	-----	27.6	-----
Aggregate Crushing Value (%)	-----	-----	26.1	-----
Percentage Passing Sieve No 200	8.03	-----	-----	-----

(0.075mm)				
Percentage Passing Sieve No 10 (4.75mm)	-----	19.73	5.78	-----
AASHTO Classification System	A-2-6	A-1-b	A-1-b	-----
Unified Soil Classification System	SM	GM	GC	-----
Coefficient of Uniformity	2.8	0	7.2	-----
Coefficient of Curvature	0.85	0	1.44	-----
Gradation	SP	-----	GP	-----
Fineness (%)	-----	-----	-----	3
Soundness (mm)	-----	-----	-----	0.95

Table 4.1: Slump Test Result at Varying Percentages of Quarry Dust

Percentages of Quarry Dust	Height of Cone (mm)	Height of Collapse (mm)	Slump (mm)	Slump Type
0	300	265	35	True Slump
5	300	272	28	True Slump
10	300	280	20	True Slump
15	300	285	15	True Slump
20	300	290	10	True Slump
25	300	292	8	True Slump

Table 4.2: Compressive Strength Result at Varying Intervals of Curing Days

Curing Days (Age)	Compressive Strength (N/mm²)
--------------------------	--

7	23.09
14	23.57
21	23.95
28	24.23

Table 4.3: Compressive Strength Result at Varying Percentages of Quarry Dust

Percentages of Quarry Dust (%)	Compressive Strength (N/mm²)
0	23.14
5	23.54
10	23.70
15	24.06
20	24.20
25	23.52

Table 4.4: Dry Density Result at Varying Intervals of Curing Days

Curing Days (Age)	Dry Density (kg/m³)
7	2237
14	2278
21	2325
28	2357

Table 4.5: Dry Density Result at Varying Percentages of Quarry Dust

Percentages of Quarry	Dry Density (kg/m³)
------------------------------	---------------------------------------

Dust (%)	
0	2156
5	2288
10	2313
15	2342
20	2385
25	2312

4.2 Analysis of Results

4.2.1 Sieve Analysis Test

Figure 4.0 is a semi logarithmic graph showing the particle size distribution of sand, quarry dust and granite respectively. The percentage passing through sieve No 200 (0.075mm) sieve for sand was 8.03, coefficient of uniformity and curvature were 2.8 and 0.85 respectively and as a result, sand was classified as A-2-6 according to AASHTO Classification System and SM (sand mixed with silt) according to Unified Soil Classification System. The percentage passing through sieve No 4 (4.75mm) for quarry dust and granite were 19.73 and 5.78, coefficient of uniformity and curvature were 0, 0, 7.2 and 1.44 respectively and as a result, quarry dust and granite were classified as A-1-b and A-1-a according to AASHTO Classification System and GM (gravel mixed with silt) and GC (gravely mixed with clay) according to Unified Soil Classification System. The gradation of the aggregates sample revealed that sand and granite were poorly graded. The gradation of quarry dust could not be ascertained due to loss in shape parameters of the sample.

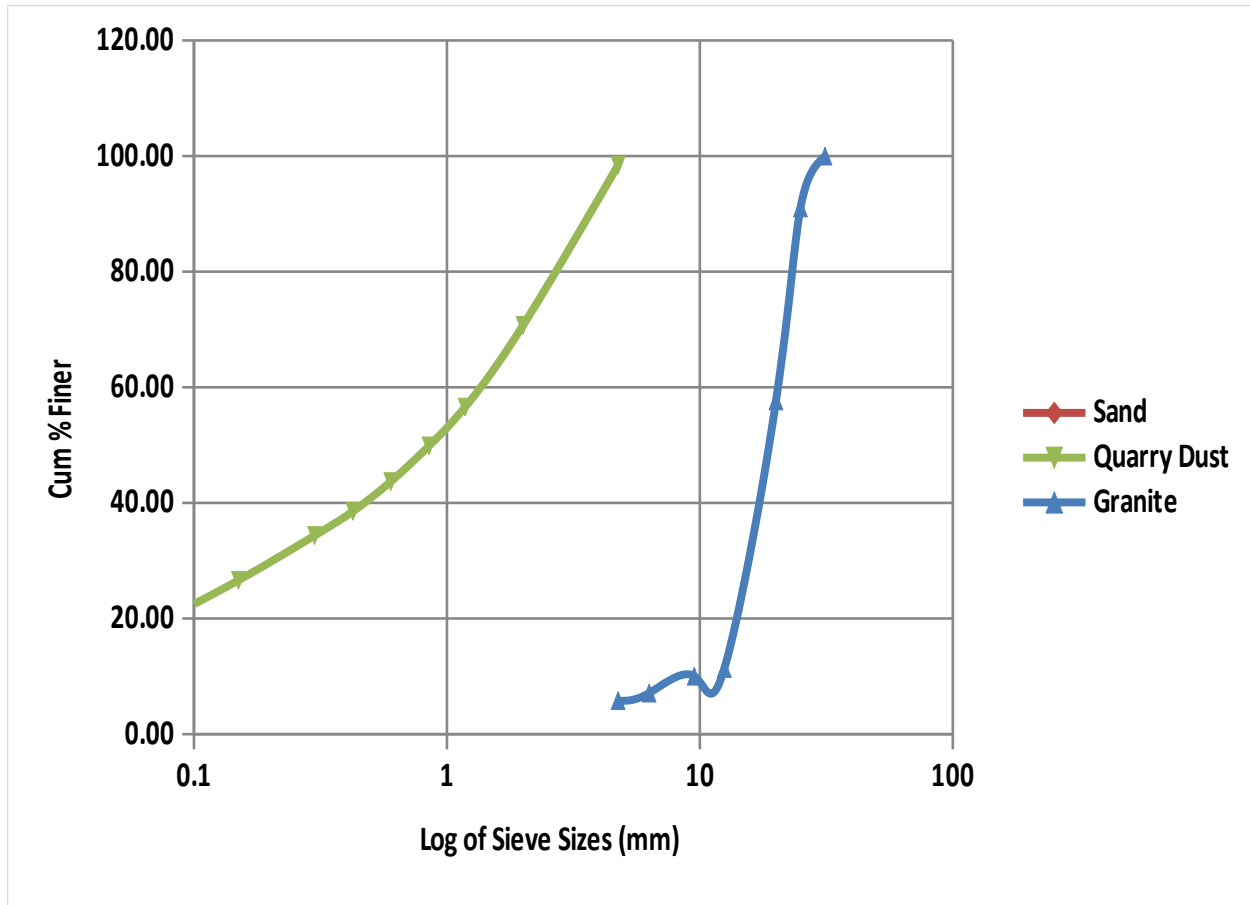


Figure 4.0: Particle Size Distribution Curve of Sand, Granite and Quarry Dust.

4.2.2 Specific Gravity

Table 4.0 and Figure 4.1 show the specific gravity of the aggregates used in the research. The specific gravity of the aggregates and additive (quarry dust) ranged from 2.55 to 2.76. It was observed that quarry dust with a specific gravity of 2.76 produced the highest specific gravity value. The aggregate sample met ASTM requirement for specific gravity of normal weight concrete which state that the specific gravity of the aggregate must exceed 2.4. This result justifies the use of the aggregate for this work.

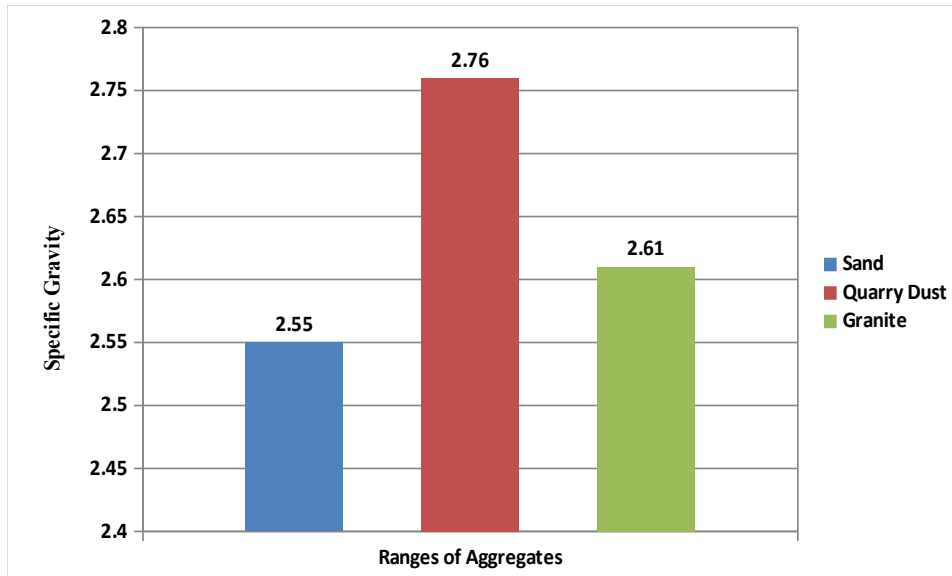


Figure 4.1: Graph Showing the Specific Gravity of the Aggregate and Concrete Additive

4.2.3 Fineness and Soundness Test of Portland cement

The fineness and soundness of cement are properties of cement that greatly influences the compressive strength of the hardened concrete (Yahaya, et al., 2014). The value soundness value obtained (0.95) for the cement falls below the 10mm maximum value which is an indication that the amount of un-burnt lime during cement manufacturing process is small which makes them suitable for use in cement and quarry dust concrete production.

The fineness result (3%) obtained for the Portland cement was less than 5% according to British Standard Specification (BS EN, 197-1: 2011) for Portland cement. This implies that the cement type employed in the research is suitable for production of concrete since their respective fineness is within the specified maximum limit of 5%.

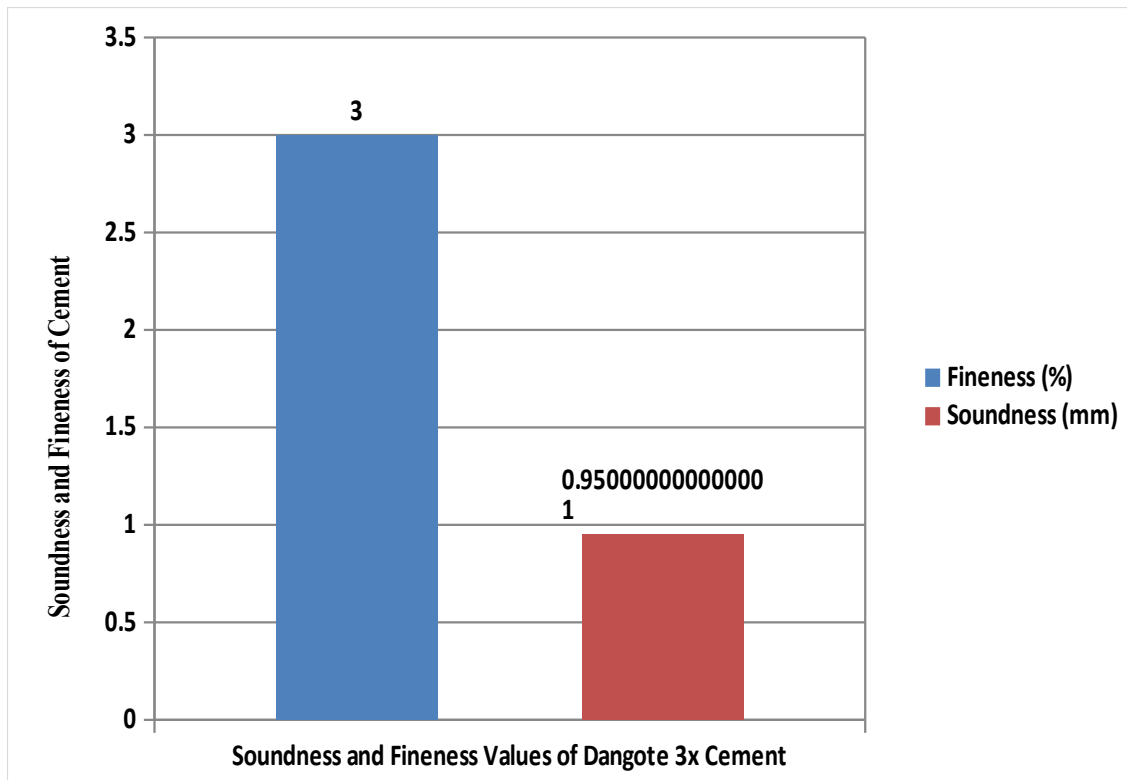


Figure 4.2: Soundness and Fineness Values of Portland cement

4.2.4 Aggregate Impact and Crushing Value

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

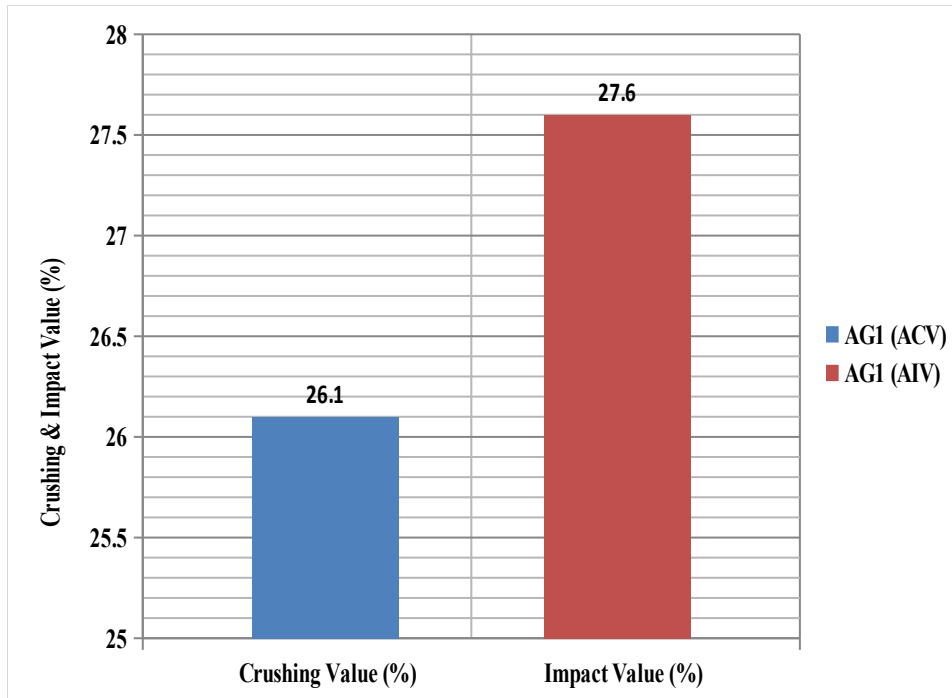


Figure 4.3: Charts Showing the Impact and Crushing Values of Aggregates

4.2.5 Compressive Strength

Table 4.2 and 4.3 and Figure 4.4 and 4.5 shows the results of compressive strength at varying percentages of quarry dust and curing days of 7, 14, 21 and 28 days respectively. It was observed that the compressive strength of the hardened concrete increased with curing days. This result is in the agreement with the works of Olalere and Raheem, (2020) which stated that hardened concrete gains 60% of its compressive strength at 28 days of curing. The maximum compressive strength was recorded at 20% replacement of sand with quarry dust. It was observed that the compressive strength of the control specimen increased from 5% addition of quarry dust to 20% addition of quarry dust to the concrete. The increase in compressive strength of the hardened concrete could be attributed to the fineness and bulk density of quarry dust. The latter decline in compressive strength could be attributed to the high content of quarry dust which depressed the

workability and invariably, the compressive strength of the concrete. Works indicative of these findings are the works of Olalere and Raheem, (2020) and Subramanian and Kannan, (2013).

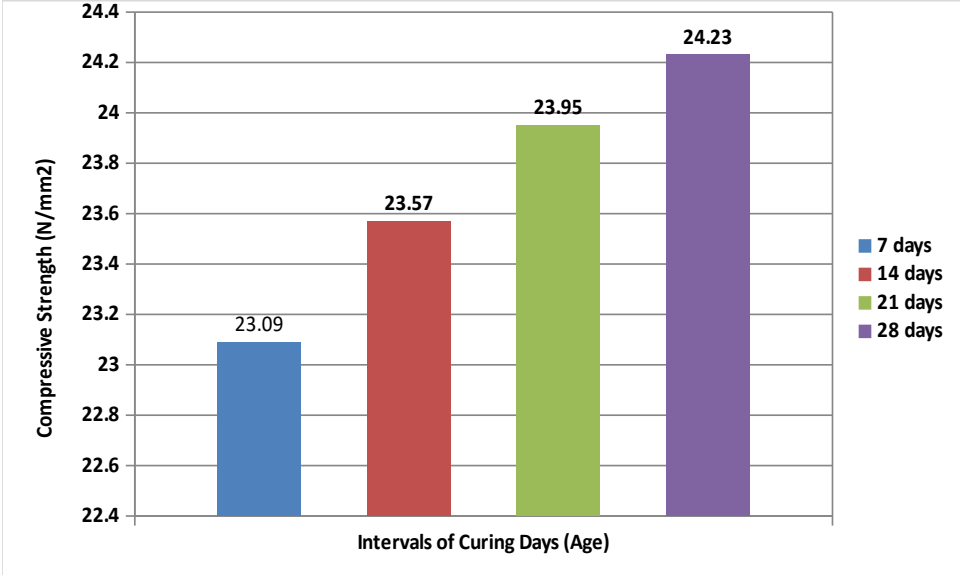


Figure 4.4: Graph of Compressive Strength against Curing Days

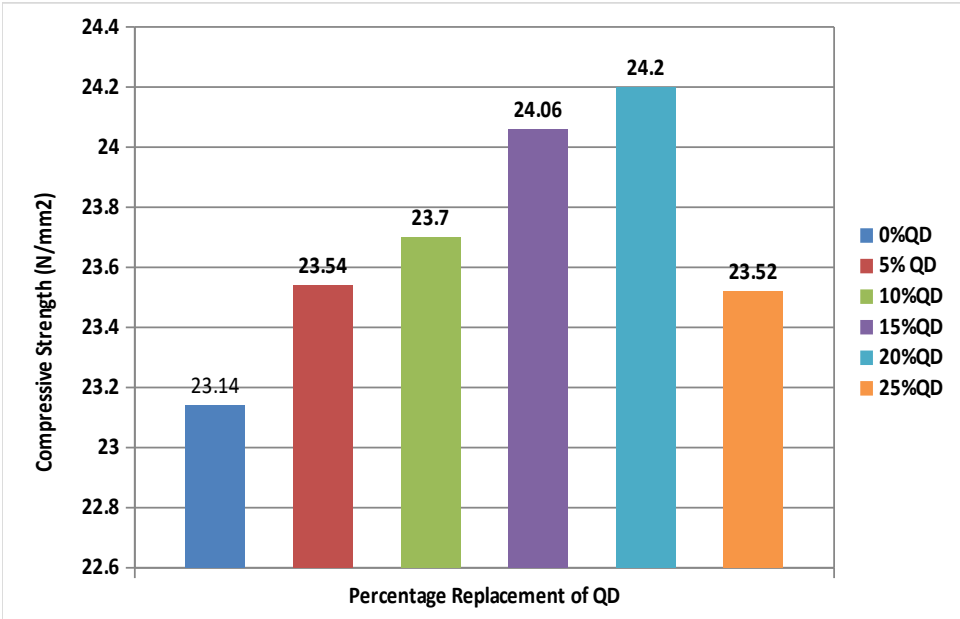


Figure 4.5: Graph of Compressive Strength against Varying Percentages of Quarry Dust

4.2.6 Hardened Concrete Density

Table 4.4 and 4.5 and Figure 4.6 and 4.7 respectively shows the result of the hardened concrete density at varying percentages of quarry dust and curing days ranging from 7-14-21-28 days respectively. It was observed that the dry density of the concrete increased with curing days. On consistent addition of quarry dust to the concrete from 5% to 25% by weight of sand, it was observed that the dry density of the concrete increased from 5% addition of quarry dust to 20% addition of quarry dust to the concrete beyond 20% quarry dust content, the dry density decreased. The initial improvement in dry density of the concrete from 5% quarry dust content to 20% quarry dust content could be attributed to the density and fineness of quarry dust as relative fineness increases the density of concrete to a reasonable extent. The latter decline in dry density could be attributable to the high content of quarry dust in the concrete mix.

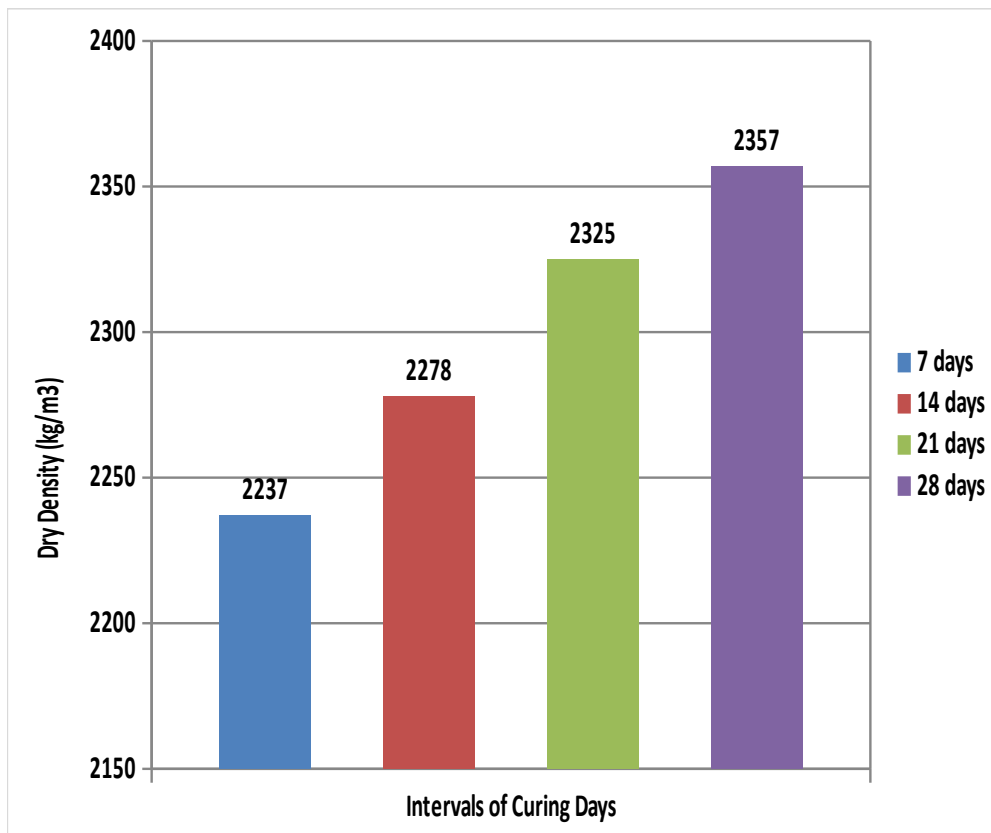


Figure 4.6: Graph of Dry Density against Intervals of Curing Days

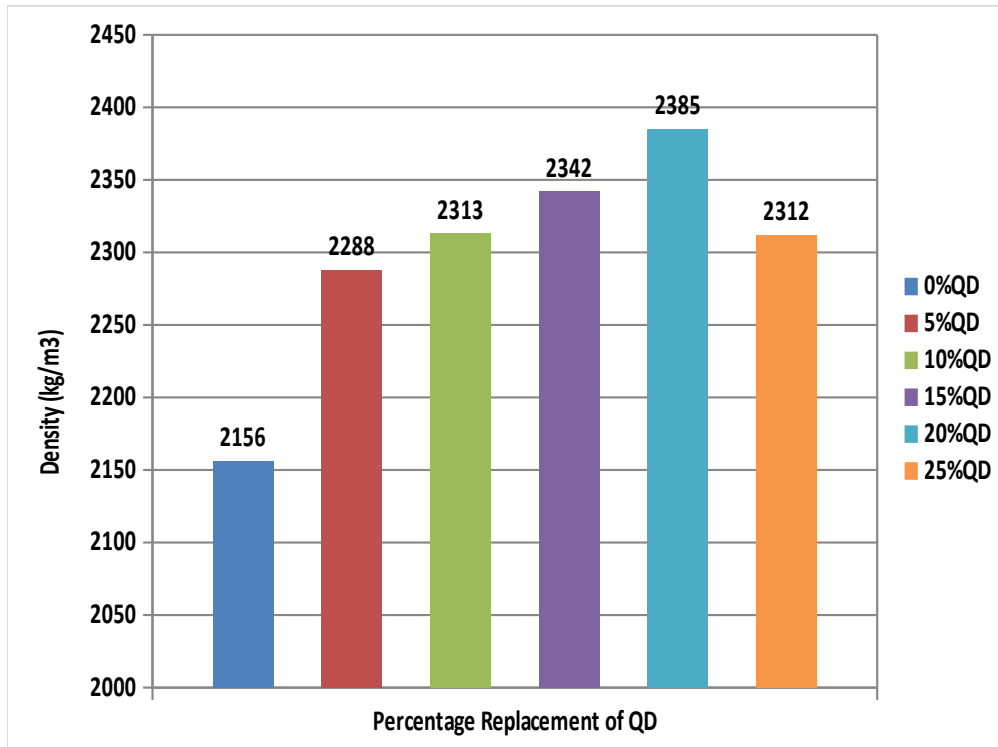


Figure 4.7: Graph of Dry Density against Varying Percentages of Quarry Dust

4.2.7 Slump

The result of slump test conducted at constant water to cement ratio for the fresh concrete are shown in Table 4.1 and Figure 4.8 respectively. It was observed that the slump of the fresh concrete decreased on consistent addition of quarry dust to the concrete. The consistent decline in slump of the fresh concrete could be attributed to the fineness of quarry dust. Fineness property of quarry dust extends the surface area required for hydration of cement thereby requiring more water for hydration and adequate workability of the fresh concrete. It implies that more water to cement ratio will be required to ensure adequate workability of the fresh concrete. The result obtained from this study is similar to that obtained by Olalere and Raheem, (2020) and Subramanian and Kannan, (2013).

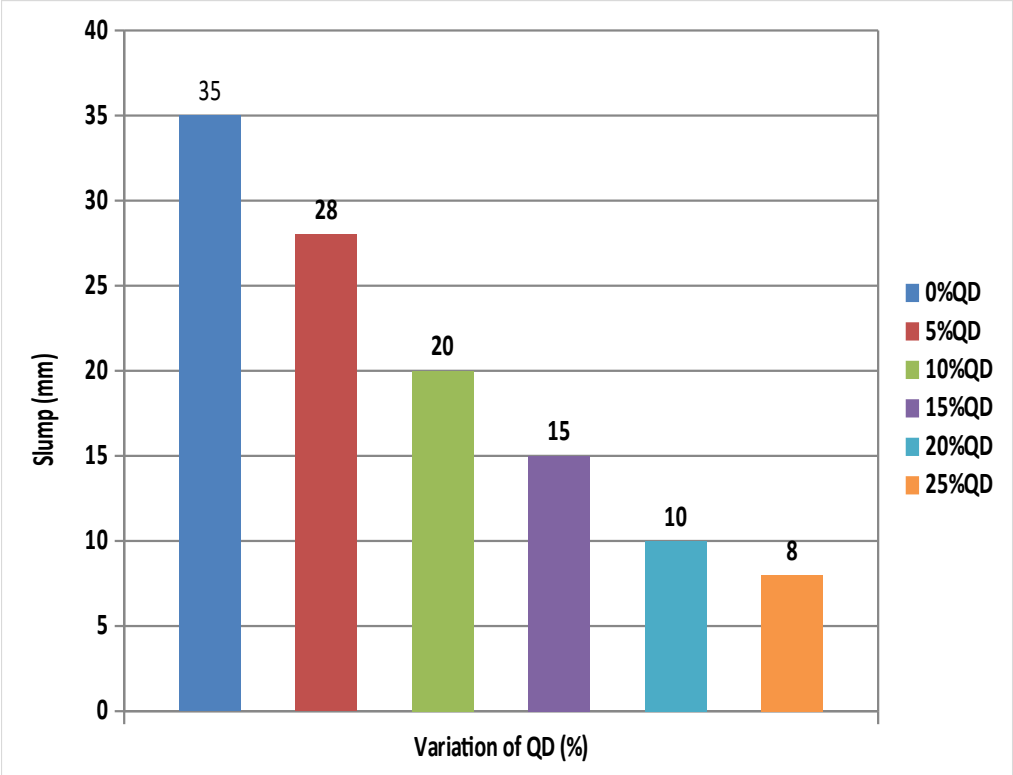


Figure 4.8: Graph Showing the Slump of the Concrete at Varying Percentages of Quarry Dust

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the findings obtained on evaluation of strength properties of concrete produced with partial replacement of sand with quarry dust, the following conclusion can be drawn:

- 1 Preliminary investigation of the aggregate and cement used for the production of concrete revealed that the cement and aggregate sample satisfied the standard requirement and justifies their use for the production of concrete.
- 2 The slump of the fresh concrete was found to decrease with consistent addition of quarry dust to the concrete.
- 3 Similar results were obtained for the dry density and compressive strength of the hardened concrete as the dry density and compressive strength of the concrete increased from 5% addition of quarry dust to 20% addition of quarry dust to the concrete beyond 20% quarry dust content, the compressive strength was found to decrease.
- 4 The quarry dust employed in the study was adjudged as a feasible and effective alternative for strength enhancement in concrete.

5.2 Recommendation

The recommendation on strength evaluation of concrete produced with partial replacement of sand with quarry dust is as follows:

- 1 Concrete produced with partial replacement of sand with quarry dust should be done at reasonable amount (not exceeding 20% content) as progressive advancement from the stated limit undermines the compressive strength of the hardened.

- 2 Painstaking attention must be given in the selection of quarry dust samples for concrete production particularly as it regards the fineness property of quarry dust as excess fineness undermines the density and compressive strength of hardened concrete.

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APPENDICES

APPENDIX A

COMPRESSIVE STRENGTH TEST

Table A1: Compressive Strength Test Result for 0%QD

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
7 days	1: 2: 4	504.8	22.44	22.53
		510.4	22.68	
		505.3	22.46	
14 days	1: 2: 4	515.7	22.92	23.03
		518.4	23.04	
		520.3	23.12	
21 days	1: 2:4	520.4	23.13	23.33
		525.5	23.36	
		528.8	23.50	
28 days	1: 2: 4	532.4	23.66	23.68
		535.8	23.81	
		530.4	23.57	

Table A2: Compressive Strength Test Result for 5%QD

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
7 days	1: 2: 4	518.7	22.70	22.91
		515.8	22.92	
		520.3	23.12	

14 days	1: 2: 4	524.8	23.32	23.48
		531.5	23.62	
		528.5	23.49	
21 days	1: 2:4	530.4	23.57	23.75
		534.5	23.76	
		538.5	23.93	
28 days	1: 2: 4	540.2	24.01	24.02
		538.7	23.94	
		542.5	24.11	

Table A3: Compressive Strength Test Result for 10%QD

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
7 days	1: 2: 4	518.8	23.06	23.21
		522.5	23.22	
		525.7	23.36	
14 days	1: 2: 4	530.2	23.56	23.67
		532.4	23.66	
		535.8	23.81	
21 days	1: 2:4	535.8	23.81	24.00
		540.2	24.01	
		542.4	24.11	
28 days	1: 2: 4	548.7	24.39	24.30
		546.8	24.30	
		544.5	24.20	

Table A4: Compressive Strength Test Result for 15%QD

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
7 days	1: 2: 4	524.8	23.80	23.93
		528.7	23.92	
		530.2	24.06	
14 days	1: 2: 4	535.5	23.80	23.93
		538.2	23.92	
		541.3	24.06	

21 days	1: 2:4	544.5	24.2	23.93
		548.7	24.39	
		550.3	24.46	
28 days	1: 2: 4	550.4	24.46	24.54
		552.8	24.57	
		553.5	24.60	

Table A5: Compressive Strength Test Result for 20%QD

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
7 days	1: 2: 4	526.4	23.40	23.53
		530.3	23.57	
		531.5	23.62	
14 days	1: 2: 4	536.7	23.85	23.98
		539.3	23.97	
		542.4	24.11	
21 days	1: 2:4	548.7	24.39	24.48
		550.2	24.45	
		553.5	24.60	
28 days	1: 2: 4	556.6	24.74	24.82
		558.5	24.82	
		560.2	24.90	

Table A6: Compressive Strength Test Result for 25%QD

Curing Days (Age)	Mix by Volume	Failure Load (kN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
7 days	1: 2: 4	514.5	22.87	22.94
		522.3	23.21	
		511.4	22.73	
14 days	1: 2: 4	521.5	23.18	23.31
		527.2	23.43	

		524.5	23.31	
21 days	1: 2:4	530.4	23.57	23.76
		535.3	23.79	
		538.5	23.93	
28 days	1: 2: 4	540.2	24.01	24.09
		544.3	24.19	
		541.7	24.08	

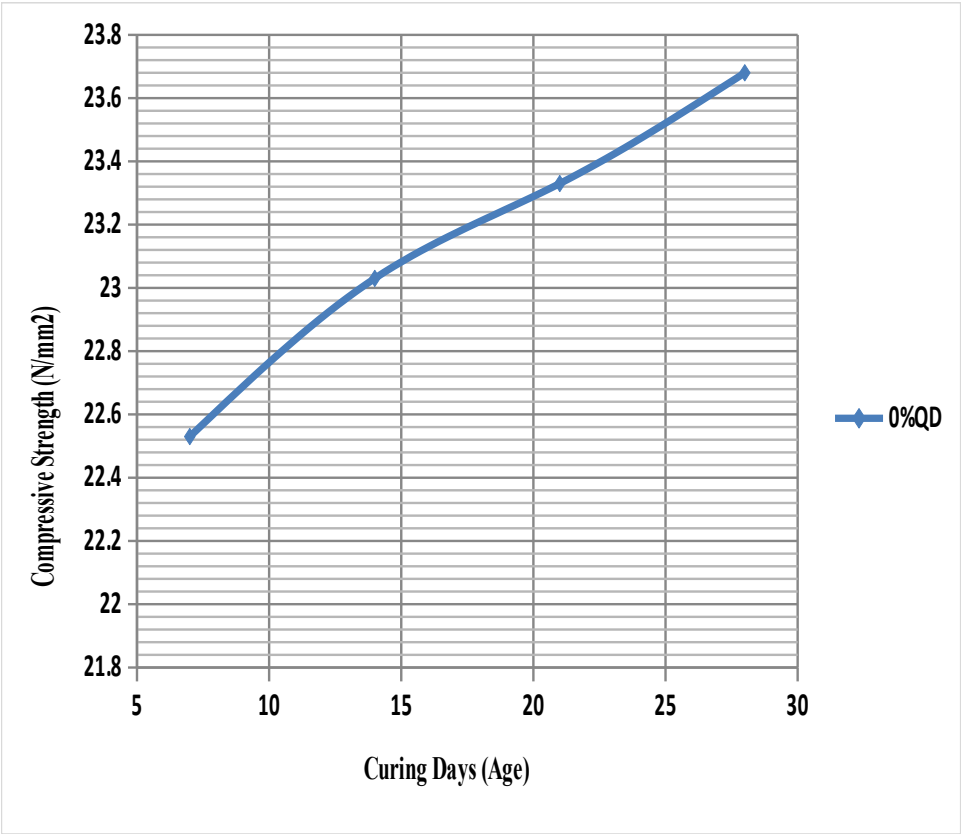


Figure A1: Graph of Compressive Strength against Curing Days at 0% Quarry Dust

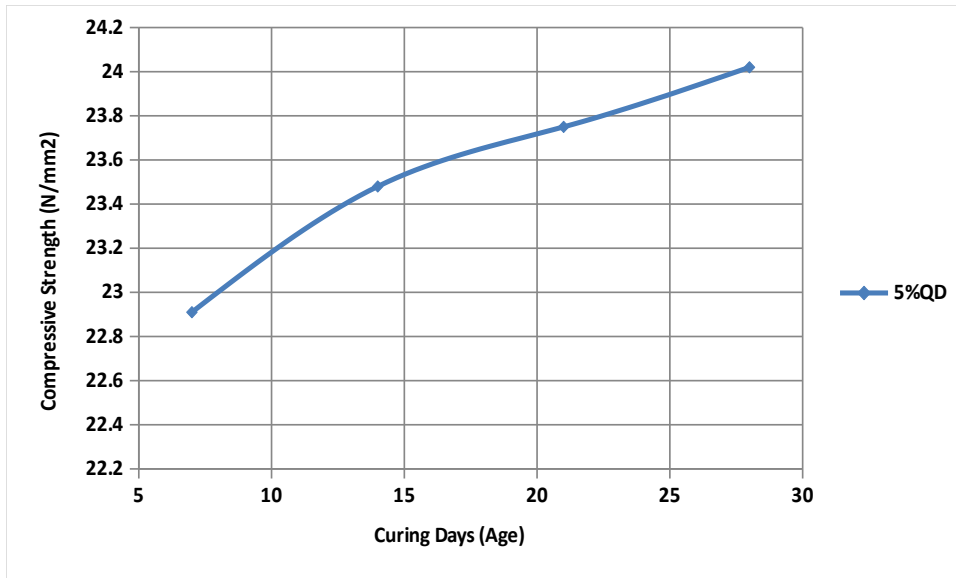


Figure A2: Graph of Compressive Strength against Curing Days at 5% Quarry Dust

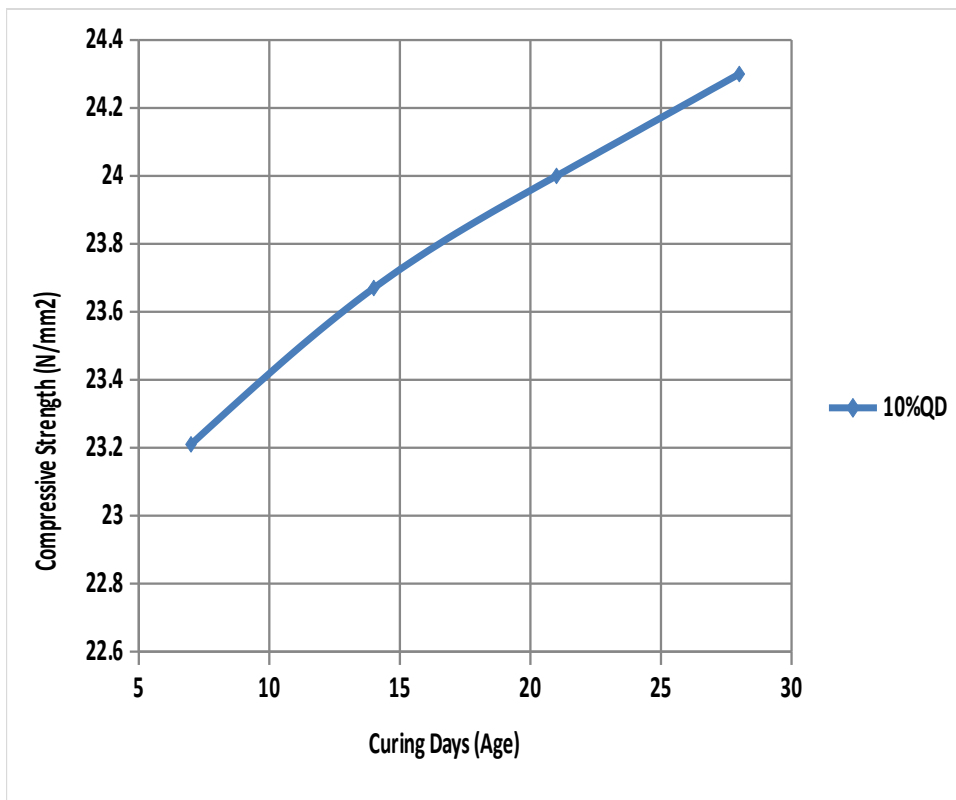


Figure A3: Graph of Compressive Strength against Curing Days at 10% Quarry Dust

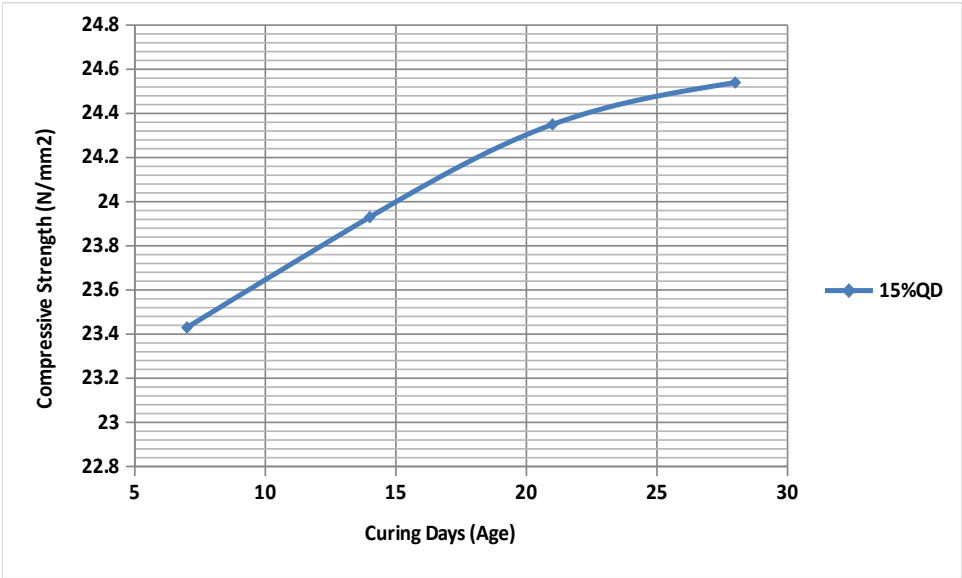


Figure A4: Graph of Compressive Strength against Curing Days at 15% Quarry Dust

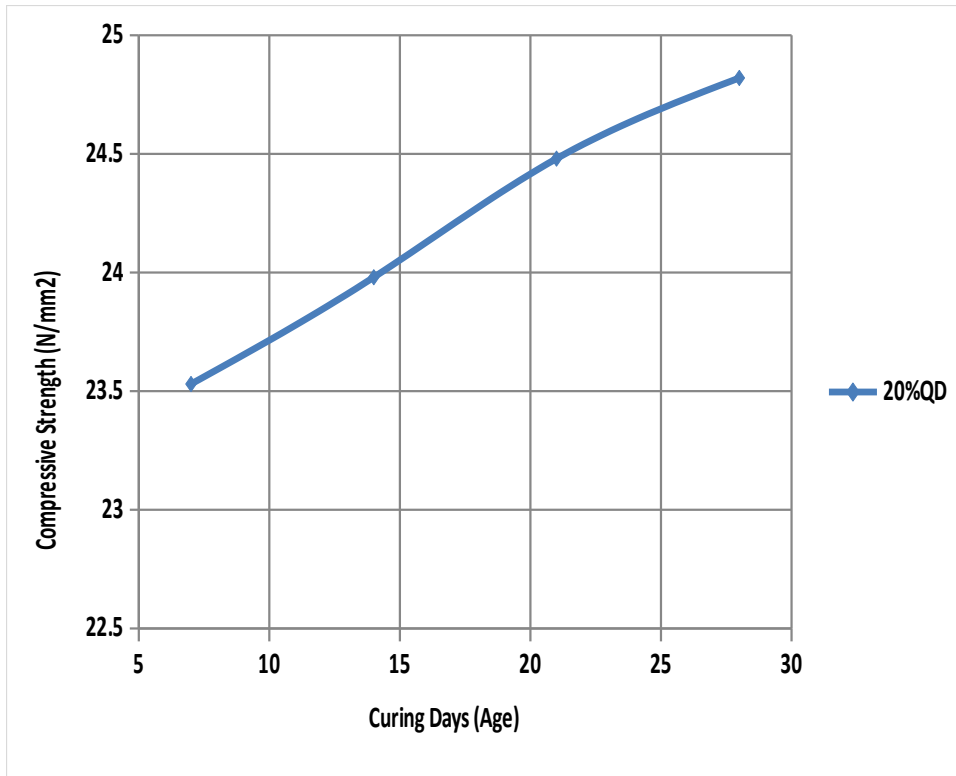


Figure A5: Graph of Compressive Strength against Curing Days at 20% Quarry Dust

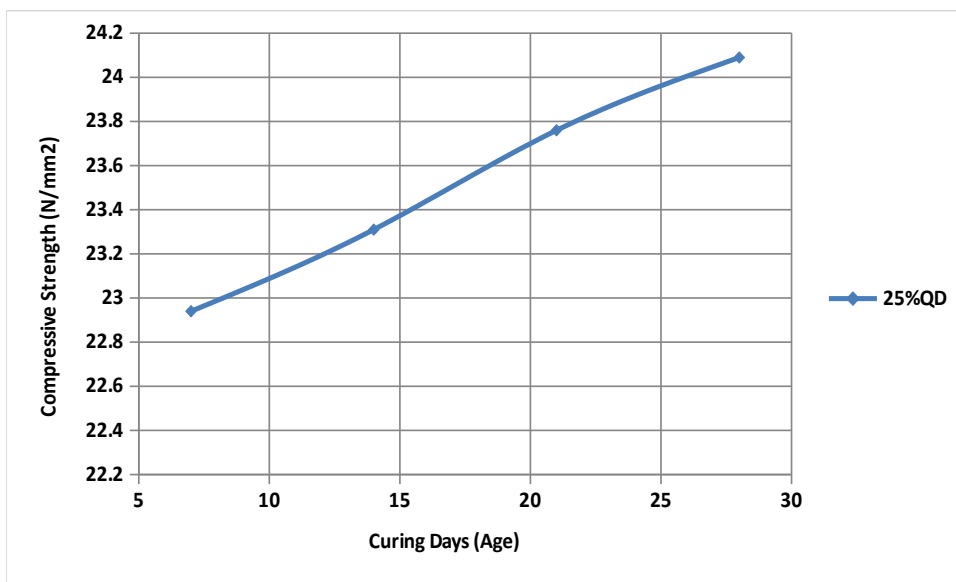


Figure A6: Graph of Compressive Strength against Curing Days at 25% Quarry Dust

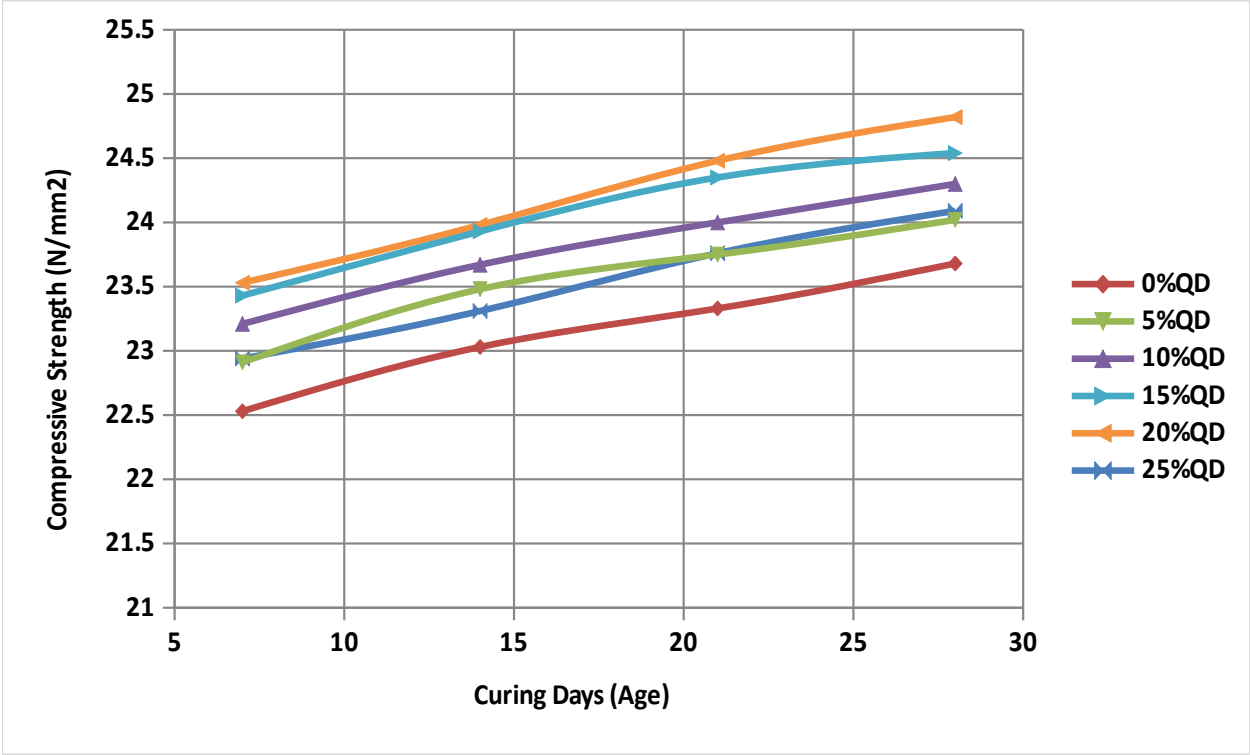


Figure A7: Graph of Compressive Strength against Curing Days at Varying Percentages of Quarry Dust

APPENDIX B

DRY DENSITY TEST

Table B1: Density Test Result for 0%QD

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m³)	Average Density (kg/m³)
7 days	7.14	7.09	2116	2115
	7.12		2110	
	7.15		2119	
14 days	7.21	7.21	2137	2136
	7.18		2127	
	7.24		2145	
21 days	7.30	7.34	2163	2174
	7.33		2172	
	7.38		2187	
28 days	7.4	7.42	2192	2199
	7.42		2199	
	7.44		2204	

Table B2: Density Test Result for 5%QD

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m³)	Average Density (kg/m³)
7 days	7.48	7.52	2216	2227
	7.52		2228	
	7.55		2237	
14 days	7.62	7.67	2258	2273
	7.68		2276	
	7.71		2284	
21 days	7.78	7.82	2305	2316
	7.82		2317	
	7.85		2326	
28 days	7.89	7.88	2338	2334
	7.95		2356	

	7.79		2308	
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Table B3: Density Test Result for 10%QD

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m³)	Average Density (kg/m³)
7 days	7.58	7.61	2246	2254
	7.61		2255	
	7.63		2261	
14 days	7.68	7.74	2276	2293
	7.75		2296	
	7.79		2300	
21 days	7.81	7.86	2314	2329
	7.87		2332	
	7.90		2341	
28 days	7.95	8.02	2356	2375
	8.02		2376	
	8.08		2394	

Table B4: Density Test Result for 15%QD

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m³)	Average Density (kg/m³)
7 days	7.64	7.69	2264	2278
	7.68		2276	
	7.74		2293	
14 days	7.79	7.82	2308	2317
	7.82		2317	
	7.85		2326	
21 days	7.92	7.96	2347	2365
	7.98		2364	
	8.05		2385	
28 days	8.12	8.12	2406	2405
	8.15		2415	
	8.10		2400	

Table B5: Density Test Result for 20%QD

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m³)	Average Density (kg/m³)
7 days	7.82	7.82	2317	2316
	7.84		2323	
	7.79		2308	
14 days	7.88	7.94	2335	2352
	7.91		2352	
	8.02		2376	
21 days	8.14	8.18	2412	2423
	8.18		2424	
	8.21		2433	
28 days	8.23	8.24	2439	2450
	8.28		2453	
	8.30		2459	

Table B6: Density Test Result for 25%QD

Curing days (Age)	Weight (kg)	Average Weight (kg)	Density (kg/m³)	Average Density (kg/m³)
7 days	7.61	7.54	2255	2233
	7.52		2228	
	7.48		2216	
14 days	7.75	7.74	2296	2294
	7.70		2281	
	7.78		2305	
21 days	7.94	7.90	2353	2340
	7.85		2326	
	7.9		2341	
28 days	8.04	8.04	2382	2381
	7.99		2367	
	8.08		2394	

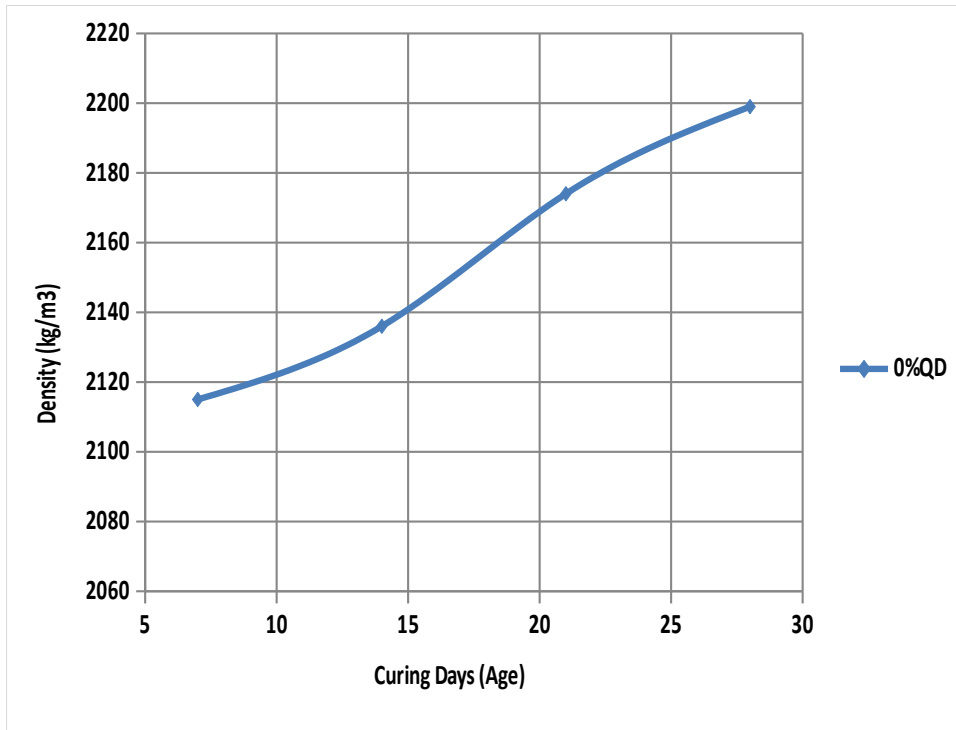


Figure B1: Charts Showing the Dry Density against Curing Days at 0% Quarry Dust Content.

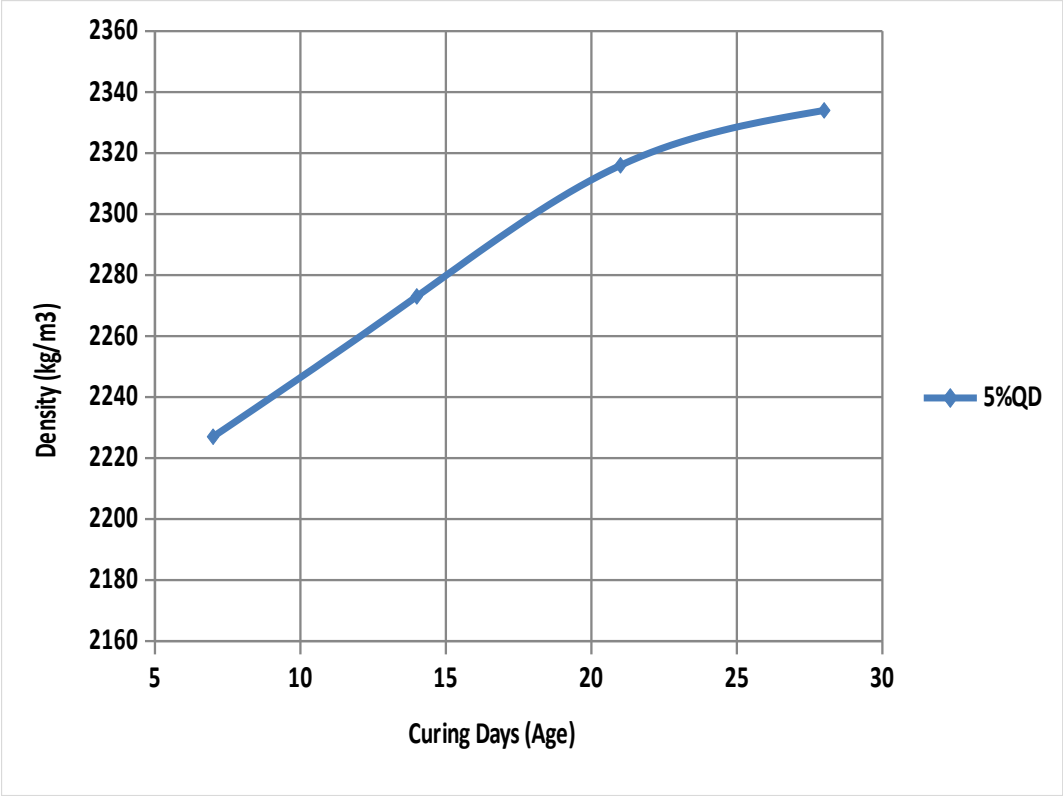


Figure B2: Charts Showing the Dry Density against Curing Days at 5% Quarry Dust Content.

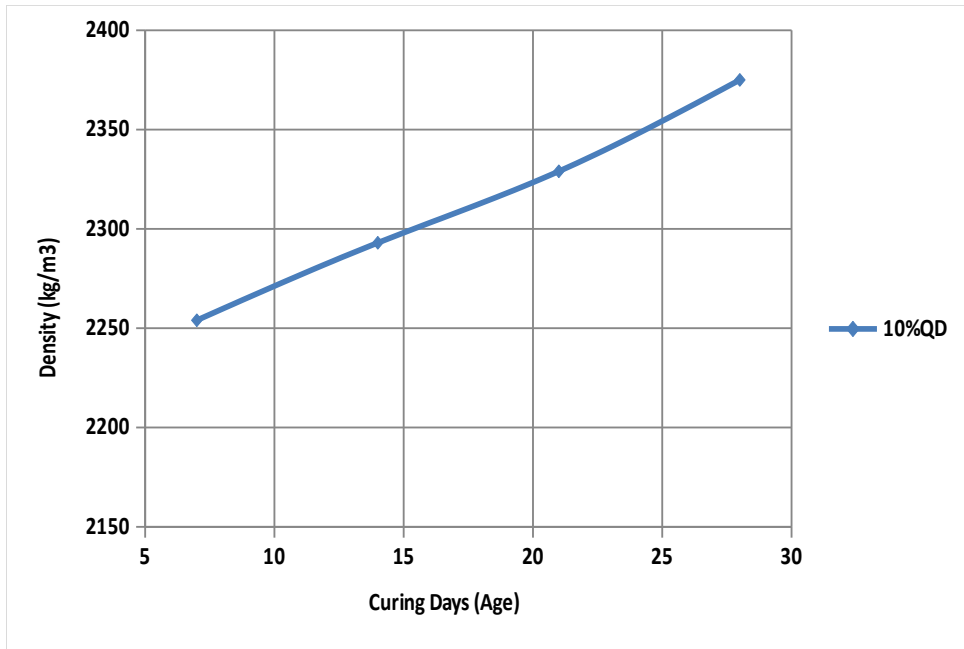


Figure B3: Charts Showing the Dry Density against Curing Days at 10% Quarry Dust Content.

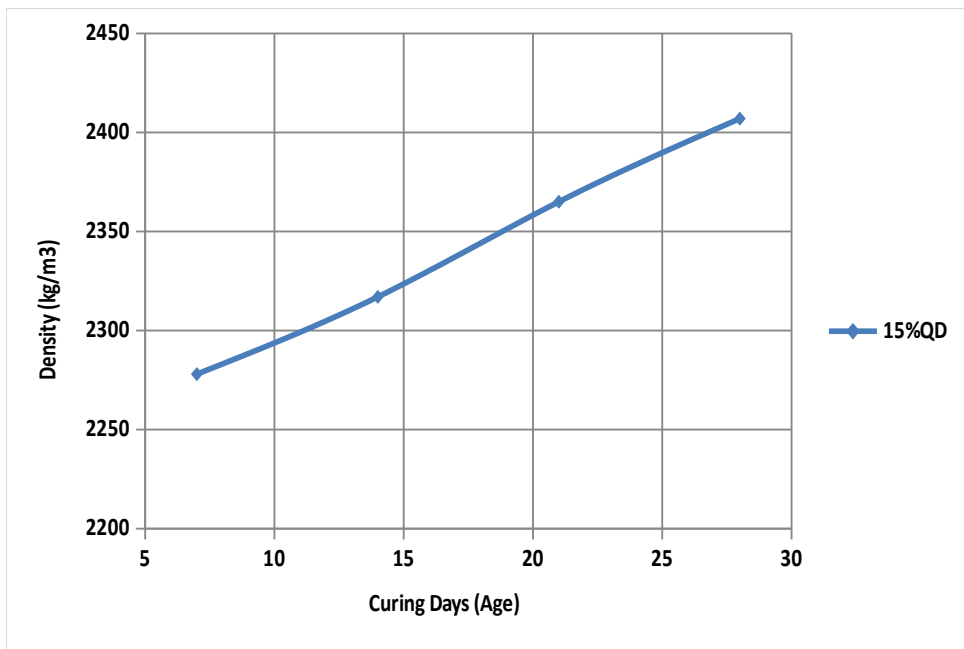


Figure B4: Charts Showing the Dry Density against Curing Days at 15% Quarry Dust Content.

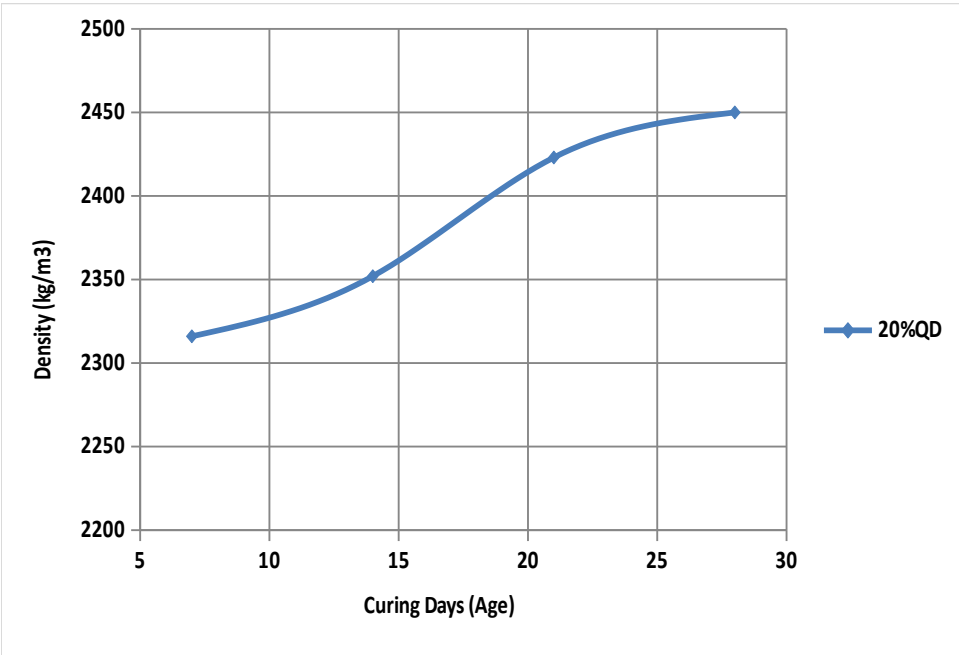


Figure B5: Charts Showing the Dry Density against Curing Days at 20% Quarry Dust Content.

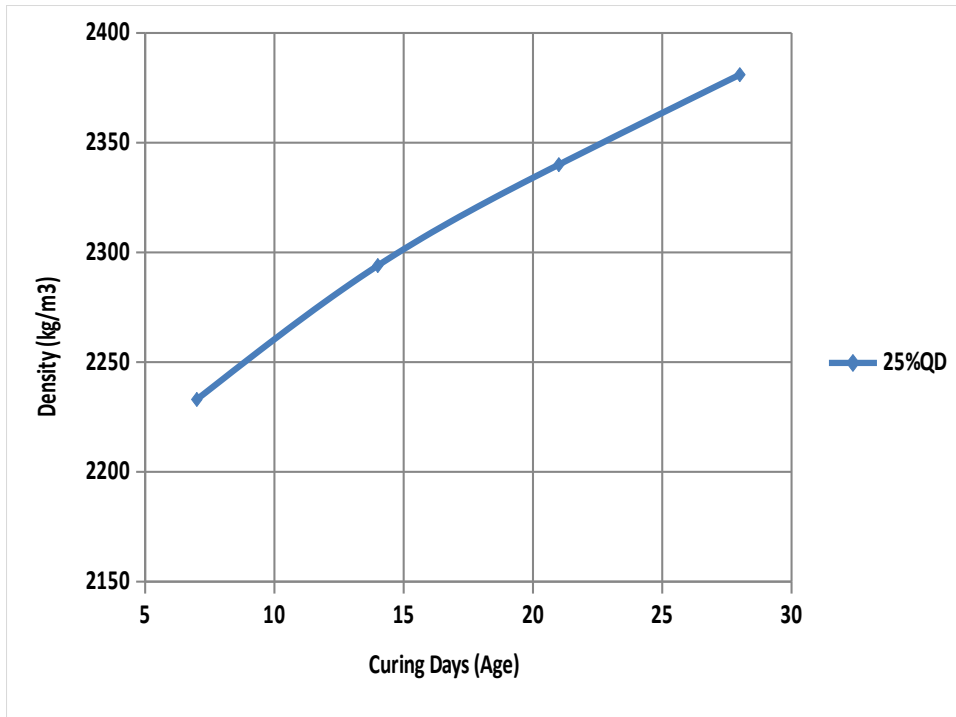


Figure B6: Charts Showing the Dry Density against Curing Days at 25% Quarry Dust Content.

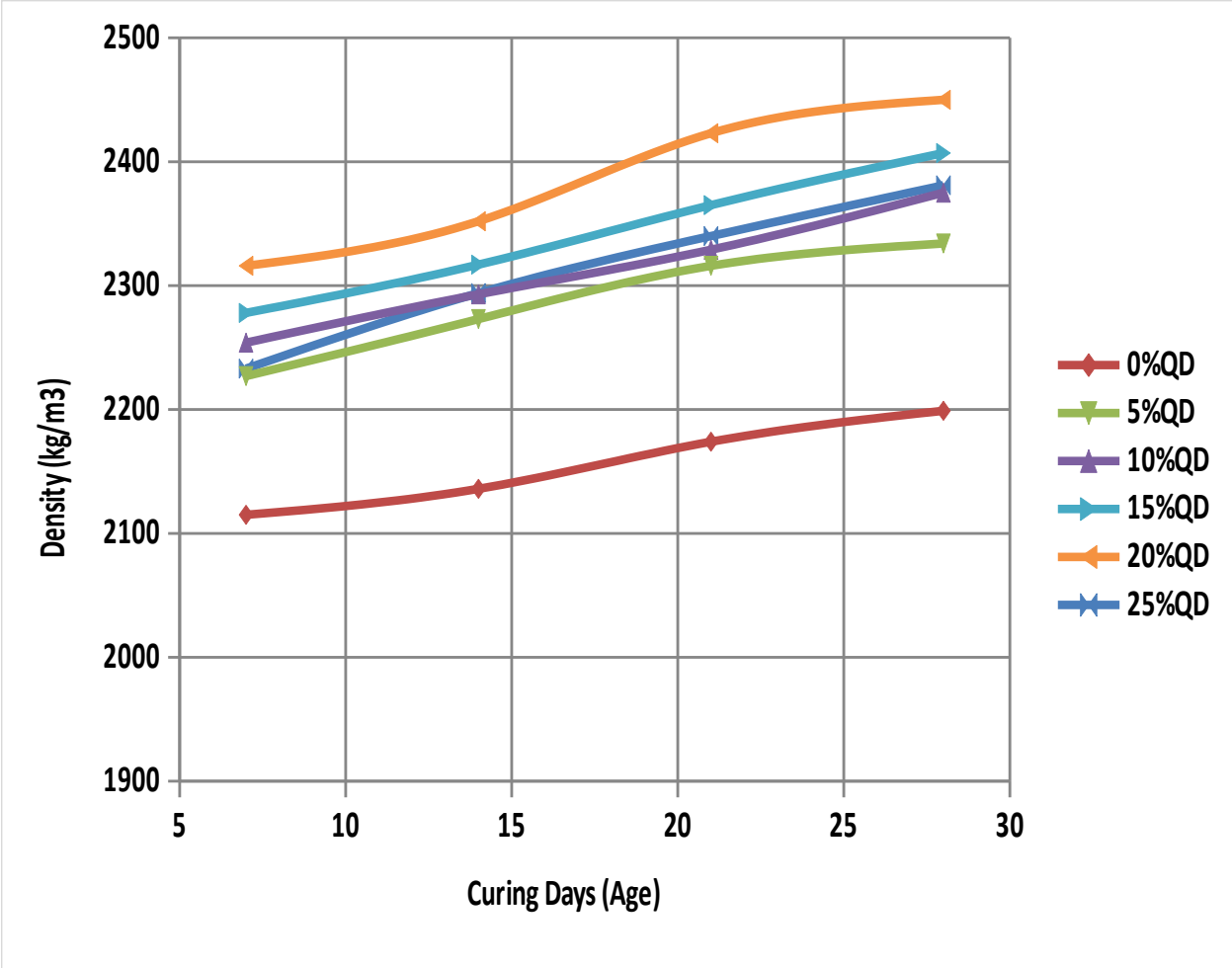


Figure B7: Charts Showing the Dry Density against Curing Days at Varying Percentages of Quarry Dust

APPENDIX C

SLUMP TEST

Table C1: Slump Test Result at Varying Percentages of Quarry Dust

Percentages of Quarry Dust	Height of Cone (mm)	Height of Collapse (mm)	Slump (mm)	Slump Type
0	300	265	35	True Slump
5	300	272	28	True Slump
10	300	280	20	True Slump
15	300	285	15	True Slump
20	300	290	10	True Slump
25	300	292	8	True Slump

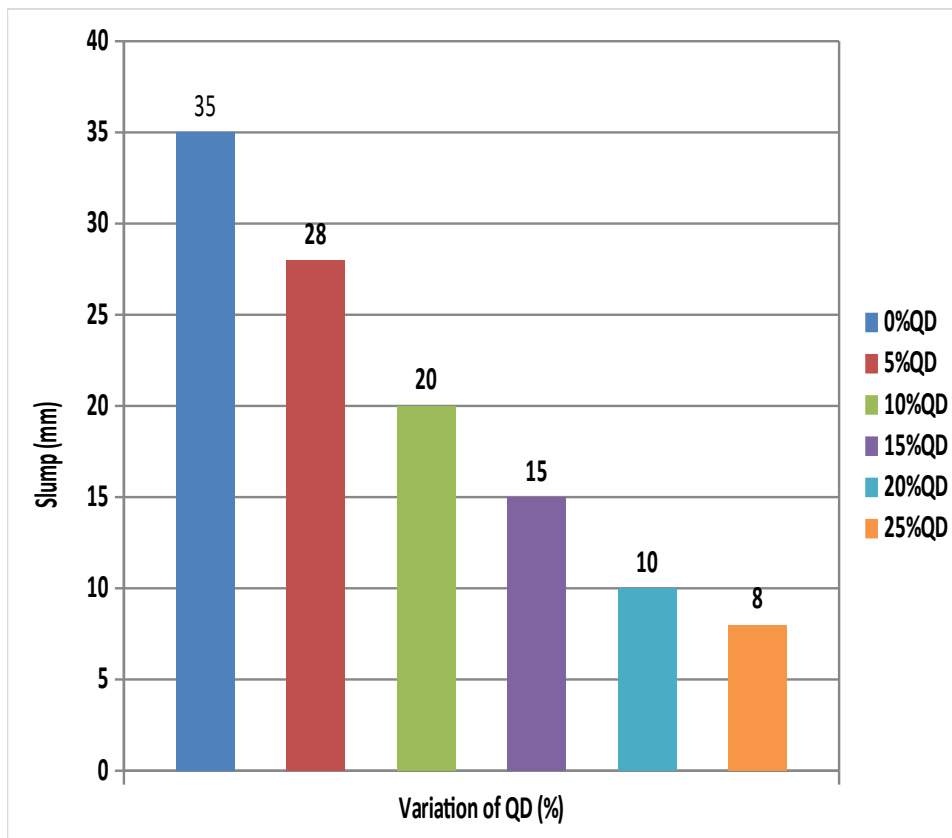


Figure C1: Charts Showing the Slump Value of the Concrete at Varying Percentages of Quarry Dust

APPENDIX D

SIEVE ANALYSIS TEST

Table D1: Sieve Analysis Test Result for Sand

Sieve Sizes	Mass Retained (g)	% Mass Retained (g)	Cum % Retained	Cum % Finer
2	7.97	2.66	2.66	97.34
1.18	9.98	3.33	5.99	94.01
0.85	11.73	3.91	9.90	90.10
0.6	27.95	9.32	19.21	80.79
0.425	44.02	14.67	33.89	66.11
0.3	53.69	17.90	51.78	48.22
0.15	112.1	37.37	89.15	10.85
0.075	8.46	2.82	91.97	8.03
Tray	2.3	0.77	92.74	7.26

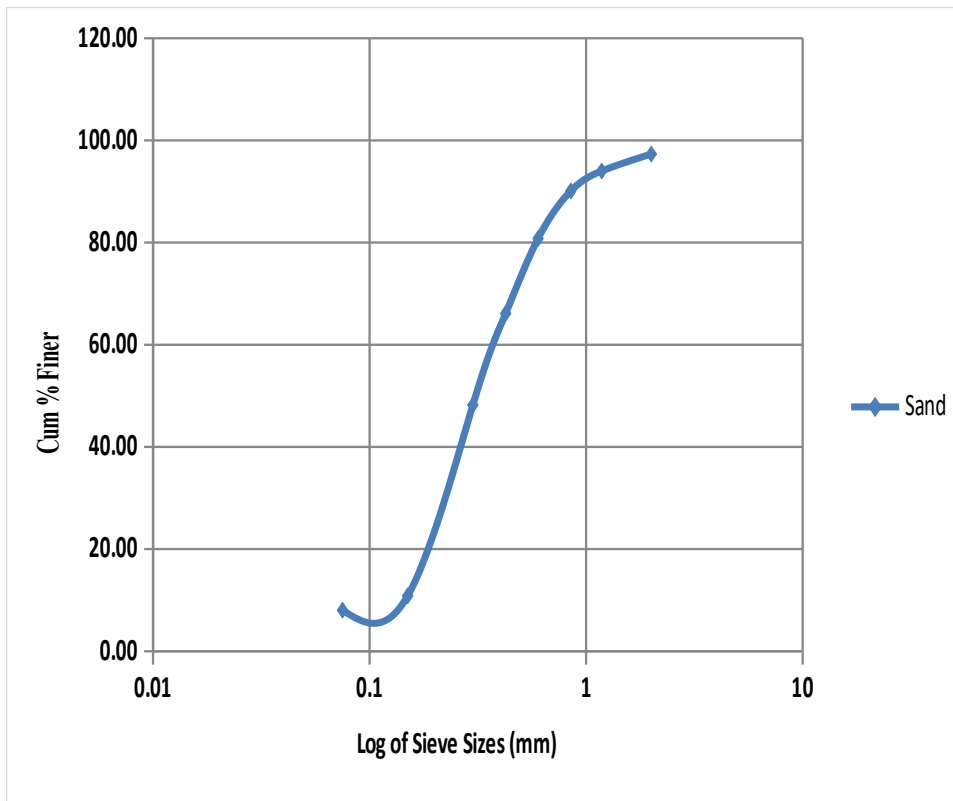


Figure D1: Particle Size Distribution Curve for Sand

Table D2: Sieve Analysis Test Results for Quarry Dust

Sieve Sizes	Mass Retained (g)	% Mass Retained (g)	Cum % Retained	Cum % Finer
4.75	7.96	1.59	1.59	98.41
2	138.46	27.69	29.28	70.72
1.18	70.72	14.14	43.43	56.57
0.85	33.56	6.71	50.14	49.86
0.6	30.85	6.17	56.31	43.69
0.425	25.78	5.16	61.46	38.54
0.3	20.9	4.18	65.64	34.36
0.15	38.7	7.74	73.38	26.62
0.075	34.44	6.89	80.27	19.73
Tray	40.4	8.08	88.35	11.65

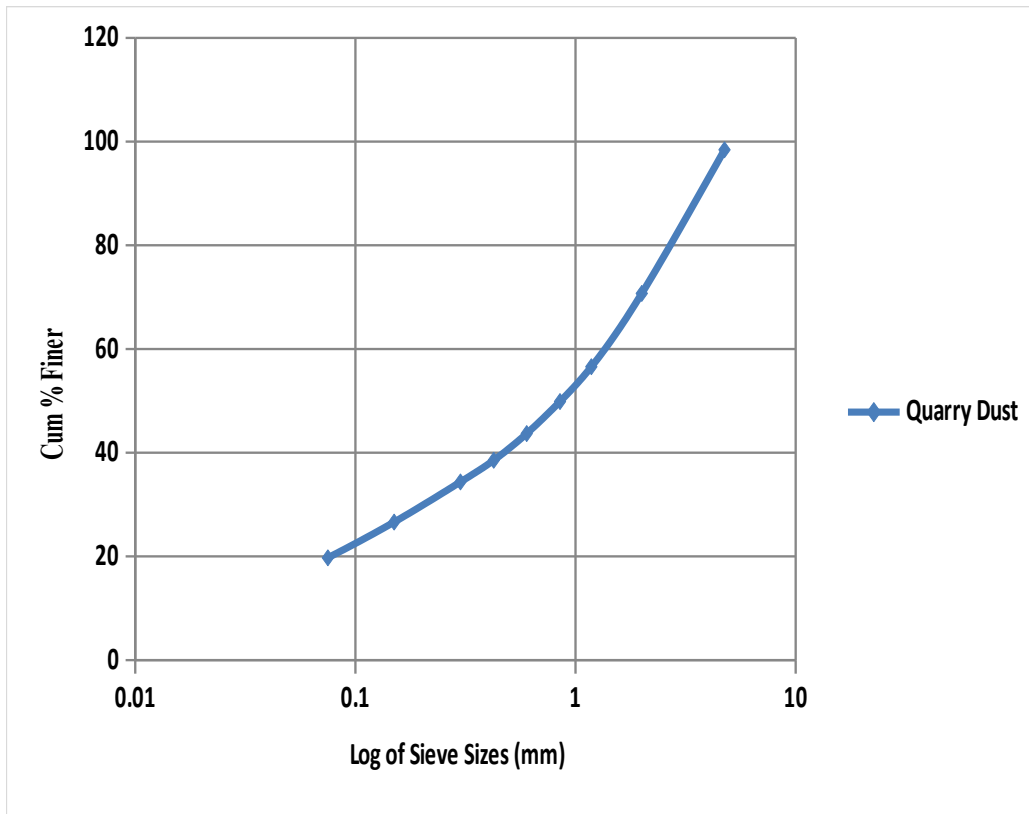


Figure D2: Particle Size Distribution Curve for Quarry Dust

Table D3: Sieve Analysis Test Result for Granite

Sieve Sizes	Mass Retained (g)	% Mass Retained (g)	Cum % Retained	Cum % Finer
31.25	0.18	0.02	0.02	99.98
25	98.6	8.96	8.98	91.02
20	367.27	33.39	42.37	57.63
12.5	509	46.27	88.64	11.36
9.5	14.71	1.34	89.98	10.02
6.3	32.11	2.92	92.90	7.10
4.75	14.53	1.32	94.22	5.78
Tray	12.48	1.13	95.36	4.64

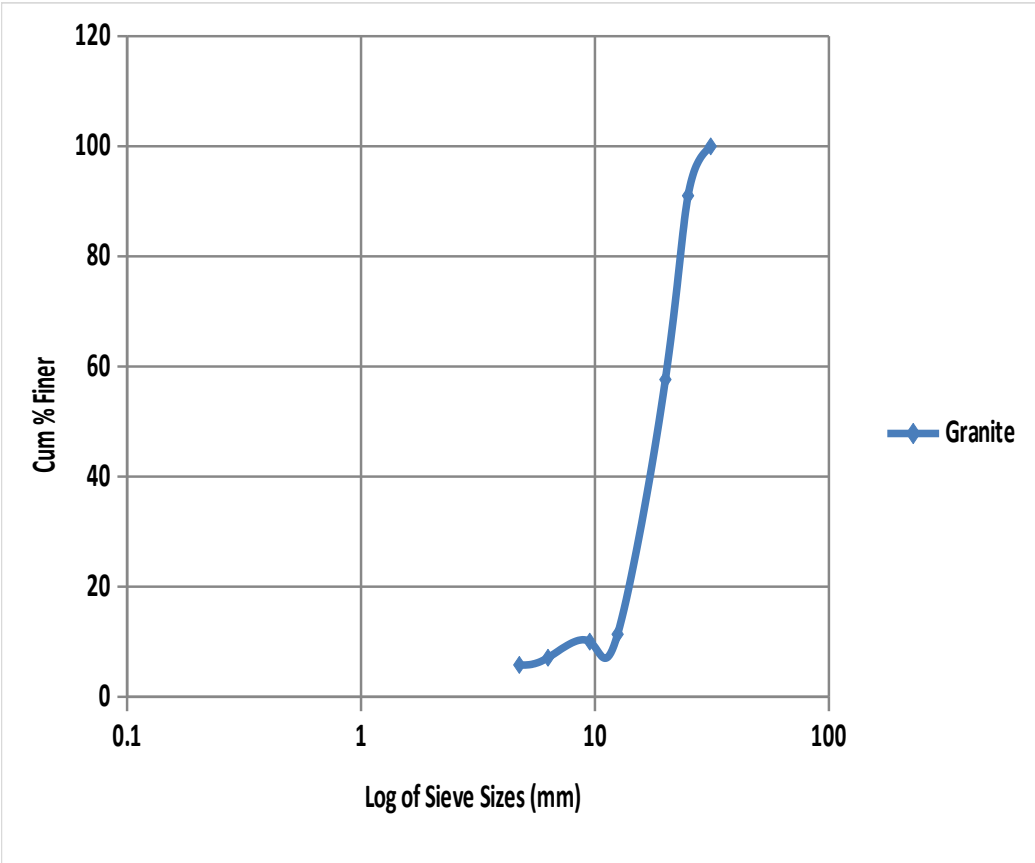
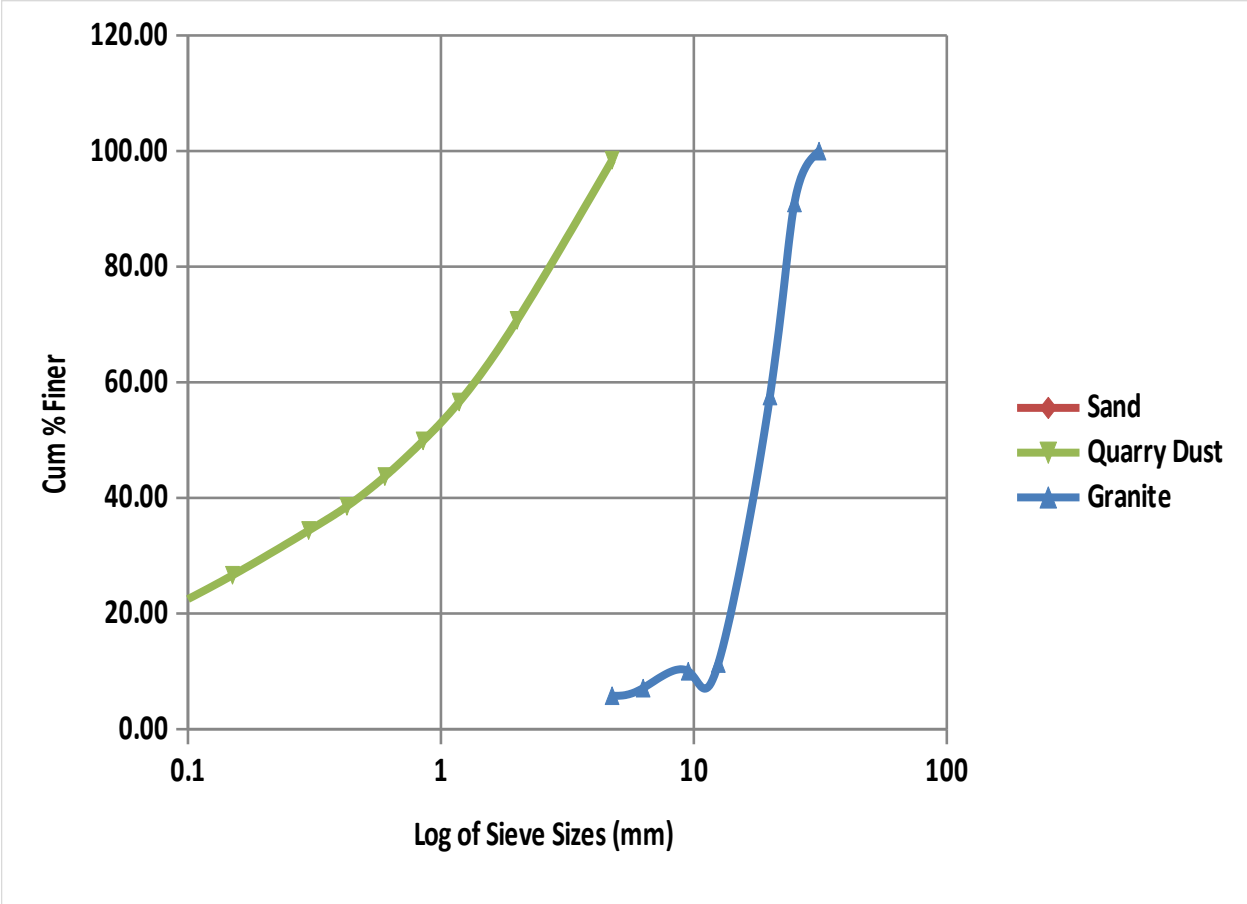


Figure D3: Particle Size Distribution Curve for Granite



Particle Size Distribution Curve for Granite, Quarry Dust and Sand.

APPENDIX E

AGGREGATE IMPACT AND CRUSHING VALUE TEST

Table E1: Impact Test Results for Granite Samples

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

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

Table E2: Crushing Test Results for Granite Samples

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

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

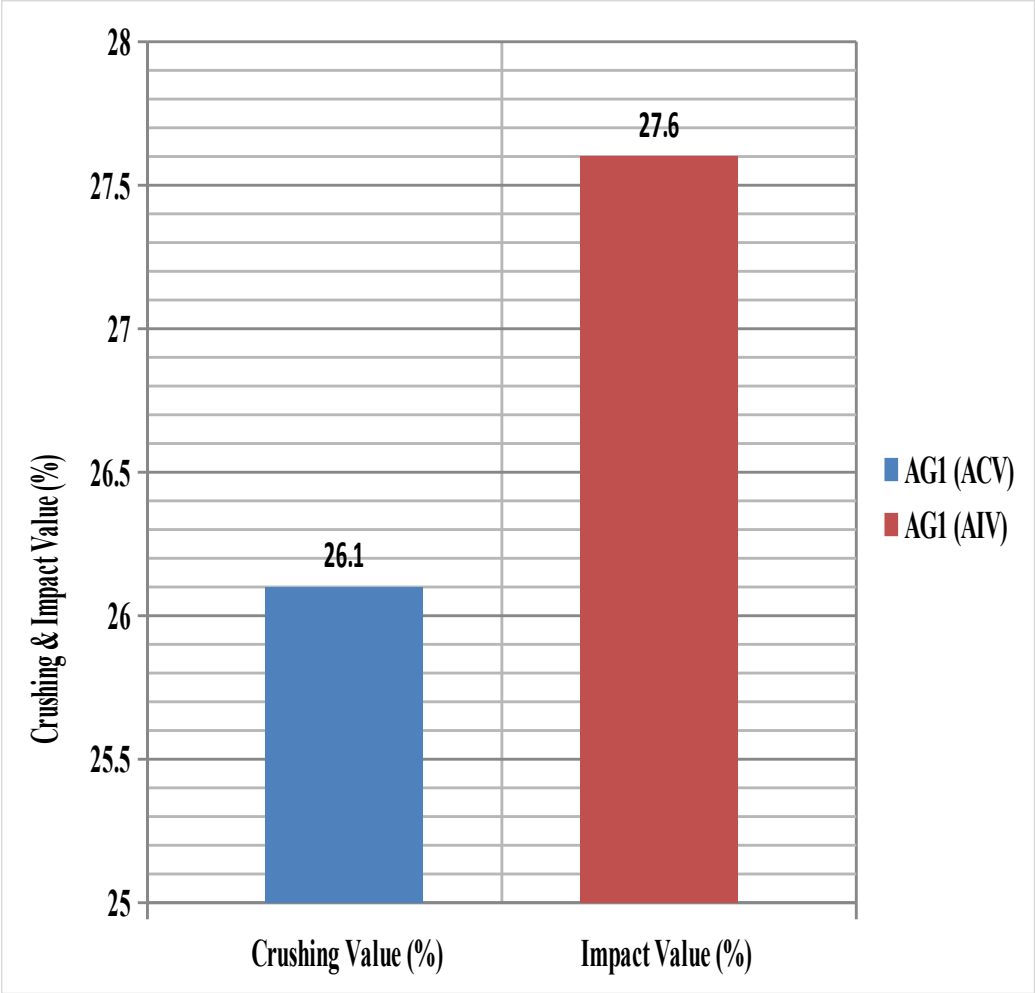


Figure E1: Charts Showing the Impact and Crushing Value of Aggregate

APPENDIX F

SPECIFIC GRAVITY TEST

Table F1: Specific Gravity Result for Crushed Granite.

Determinants	Trial 1	Trial 2	Trial 3
Wt of Saturated aggregate and bucket in water W_1 (g).	458.72	460.68	462.46
Wt of bucket in Water W_2 (g).	190.48	192.84	192.88
Wt of Saturated aggregate in air W_3 (g).	438.62	442.24	440.82
Wt of Oven-dried aggregate in air W_4 (g).	432.80	434.28	434.86

The Specific gravity of the sample is calculated as follows:

Apparent Specific Gravity for Crushed Granite.

$$\text{Trial 1 } (G_{s1}) = \frac{W_4}{\cancel{\cancel{11}}} = \frac{432.80}{\cancel{\cancel{11}}} = 2.63$$

$$\text{Trial 2 } (G_{s2}) = \cancel{\cancel{11}} = \frac{434.28}{\cancel{\cancel{11}}} = 2.61$$

$$\text{Trial 3 (G}_{s3}) = \frac{W_4}{\cancel{V}} = \frac{434.86}{\cancel{V}} = 2.60$$

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

Bulk Specific Gravity for Crushed Granite.

$$\text{Trial 1 (G}_{s1}) = \frac{W_4}{\cancel{V}} = \frac{432.80}{\cancel{V}} = 2.48$$

Table F2: Specific Gravity Result for Sand

Determinants	Trial 1	Trial 2	Trial 3
Wt of density bottle, W ₁ (g).	24.50	25.32	25.12
Wt of bottle + dry soil, W ₂ (g).	34.48	35.31	35.10
Wt of bottle + soil + water, W ₃ (g).	84.43	86.39	85.03
Wt of bottle + water, W ₄ (g).	78.35	80.32	78.93

The Specific gravity of the sample is calculated as follows:

Specific Gravity for Sand.

$$\text{Trial 1 (G}_{s1}) = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)} = \frac{(34.48 - 24.50)}{(34.48 - 24.50) - (84.43 - 78.35)} = 2.56$$

$$\text{Trial 2 (G}_{s2}) = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)} = \frac{(35.31 - 25.32)}{(35.31 - 25.32) - (86.39 - 80.32)} = 2.55$$

$$\text{Trial 3 (G}_{s3}) = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)} = \frac{(35.10 - 25.12)}{(35.10 - 25.12) - (85.03 - 78.93)} = 2.53$$

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

Table F3. Specific Gravity Result For QD.

Determinants	Trial 1	Trial 2	Trial 3
Wt of density bottle, W_1 (g).	27.66	26.83	25.02
Wt of bottle + dry soil, W_2 (g).	37.66	36.83	35.02
Wt of bottle + soil + water, W_3 (g).	88.06	85.46	85.73
Wt of bottle + water, W_4 (g).	81.81	79.22	78.50

The Specific gravity of the sample is calculated as follows:

Specific Gravity for Quarry Dust

$$\text{Trial 1 } (G_{S1}) = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)} = \frac{(34.98 - 24.98)}{(34.98 - 24.98) - (84.90 - 78.51)} = \mathbf{2.77}$$

$$\text{Trial 2 } (G_{S2}) = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)} = \frac{(35.90 - 25.90)}{(35.90 - 25.90) - (85.79 - 79.41)} = \mathbf{2.76}$$

$$\text{Trial 3 } (G_{S3}) = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)} = \frac{(35.73 - 25.73)}{(35.73 - 25.73) - (85.62 - 79.25)} = \mathbf{2.75}$$

$$\text{Specific Gravity} = \frac{(GS1+GS2+GS3)}{3} = \frac{(2.77+2.76+2.75)}{3} = \mathbf{2.76}$$

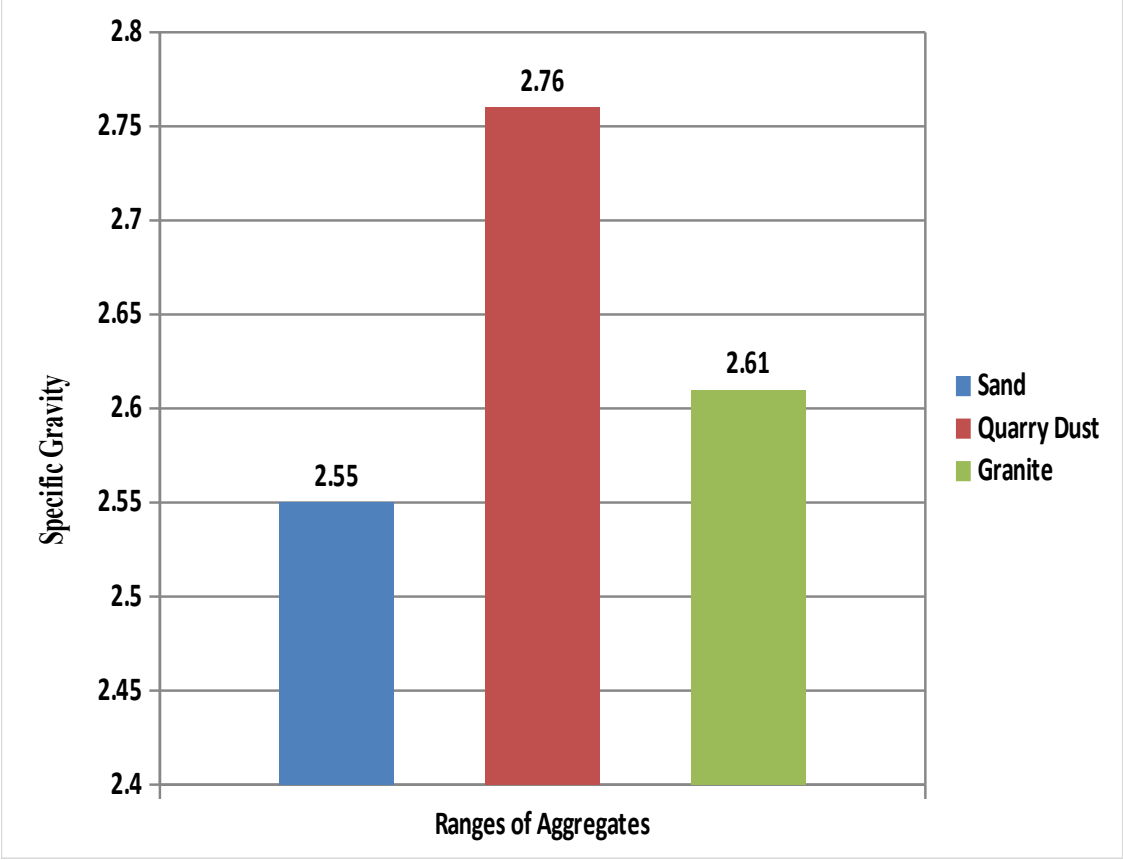


Figure F1: Specific Gravity of Aggregates used for Concrete Production

APPENDIX G

SOUNDNESS AND FINENESS TEST OF CEMENT

Table G1: Fineness Test of Cement

Sample	Dangote 3x cement
Initial Weight (g)	100
Final Weight (g)	97
Fineness (%)	3

Table G2: Soundness Test Results

Sample	Trial 1	Trial 2	Trial 3
Initial Diameter (mm)	30	30	30
Final Diameter (mm)	28.82	29.33	29.01
Soundness	1.18	0.67	0.99
Average Soundness	0.95		

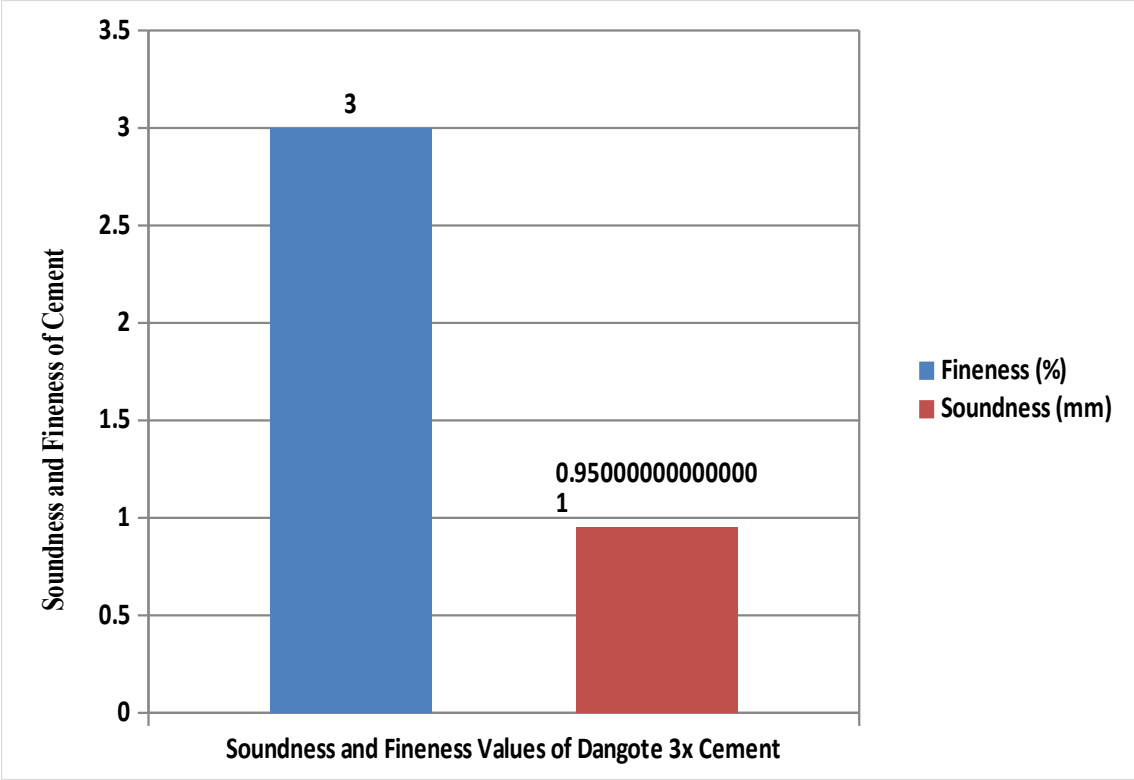


Figure G1: Soundness and Fineness Values of Dangote 3x Cement