

**PERFORMANCE EVALUATION OF CONCRETE MADE BY PARTIALLY
REPLACING CEMENT WITH GRANITE POWDER**

M .Sc. THESIS

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HAWASSA UNIVERSITY, HAWASSSA, ETHIOPIA

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**PERFORMANCE EVALUATION OF CONCRETE MADE BY PARTIALLY
REPLACING CEMENT WITH GRANITE POWDER**

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A THESIS SUBMITTED TO

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HAWASSA UNIVERSITY
INSTITUTE OF TECHNOLOGY
DEPARTMENT OF CIVIL ENGINEERING
SCHOOL OF GRADUATE STUDIES
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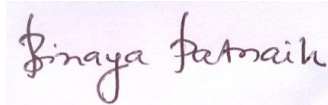
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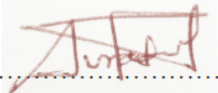
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DEDICATION

First and foremost praises and thanks to God!

Secondly,

To

My Family

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TABLE OF CONTENTS

Contents	Page
DEDICATION.....	i
ACKNOWLEDGMENT	ii
TABLE OF CONTENTS.....	iii
LIST OF TABLES.....	vi
LIST OF FIGURES	viii
LIST OF TABLES IN APPENDICES	x
LIST OF FIGURES IN APPENDICES.....	xi
LIST OF ABBREVIATION	xii
ABSTRACT.....	xiii
1. INTRODUCTION	1
1.1 Background	1
1.2 Problem Statements.....	3
1.3 Objectives.....	3
1.3.1 General objective.....	3
1.3.2 Specific objectives.....	4
1.4 Research Questions	4
1.5 Significance of the Study	5
1.6 Scope and Limitations of the Study	5
1.7 Structure of Thesis Report	6
2. LITERATURE REVIEW.....	7
2.1 Introduction	7
2.2 Concrete Composing Materials.....	8
2.2.1 Cement.....	8
2.2.2 Water	14
2.2.3 Aggregate	16
2.2.4 Admixtures	19
2.3 Granite.....	21
2.3.1 Physical Properties of Granite.....	21

2.3.2 Chemical Properties of granite	22
2.4 Granite Powder.....	23
2.5 Review of Related Works	24
2.6 Concluding Remarks	41
3. MATERIALS AND METHODS	42
3.1 Introduction	42
3.2 Materials.....	43
3.2.1 Cement.....	43
3.2.2 Fine aggregate	44
3.2.3 Coarse aggregate	46
3.2.4 Water	48
3.2.5 Granite powder	48
3.2.6 High Range Water Reducer	50
3.3 Experimental Programs	50
3.3.1 Slump test	50
3.3.2 Compressive strength test.....	51
3.3.3 Flexural tensile strength test	54
3.3.4 Water absorption test.....	55
3.3.5 Sorptivity test.....	56
3.3.6 Chemical attack tests	58
4. TEST RESULT AND DISCUSSION.....	60
4.1 Introduction	60
4.2 Workability of fresh concrete.....	60
4.3 Compressive strength.....	61
4.3.1 C20/25 as NSC	61
4.3.2 C55/67 as HSC	63
4.4 Flexural tensile strength	66
4.4.1 C20/25 as NSC	66
4.4.2 C55/67 as HSC	67
4.5 Water absorption	69
4.5.1 C20/25 as NSC	69

4.5.2 C55/67 as HSC	69
4.6 Sorptivity	70
4.6.1 C20/25 as NSC	71
4.6.2 C55/67 as HSC	72
4.7 Sulphate attack	73
4.7.1 C20/25 as NSC	73
4.7.2 C55/67 as HSC	73
4.8 Chloride attack	74
4.8.1 C20/25 as NSC	74
4.8.2 C55/67 as HSC	75
5. SUMMARY AND CONCLUSION	76
5.1 Summary	76
5.2 Conclusions	76
5.2.2 C20/25 as NSC	76
5.2.3 C55/67 as HSC	78
References	79
Appendices	85
Appendix A: Photos showing collection of granite powder, its specific gravity and chemical test results.	85
Appendix B: Photos on collecting materials for concrete production	90
Appendix C: Material tests for concrete proportioning	91
Appendix C 1: Test on fine aggregate	91
Appendix C 2: Test on coarse aggregate	93
Appendix C 3: Summary of test results	97
Appendix C 4: Mix design	98

LIST OF TABLES

Table	Page
Table 2.1: Types and uses of cements	11
Table 2.2: Properties of compounds of cement	13
Table 2.3: Chemical composition of granite.....	22
Table 2. 4: Percentage composition of oxides in granite powder and cement.....	23
Table 3.1: Physical and chemical properties of Dangote OPC	43
Table 3.2: Chemical oxides composition of Dangote OPC	43
Table 3.3: Sieve analysis results of fine aggregate.....	44
Table 3.4: Summary of physical properties of fine aggregate.....	45
Table 3.5: Sieve analysis results of coarse aggregate.....	46
Table 3.6: Summary of physical properties of coarse aggregate.....	47
Table 3.7: Physical property of Granite powder.....	49
Table 3.8: Chemical composition of granite powder.....	49
Table 3.9: Properties of superplasticizer.....	50
Table 3.10: Compressive strength test specimens	53
Table 3.11: Number of concrete beam specimens.....	54
Table 3.12: Number of cubes for water absorption test.....	56
Table 3.13: 100 mm X 50 mm cylindrical test specimens for Sorptivity test.	57
Table 4.1: Slump height measures of C25 and C67 grade concrete	60

Table 4.2: Compressive strength test on C20/25 concrete.....	62
Table 4.3: Compressive strength test on C55/67 concrete.....	64
Table 4.4: Flexural strength test on C20/25 concrete.	66
Table 4.5: Flexural strength test on C55/67 concrete	68
Table 4.6: Initial rate of water absorption on C20/25	71
Table 4.7: Initial rate of water absorption on C55/67.....	72

LIST OF FIGURES

Figure	Page
Figure 3.1: Grain size distribution of fine aggregate.....	45
Figure 3.2: Grain size distribution of coarse aggregate.....	47
Figure 3.3: Slump apparatus and slump test.....	51
Figure 3.4: Compressive strength testing.....	53
Figure 3.5: Concrete beam specimens.....	55
Figure 3.6: Cube specimens for water absorption test.....	56
Figure 3.7: Sorptivity test specimens after cutting the parent cylinders.....	57
Figure 3.8: Measuring of mass of specimens.....	58
Figure 3.9: Samples in sulphate solution and Na ₂ SO ₄ powder.....	59
Figure 3.10: Samples in chloride solution and NaCl Powder.....	59
Figure 4.1: Compressive strength test result of C20/25 concrete.....	63
Figure 4.2: Compressive strength test result of C55/67 concrete.....	65
Figure 4.3: Flexural strength test result of C20/25 concrete.....	67
Figure 4.4: Flexural strength test result of C55/67 concrete.....	68
Figure 4.5: Water absorption test result of C20/25 concrete.....	69
Figure 4.6: Water absorption test result of C55/67 concrete.....	70
Figure 4.7: Graphical representation of rate of water absorption on C20/25 concrete.....	71
Figure 4.8: Graphical representation of rate of water absorption on C55/67 concrete.....	72
Figure 4.9: Sulphate attack test result of C20/25 concrete.....	73

Figure 4.10: Sulphate attack test result of C55/67 concrete	74
Figure 4.11: Chloride attack test result of C20/25 concrete	75
Figure 4.12: Chloride attack test result of C55/67 concrete	75

LIST OF TABLES IN APPENDICES

Table	Page
Table C 1: Unit weight and void content of fine aggregate.....	91
Table C 2: Specific gravity and water absorption test on Sand	92
Table C 3: Silt content test.....	92
Table C 4: Sieve analysis test on sand.....	93
Table C 5: Unit weight test on 25mm size coarse aggregate.....	94
Table C 6: Unite weight test on 19mm size aggregate	95
Table C 7: Specific gravity and water absorption test on 25mm & 19mm size coarse aggregates and found the same.....	95
Table C 8: Sieve analysis for 25mm size coarse aggregate	96
Table C 9 : Sieve analysis for 19mm size coarse aggregate	96
Table C 10: Summary of properties of aggregates	97

LIST OF FIGURES IN APPENDICES

Figure A 1: Granite sludge in reservoir tank	85
Figure A 2: Collection of granite powder	85
Figure A 3: Granite powder used in concrete mixes	86
Figure A 4: Granite powder finer than 45 μ m	86
Figure A 5: Granite powder wastage in other workshop	87
Figure A 6: Mixing of cement and granite powder during replacement	87
Figure A 7: Specific gravity test result of GP	88
Figure A 8: Chemical test result of GP	89
Figure B 1: Coarse aggregate quarry	90
Figure B 2: Dangote 42.5R grade cement.....	90
Figure C 1: Sieve analysis, specific gravity & silt content tests on sand	91
Figure C 2: Washed aggregate and specific gravity test on coarse aggregate.....	93

LIST OF ABBREVIATION

ACI	America Concrete Institute
ASTM	America Society of Testing Material
GP	Granite Powder
HSC	High Strength Concrete
NSC	Normal Strength Concrete
OD	Oven Dry
SSD	Saturated Surface Dry
OPC	Ordinary Portland cement

ABSTRACT

This experimental investigation has been performed to evaluate the strength and durability properties of concrete, in which cement was partially replaced with granite powder at 0%, 5%, 10%, 15% and 20% by volume. A total of five concrete mix proportions were developed for control and concrete with granite powder. Fresh properties of concrete using slump test and strength and durability tests on hardened concrete were performed. Compressive strength test and flexure tensile strength test were done to evaluate the strength properties. To study the durability properties, water absorption test, Sorptivity test, chloride attack test and sulphate attack tests were performed on all concrete mixes, and these strength and durability tests were done for C20/25 as normal and C55/67 as high strength concrete. The experimental result showed a positive influence in strength and durability properties of concrete.

The workability of concrete decreased as the percentage replacement increased in both C20/25 and C55/67 grade concrete. The compressive strength was enhanced up to 10% replacement in C20/25 and at 5% replacement in C55/67 concrete. The flexural tensile strength was improves up to 10% in both concrete grades. Denser concrete against water absorption was made at 5% & 10% in C20/25 and at 5% in C55/67. The initial rate of water absorption (Sorptivity) was good at 5% in C20/25 and at 10% in C55/67. The secondary rate of absorption was enhanced for all replacements in C20/25 concrete but for none of the replacements in C55/67. The resistance to chloride and sulphate attack was better at all percentage replacement in both concrete grades.

Key words: Granite powder, cement replacement, strength, durability

1. INTRODUCTION

1.1 Background

Concrete is a construction material which is composed of cement, fine aggregate, coarse aggregate and water. The construction industry is now rapidly growing consuming large amount of material especially concrete. Concrete is widely used construction material for various types of structure due to its higher strength and durability properties.

Cement is one of the most basic ingredient in concrete production. The high amount of CO₂ emission from cement factories affect the environment highly. The influence of cement on global warming and the increase cost of cement leads many researcher to find a cheaper and environmental friendly alternative materials to replace cement in concrete.

To deal with the above mentioned practical problems, different studies have been carried out world-wide to investigate an alternative cementing materials that can potentially substitute cement. From such pozzolanic materials granite powder is one of the promising pozzolanic material that has been replacing cement, sand and coarse aggregate in concrete production.

Soman. K and Miss. Divya Sasi (2014) studied on the possibility of using granite quarry sludge from rock processing quarries and crusher units in concrete production. They did an experimental investigation on strength properties of concrete made with 2.5% to 20% replacement of cement by quarry dust. Result showed that, up to 7.5% of replacement of cement by granite quarry dust there is no reduction in the compressive, splitting tensile strength and flexural strength.

Mr. G. Raja (2016) also indicate the potential of granite fines to replace fine aggregate in concrete. The granite fines used was by-product in granite factories and its properties was similar with ordinary sand. He used 0, 10, 20, 30, 40, 50 and 100% replacement of granite fines for M20 grade concrete. He found that the specimens with 40% replacement of granite fines gives higher strength in compressive, splitting tensile and flexural tests.

R. Siva Kumar and H. Mohammed (2016) did an experimental study on partial replacement for coarse aggregate by granite waste. The granite wastes were properly cut down to the size of coarse aggregate and were mixed with the concrete. The investigation found that, granite waste can also replace the coarse aggregate in concrete.

From the past research studies, it can be observed that granite waste is a promising material in replacing cement, fine aggregate and coarse aggregate in concrete.

In Ethiopia, there are many importers and suppliers of the finished/polished granites especially in Addis Ababa. They import these granite finish usually from china. The imported granite finishes used for different purposes such as trade and riser of stair cases, for window sill, under doors, kitchen top and for many other design elements. The imported granite finishes are larger in size and will not exactly fit to the desired purposes. In order to resize them based on the customer's interest, they uses cutting and grinding machines. When they cut, bullnose or groove the larger granite finish to smaller and suitable form granite powder is formed.

1.2 Problem Statements

The behaviour of harden concrete basically depends on the paste formed due to the reaction between water and cement known as calcium-silicate-hydrate(C-S-H). The size, number and distribution of voids on C-S-H gel will determine the mechanical properties of concrete. When pozzolanic materials are incorporated in concrete, the secondary reaction between the calcium hydroxide (CH) of cement and silica (S) of the material produces additional hydration product (C-S-H) which will reduces the voids and enhance the behaviour of concrete. This enhancement could be a solution for lower tensile strength and some durability problem like leakage in concrete structures.

The increase in the construction activity in Ethiopia has created a large demand for the need for cement. Unlike the other ingredients of concrete, cement is not always accessible and cheaper. The increase in the cost and shortage of cement are now common problems in our country which leads to delay in construction projects.

The high production of concrete material in the construction industries requires higher amount of cement production. Cement manufacturing process emits large amount of CO₂ leading to global warming. In order to reduce the effect of global warming, it is highly essential to use alternative cementing materials for the production of concrete.

1.3 Objectives

1.3.1 General objective

Investigating the impact of granite powder in the strength and durability properties of C20/25 as normal and C55/67 as high strength concrete.

1.3.2 Specific objectives

The general objective of the research can be achieved through the following specific objectives:

- Identifying the effect of granite powder on the fresh properties of concrete, such as workability by slump test.
- Investigating the compressive strength and tensile strength of C25 and C67 concrete for each percentage replacement of granite powder.
- Studying the influence of granite powder on the water absorption capacity of C25 and C67 concretes.
- Exploring the effect of granite powder on the initial and secondary rate of water absorptions (Sorptivity) at each percentage replacements on both concrete grades.
- Studying the resistance of concrete with and without granite powder when it exposed to chloride and sulphate attacks.
- Finally recommending the optimum percentage replacement of granite powder which enhanced the strength and durability properties of C25 as well as C67 grade concrete.

1.4 Research Questions

The research try to addresses the following research questions:

- What is the effect of granite powder on strength properties of concrete?
- Can granite powder improve the durability properties of concrete?

- Which percentage replacement will give the highest benefit in terms of strength and durability properties of concrete?

1.5 Significance of the Study

- To understand the strength and durability aspects of concrete containing granite powder as cementing material.
- Reducing greenhouse effect by reducing CO₂ emission.
- Reducing the cost expense for cement, hence lower overall cost of concrete production.
- Reducing the disposal problems seen around the workshops or factories.

1.6 Scope and Limitations of the Study

This research covered experimental investigation on strength and durability properties of concrete with and without granite powder. Studying the physical and chemical properties of granite powder as a first task. After the analysis of the properties of granite powder to use in concrete as cement replacement, different concrete mixes with and without granite powder were prepared.

The experiment investigate the fresh and hardened properties of normal as well as high strength grade concretes incorporating granite powder as partial replacement of cement. Fresh concrete property (workability) by slump measure was done for each replacement and compared with the conventional one. The hardened property of concrete was evaluated through strength and durability tests. Compressive strength and flexural strength tests as a

part of strength properties. To study durability property, water absorption, Sorptivity, sulphate attack and chloride attack test has been done and these investigations were done for normal and high strength grade concretes.

Permeability and temperature tests were scheduled to include in this research but, due to the absence of testing machine these tests cannot be performed and Additional durability tests could not be performed due to time constraint.

1.7 Structure of Thesis Report

Following this introduction, chapter 2 presents a general literature review for studying the behaviour of concrete using granite powder as partial replacement of cement in concrete. The review part highlighted the different properties of ingredients of concrete and review of related research on partial replacement of granite powder in concrete.

Chapter 3 demonstrates the materials, methods and testing programs of the study. In the material section cement, sand, coarse aggregate, water, superplasticizer and granite powder are described well. In the test program section different strength and durability test methods and procedures are discussed briefly.

Chapter 4 presents the result and discussion part of the study.

Finally, a comprehensive summary of this research study, and its major conclusion are presented on chapter 5.

2. LITRATURE REVIEW

2.1 Introduction

Concrete is a composite material composed of aggregate, generally sand and gravel chemically bounded together by hydrated cement. The aggregate generally is graded in size from sand to gravel (Macgregor, 2009). Concrete and (volcanic) constituents, such as pozzolanic ash have been used since the days of Greeks, the Romans and possibly earlier ancient civilization. However, the early part of the nineteen century marks the start of more intensive use of the material (G. Ediward Nawy, 2009). Concrete industries are one of the major consumers of natural resources as they spends annually 1.5 billion tons of cement, 900 million liters of water and 9 million tons of sand. Concrete is the single largest manufactured material in the world and accounts for more than 6 billion metric tons of materials annually (Shah, Gohil, Chavda, & Khediya, 2015).

The compressive strength of concrete is one of the most important and useful property of concrete. In most structural application concrete is employed primarily to resist compressive stresses. Strength of concrete is its resistance to rupture. It may be measured in a number of ways, such as strength in compression, in tension, in shear or in flexure (Shetty, 2019).

Although compressive strength is a measure of durability to a great extent, it is not entirely true that the strong concrete is always a durable concrete. It is recognized that strength of concrete alone is not sufficient, the degree of harness of the environmental condition to which concrete is exposed over its entire life is equally important (Shetty, 2019).

The strength and durability properties of concrete is directly related with the properties of the ingredient materials. So that, it is possible to replacing one or more of these materials fully or partially with different other materials, which have better performance and they are convenient in terms of required properties. Granite powder is by product produced in granite factories while cutting huge granite rock to the desire shapes. This granite powder has a chemical composition like the raw materials used for manufacturing cement (A.J.Patel, 2015). Based on ASTM C- 618, since the sum of the percentage composition of silica, alumina and ferric oxide is over 70%, the material can be introduced to concrete as pozzolanic material (ASTM C618, 1998).

2.2 Concrete Composing Materials

2.2.1 Cement

Cement is a hydraulic binder and it is defined as a finely ground inorganic material which, when mixed with water, forms a paste which sets and harden by means of hydration reaction and processes which after hardening restrain its strength and stability even under water (Awol Abrar, 2011).

The history of making cementing material is as old as the history of engineering construction. Some kind of cementing materials were used by Egyptians, Romans and Indians in their ancient construction. The early Greeks and Romans used cementing materials obtained by burning limestone. The remarkable hardness of the mortar used in the early Roman brickworks, some of which still exist, present sufficient evidence of the perfection which the art of cementing material had attained in ancient times (Shetty, 2019).

The Greek and Romans had known the fact that certain volcanic ash and tuff, when mixed with lime and sand yielded mortar possessing superior strength and better durability in fresh or salt water. Romans builders used volcanic tuff found near pozzuolic village near Mount Vesuvius in Italy. This volcanic tuff or ash mostly siliceous in nature thus acquired the name pozzolana. Later on, the name pozzolana was applied to any other material, natural or artificial, having nearly the same composition as that of volcanic tuff or ash found at Pozzuoli village. The Romans, in the absence of natural volcanic ash, used powdered tiles or pottery as pozzolana (Shetty, 2019).

When we come to more recent times, the most important advanced in the knowledge of cement, the forerunner to the discoveries and manufacturing of all modern cements is undoubtedly the investigation carried out by Johan Smeaton. When he was called up on to rebuild the Eddy Stone Light House in 1756, he made extensive enquiries in to the state of art existing in those days and also conducted experiments with a view to find out the best material to withstand the sever action of sea water. Finally, he conclude that limestone which contained considerable proportion of clayey material yielded better lime possessing superior hydraulic properties. In spite of the success of Smeaton's experiment, the use of hydraulic lime made little progress, and the old practices of lime and pozzolana remained popular for a longer period. In 1776 hydraulic cement was made by calcining nodules of argillaceous limestone. In the 1800 the product thus obtained was called Roman cement. This type of cement was in use till about 1850 after which this was outdated by Portland cement (Shetty, 2019).

2.2.1.1 Types of cements

Cement exhibits different properties and characteristics depending upon their chemical composition. By changing the fineness of grinding or the oxide composition, cement can be made to exhibit different properties. In the past continuous effort were made to produce different kinds of cements, suitable for different situations by changing oxides composition and fineness of grinding. With the extensive use of cement for widely varying conditions, the types of cements that could be made only by varying the relative proportions of oxides compositions were not found to be sufficient. Then recourse has been taken to add one or two more new materials known as additives, to the clinker at the time of grinding or to the use of entirely different basic raw materials in the manufacturing of cements. Hence the use of additives, changing chemical composition, and use of different raw materials have resulted in the availability of many types of cements to cater to the need of the construction industries for specific purposes (Shetty, 2019).

There are various kinds of cements. These cements are classified as Portland cements and non-Portland cements. The distinction is mainly based on the methods of manufacturing. Ordinary Portland cements of different grades, Rapid hardening cement, Sulphate resistance cement, Portland slag cement, Quick setting cement, super sulphated cement, Low heat cement. Portland pozzolanic cement, Air entraining cement, Coloured cement, Hydraulic cement, Masonry cement, Expansive cement, Oil well cement, Rediset cement, Concrete sleeper grade cement, High alumina cement and Very high strength cement (Shetty, 2019).

2.2.1.2 Types and standard of cement

There are different standard for classification of Portland cement. The two major standard are the ASTM C-150 standard, used primarily in U.S and European EN-197 standard.

2.2.1.2.1 American standard (ASTM)

Eight types of Portland cements are classified under ASTM (American Society for Testing Materials). As per ASTM, cement is designated as Type I, Type II, Type III, Type IV, Type V and other minor types like Type IA IIA and IIIA are described on c-150 standard section (ASTM, 1998). The types and brief description of their uses are listed in the table below.

Table 2.1: Types and uses of cements

Types of cement	Use
I	For use in general concrete production where the special properties specified for Types II, III, IV and V are not required (ordinary Portland cement).
II	For use in general concrete construction exposed to moderate sulphate attack or moderate heat of hydration is required.
III	When high early strength is desired (Rapid Hardening Cement).
IV	When low heat of hydration is desired (Low Heat Cement).
V	When high sulphate resistance is required (Sulphate Resisting Cement).
IA	A type I cement containing an integral air-entraining agent
IIA	A type II cement containing an integral air-entraining agent
IIIA	A type III cement containing an integral air-entraining agent

ASTM standard also have cement of the type IS. This consist of an intimate and uniform blend of Portland cement of type I and fine granulated slag. The slag content is between 25 and 70 per cent of the weight of Portland Blast-Furnace Slag Cement (Shetty, 2019).

2.2.1.2.2 European standard

In Europe, cement are covered by the standard EN 197-1 (composition, specification and conformity criteria). It defines five classes of common cements that comprises Portland cement as a main constituent(T. Hirschi, H. Knauber, M. Lanz, J. Schrabback, C. Spig, 2005). These classes differ from the ASTM classification (T. Hirschi, H. Knauber, M. Lanz, J. Schrabback, C. Spig, 2005).

I. Portland cement (CEM I): comprising Portland cement and up to 5% of minor additional constituents.

II. Portland composite cement (CEM II): Portland cement and up to 35% of other single constituents.

III. Blast furnace cement (CEM III): Portland cement and higher percentage of blast furnace slag.

IV. Pozzolanic cement (CEM IV): Portland cement and up to 55% of pozzolanic constituents.

V. Composite cement (CEM V): Portland cement, blast furnace stage and pozzolana or fly ash.

2.2.1.3 Chemical composition of cements

The raw materials used for manufacturing of cement consist mainly of lime (CaO), silica (SiO₂), alumina (Al₂O₃) and iron oxide (Fe₂O₃). These oxides interact with one another in the kiln at high temperature to form more complex compounds. These compounds are Tricalcium silicate (C₃S), Dicalcium silicate (C₂S), Tricalcium aluminate (C₃A) and Tetracalcium aluminoferrite (C₄AF) The relative proportion of these oxides components

are responsible for influencing the various properties of cement, in addition to rate of cooling and fineness of grinding (Shetty, 2019).

2.2.1.4 Strength of cements

The strength of cements is the result of a process of hydration. This chemical process result in recrystallization in the form of interlocking crystals producing the cement gel, which has high compressive strength when it hardens. The early strength of Portland cement is higher with the higher percentage of C3S. If moist curing is continuous, later strength levels will be greater, with higher percentage of C2S. C3A contribute to the strength development during the first day after placing of the concrete because it is the earliest to hydrate (G. Ediward Nawy, 2009).

Table 2.2: Properties of compounds of cement

Compound components	Rate of reaction	Heat liberated	Ultimate cementing value
Tricalcium silicate, C3S	Medium	Medium	Good
Dicalcium silicate, C2S	Slow	Small	Good
Tricalcium aluminate, C3A	Fast	Large	Poor
Tetracalcium aluminoferrite, C4AF	Slow	Small	Poor

When Portland cement combines with water during setting and hardening, lime is liberated from some of the compounds. The amount of lime liberated is approximately 20% by weight of the cement. Under unfavourable conditions, this might cause disintegration of a structure owing to leaching of the lime from the cement. Such a situation should be prevented by

adding a silicious mineral such as pozzolana to the cement which react with lime in the presence of moisture and produce strong calcium silicate (G. Ediward Nawy, 2009).

2.2.1.5 Effect of fineness in the strength of cement

The size of the cement particles strongly affect the rate of reaction of cement with water. For a given weight of finely ground cement, the surface area of the particles is greater than that of the coarsely ground cement. This results a greater rate of reaction with water and a more rapid hardening process for larger surface areas. This is the reason for the high early strength type-III cement giving in 3 days a strength that type I gives in 7 days and a strength in 7 days that type I gives in 28 days (G. Ediward Nawy, 2009).

2.2.2 Water

Water is generally used in concrete making; (1) As mixing water; (2) For curing of concrete and (3) For washing. The amount of impurities in the water is restricted for each cases (Popovics, 1992).

Impurities may be either dissolved in the water or present in the form of suspensions. Some of these impurities such as sugar, tannic acid, vegetable matter, oil, greases and sulphates, may interfere with the hydration of cement, thus delay in setting and reducing strength of the concrete. Therefore if there is any question about the concrete making quality of water, a sample should be tested, for instance with trial mixes or to be submitted to a laboratory for testing and recommendation.

The mixing water, which is the free encountered in freshly mixed concrete has three main functions: (1) it react with the cement powder to produce hydration; (2) it act as a lubricant

contributing to the workability of concrete; and (3) it secures the necessary space in the paste for the development of hydration products (Popovics, 1992). Since it helps to form the strength giving gel, the quality and quantity of water is required to be looked very carefully (Shetty, 2019). As the rule of thumb, if the water is potable, it is suitable as mixing water for concrete. But it does not appear to be a true statement for all conditions. Some water containing a small amount of sugar would be suitable for drinking but not for mixing concrete and conversely water suitable for making concrete may not necessarily be fit for drinking (Shetty, 2019).

The requirement for curing water are less stringent than those for mixing water, mainly because curing water is in contact with concrete for a relatively short time. Such water may contain more inorganic and organic materials, sulphuric anhydride, acids, chlorides, and so on, than an acceptable mixing water, especially when slight discoloration of the concrete surface is not objectionable. Nevertheless, the permissible amount of the impurities are still restricted. In case of any doubt the water should be sent to a laboratory for testing and recommendations (Popovics, 1992).

Water for washing aggregate should not contain material in quantities larger enough to produce harmful films or coating on the surface of aggregate particles. The same requirements hold when water is used to cleaning of concrete mixer and other concreting equipment (Popovics, 1992).

2.2.3 Aggregate

Concrete aggregate is more or less inert, granular, usually inorganic consisting normally of stone or stone like solids (Popovics, 1992). Aggregates were considered as chemically inert material but now it has been recognised that some of the aggregate are chemically active and also that certain aggregate exhibits chemical bond at the interface of aggregate and paste. The mere fact that the aggregate occupy 70-80 per cent of the volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable. Without the study of the aggregate in depth and range, the study of concrete is incomplete (Shetty, 2019).

Aggregate can be classified in several different ways: whether they are natural or manufactured; according to their petrography; according to their specific density; whether they are crushed or naturally processed; whether they are inert or reactive; and according to the size of their grains or particles (Popovics, 1992).

The most frequently used aggregate classification is based on the size of the particles. An aggregate consisting of large particles is called coarse aggregate whereas an aggregate consisting of small particle is called fine aggregate. The dividing line between fine and coarse aggregate is arbitrary and may vary from discipline to discipline or from county to country. In concrete technology this dividing line is usually No. 4 sieve in United States (ASTM C-125-88) which, according to ASTM E 11-87, has a nominal net opening of 4.75mm. In other word particle passing through a no. 4 sieve are called fine aggregate. Whereas particles retained on this sieve forms coarse aggregate. Typical examples of fine aggregate are sand

and crushed sand and those of coarse aggregate are gravel, crushed stone, and crushed slag. Aggregate passing through a no. 16 sieve which has a nominal opening of 1.18mm may called fine sand. Particle passing through a no. 200 sieve, which has a nominal net opening of 0.075mm are called silt or if they are smaller than 2 μ m, are usually called clay (Popovics, 1992).

There are different types of tests which going to done on the aggregate used in concrete production. ACI mix design process needs at least information on unit weight of coarse aggregate, bulk specific gravity, water absorption, bulk density and sieve analysis of fine and coarse aggregate. The bulk density or unit weight of an aggregate gives valuable information regarding the shape and grading of aggregate. The higher the bulk density, the lower is the void content to be filled by sand and cement, resulting right sample for making economical concrete. For determining of the bulk density the aggregate are filled in the container of known volume and then they are compacted in a standard manner. The weight of the aggregate gives the bulk density in kg/litre (Shetty, 2019). With the specific gravity of each constituent known, its weight can be converted into solid volume and hence a theoretical yield of concrete per unit volume can be calculated. Average specific gravity of the rocks vary from 2.6 to 2.8. The usual normal weight concrete aggregates have 2.6 bulk specific gravity, heavy weight concrete aggregates have specific gravity above 2.8 and aggregates with specific gravity less than 2.4 are called light weight aggregate (Popovics, 1992).

Absorption and moisture content of aggregate highly affect the quality of concrete. In proportioning of materials for concrete, it is always sure that the aggregates are saturated and surface dry. In mix design calculation the relative weight of the aggregate are based on the

condition that the aggregate are saturated and surface dry. But in practice, aggregates in such ideal condition is rarely met with. Aggregates are either dry or they have surface moisture. If the aggregates are dry they absorb water from the concrete mixing and thereby affect the workability. On the other hand if they contain surface moisture they will contribute extra water to the concrete mix and increase the water to cement ratio resulting in a decrease in the strength of concrete. Both these conditions highly affect the quality of the concrete. It is very essential that corrective measures should be taken both for absorption and for free moisture so that the water to cement ratio is kept exactly as per the design (Shetty, 2019).

One of the most important factors for producing workable concrete is good gradation of aggregate. Good grading implies that a sample of aggregate contains all standard fractions of aggregates in the required proportion such that the sample contains minimum voids. A sample of well graded aggregate containing minimum voids will require minimum paste to fill up the voids in the aggregates. Minimum paste means less quantity of cement and less quantity of water, which will further mean increase in economy, higher strength, lower shrinkage and greater durability. It is the paste that is susceptible to deterioration by the attack of aggregate chemicals. In short, the paste is the weakest link in mass of concrete. The lesser the quantity of such material, the better will be the concrete. This objective can be achieved by having well graded aggregates (Shetty, 2019).

Sieve analysis, this is the name given to the operation of dividing a sample of aggregate into various fractions each consisting of particles of the same size. The aggregate used for making concrete are normally of the maximum size 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 600 microns, 300 microns and 150 microns. The aggregate fraction from 80mm to

4.75mm are termed as coarse aggregate and those fractions from 4.75mm to 150 micron are termed as fine aggregate. From sieve analysis the particle size distribution in a sample can be found out (Shetty, 2019).

2.2.4 Admixtures

Admixtures are materials other than water, aggregate, or hydraulic cement that are used as ingredients of concrete and that are added to the batch immediately before or during the mixing. Their function is to modify one or more properties of concrete so as to make it more suitable for work (G. Ediward Nawy, 2009). According to EN 206-1, concrete admixtures are liquids or powders which are added to the concrete during mixing in small quantity, normally based on the cement content (T. Hirschi, H. Knauber, M. Lanz, J. Schrabback, C. Spirg, 2005). Many admixtures affect more than one property of concrete, sometimes affecting desirable property adversely. The specific effect of an admixture may depend on a number of variables, such as the type and amount of admixture, the compound composition, amount of cement, factors influencing the kinetics of hydration, the time of addition of the admixture to fresh mix, and so on. Therefore an admixture should be employed only after appropriate evaluation of its effects (Popovics, 1992).

There are different types of admixtures, air entraining admixtures, accelerating admixtures, water-reducing and set-controlling admixtures. Air entrainment admixture made the concrete production with improved frost resistance. The entrained air should be distinguished from the entrapped air because only the entrained air improves the frost resistance and workability of the concrete.

The requirement of right workability is the essence of good concrete. High degree of workability is required in situations like deep beams, beam column joint casting, and structures with congested with reinforcement and so on. Today we have plasticizer and superplasticizer to help the concrete technology. This plasticizers can help the difficult conditions for obtaining higher workability without using excess of water. Superplasticizer is new category and improved version of plasticizer, it is high range water reducers. It is well known fact that the average molecular weight of the plasticizer is of primary importance for its efficiency as plasticizer in concrete. The higher the molecular weight, the higher is the efficiency. However, it should be noted that there is a maximum value of molecular weight beyond which efficiency is expected to decrease. It may be further noted that several intrinsic properties of the superplasticizer may influence the performance. Therefore, it is difficult to compare the efficiency of one plasticizer from the other in the absence of number of related properties of superplasticizer. (Shetty, 2019).

The purpose of using accelerating admixtures or accelerator in concrete is to increase the rate of setting, or the rate of hardening or both. The reduction of the setting time do not mean necessarily the intensification of the strength development of the concrete; but even when it does, higher early strength usually are not followed by increased concrete strength at later ages. The accelerating action is caused primarily by increasing the dissolution of certain cement compound by the presence of accelerator in the cement-water system (Popovics, 1992).

Set-retarding admixtures are used primarily to offset the accelerating effect of high temperature, and to keep concrete workable during the entire placing period. It also used to

keep concrete plastic for a sufficient long period so that succeeding lifts can be placed without development of discontinuities in the structural unit (Popovics, 1992).

2.3 Granite

Granite is a common type of felsic intrusive igneous rock that is granular and phaneritic in texture. Granite can be predominantly white, pink, or grey in colour depending on their mineralogy. It is an igneous rock with between 20% and 60% quartz by volume and at least 35% of the total is feldspar consisting of alkali feldspar. Hence granite is coarse grained igneous rock containing quartz and feldspar (Wikipedia, 2019).

2.3.1 Physical Properties of Granite

Granite is a unique material, the average density of granite is between 2.65 and 2.75g/cm³, and its compressive strength usually lies above 200Mpa. It has poor primary but strong secondary permeability (Wikipedia, 2019).

2.3.1.1 Porosity/ Permeability

Granite has almost negligible porosity ranging between 0.2 to 4% (King, 2005).

2.3.1.2 Thermal Stability

Granite is highly stable thermally, therefore shows no change with the change in temperature. It is impervious to weathering from temperature and even from the air born chemicals. It has high resistance to chemical erosion (King, 2005).

2.3.1.3 Co-efficient of expansion

The coefficient of expansion for granite varies from 4.7×10^{-6} – 9×10^{-6} (inch x inch) (Wikipedia, 2019).

2.3.2 Chemical Properties of granite

The worldwide standard of the average proportion of different chemical components that are present in granite is shown in table below (Imghost, 2015).

Table 2.3: Chemical composition of granite

Chemical compounds	Percentage composition
Silica (SiO ₂)	70-77%
Alumina (Al ₂ O ₃)	11-14%
Potassium Oxide (K ₂ O)	3-5%
Soda (Na ₂ O)	3-5%
Calcium oxide (CaO)	1.82%
Iron (Fe ₂ O ₃)	1.22%
Iron (FeO)	1.68%
Magnesia (MgO)	0.71%
Titanium dioxide (TiO ₂)	less than 1%
Manganosite (MnO)	0.05%
Water (H ₂ O)	0.03%

Based on ASTM C- 618, since the sum of the percentage composition of silica, alumina and ferric oxide is over 70%, the material can be introduced to concrete as pozzolanic material (ASTM C618, 1998).

2.4 Granite Powder

Granite powder is by-product produced in granite factories while cutting huge granite rocks to the desire shapes and it can be found either in slurry or dust form (Chiranjeevi, Kumar, & Poornima, 2015). Granite has improves properties over cement such as strength and reinforcing level, higher resistance to heat, higher resistance to fire and higher resistance to moisture (Geiger, 2009). The oxides composition in granite powder and cement is presented in the table 2.4 below (Allam, Bakhoum, & Garas, 2014; Hawaz Abrham, Quezon Emer Tucay, & Mamuye, 2018).

Table 2. 4: Percentage composition of oxides in granite powder and cement

Chemical oxides	% in Granite powder	% in Ordinary Portland cement
Silica, SiO ₂	59.58	18.7-22.0
Alumina, Al ₂ O ₃	13.01	4.7-6.3
Iron, Fe ₂ O ₃	9.77	1.6-4.4
Calcium oxide, CaO	3.8	60.6-66.3
Magnesia, MgO	0.29	0.7-4.2
Phosphorus pentoxide, P ₂ O ₅	0.07	-
Water, H ₂ O	0.03	-
Soda, Na ₂ O	5.92	1.67
Manganosite, MnO	0.17	0.03
Titanium dioxide, TiO ₂	0.37	-
Potassium oxide, K ₂ O	4.76	0.51
Sulfur trioxide, SO ₃	0.33	1.8-4.6
LOI	1.56	3

2.5 Review of Related Works

Abrham Hawaz, Emer Tucay and Mamuye B. did an investigation on the effect of varying dosage of animal bone powder in cement replacement on normal strength concrete (C25). The bones were collected from Seka waste disposal site of Jimma town, after cleaning and drying of the bones it burned in the furnace at 340°C. Then the burnt bones was allowed to cool before it grinded and sieved. The chemical oxides presented in bone powder were similar with the oxides presented in cement but lesser in content based on ASTM C-150. The percentage replacement used were at 0%, 5%, 10%, 15%, 20% & 25% by weight of cement. Then compressive strength, flexural strength and splitting tensile test were conducted. Result revealed that, the compressive strength at 7th, 14th & 28th day decreased in all percentage replacements of bone powder relative to the control. The flexural and splitting tensile strength test showed the same decrement pattern with the compressive strength results. Hence, replacing bone powder in concrete do not enhance the properties studied in this research paper (Hawaz Abrham et al., 2018).

Bililign Firdawek and Dr. Tesfaye Alemu did experiment on the performance of concrete with partial replacement of cement by lime and pumice at elevated temperature. In this experimental work, workability, compressive strength test and the reduction in the compressive strength when the concrete is exposed to high temperature, at 150°C, 300°C & 600°C were studied. Result showed that, the workability of concrete decreased as lime and pumice powder content increased. Maximum improvement in compressive strength was attained at 10% of lime. The addition of pumice powder decreased the compressive strength of concrete at all ages of curing. But concrete containing 10% lime and 10% pumice powder

showed a smaller decrement in the compressive strength after the concrete was exposed to 150°C, 300°C & 600°C elevated temperature (Bililign Firdawek, 2019).

Helen Hordofa did an experimental investigation on eggshell powder blended concrete. In this research the fresh and hardened properties of concrete were studied. Cement was replaced by eggshell powder at 3%, 7%, 11%, and 15% by volume of cement. The investigation was done on C35 grade concrete and workability, compressive strength, splitting tensile and flexural tensile strength test was performed. The compressive strength increased up to 7% replacement, the splitting tensile strength also increased up to 7% replacement and the flexural tensile strength increased at 11% replacement of cement with eggshell powder (Hordofa, 2019).

Million yehualashet and Dr. Belachew Asteray did an investigation on the mechanical properties of high performance concrete with partial replacement of cement by fly ash. High performance concrete of 50Mpa with partial replacement of cement with fly ash at 10%, 20%, 30%, and 40% were have been done. The fineness of cement used here was 2840cm²/gm. Workability by slump measure, normal consistency, initial & final setting time, compressive and flexural strength test were performed. The workability, normal consistency, initial & final setting time of fresh concrete increased as the percentage replacement increased. The compressive strength was performed at 7th and 28th days, the compressive strength both at seven and twenty eight day was above the control strength. Maximum strength was attained at 30% replacement of cement with fly ash. The splitting tensile strength increased with the increase in the fly ash content and maximum strength was attained at 40% replacement. Similar increasing pattern was seen for the flexural strength at 7th and

28th day, the maximum strength was attained at 40% (Dr. Belachew Asteray & Million Yehualashet, 2019).

Berhanu Negesse and Dr.-Ing Abebe Dinku did investigation of on the production of HCB by utilizing waste marble powder as a partial replacement of cement. The fineness of waste marble powder was tested using Blaine air-permeability method and its fineness was 3817.49cm²/gm whereas the fineness of the cement was 4103.19 cm²/gm. Cement was replaced at 0%, 10%, 20%, and 30% by weight and Class A, B and C HCBs of 20X20X40cm were produced. The compressive strength test performed at 7, 14, 21, and 28 days for the three classes of HCB. Results showed that, the compressive strength was not enhanced in all class of HCB for all percentage replacement, but the compressive strength of blended cement with 10% to 30% replacement range satisfy the minimum compressive strength set by Ethiopian standard of HCB for class A, B and C. The density and water absorption remain within the acceptable limits of the Ethiopian standard (Berhanu Negesse & Dr.- Ing Abebe Dinku, 2018).

Fitsum Nigussie and Dr. Essayas G/youhannes did an investigation using bagasse ash in cellular lightweight concrete. The lightweight concrete was made from ordinary Portland cement, sand, bagasse ash and foaming agent admixture. Cement was replaced by bagasse ash from 5% to 30% by 5% increment. Bagasse was collected from wenji sugar factory, it was burned at a temperature of 500^oc and prepared by sieving with 300 μ m sieve. The physical and chemical properties of bagasse was tested and compared with ASTM C-618 standard requirements then it confirmed the requirements. To understand the physical properties of cellular lightweight concrete wet density, air content, compressive strength,

water absorption and plastic shrinkage tests were performed. 10% replacement of cement with bagasse slightly increased the compressive strength and dry density, while 15% replacement gave the same strength with the control mix. So replacing cement up to 15% bagasse improve the compressive, dry density, water absorption and plastic shrinkage (Fitsum Nigussie & Dr. Essayas G/ youhannes, 2017).

Muhannaad Ismeik did on the mechanical properties of high strength concrete incorporating mineral admixtures. His paper reported a part of an ongoing experimental laboratory investigation on the compressive and flexural strength made with mineral admixtures and local Jordanian materials. Various percentage of silica fume and fly ash were added at different w/c rations. Results indicate that, the compressive as well as flexural strength increased with mineral admixture incorporation. Silica fume contributed to both short and long term properties of concrete, whereas fly ash showed its beneficial effect in a relatively longer time. Adding both silica fume and fly ash did not increase the compressive strength in the short term, but improvements were noticed in longer term. Compared with compressive strength, flexural strength of silica fume concrete has exhibited greater improvements (Muhannad Ismeik, 2009).

Sergii Tolmachov, Olana Belichenko and Denis Zakharov investigate the influence of additives on the flexural strength of concrete. In this research the effect of superplasticizer, especially carboxylate type, mineral additives and fiber on the flexural strength of concrete was examined. It is shown that, adding a mineral admixture into the concrete leads to an increase of flexural strength to 13%, while the compressive strength increased by no more than 6%. The use of an organomineral complex leads to an increase the early flexural strength

of concrete to 37%, and at the age of 28 days the strength gain was up to 20%. At the same time, the compressive strength increased to 37% during all test ages. But the use of complex of additives and polypropylene fibers results in an insignificant increase of flexural strength in comparison with concrete containing only a complex additives up to 4% and the compressive strength of such concrete was reduced to 11% (Sergii Tolmachov, Belichenko Olena, & Zakharov Denis, 2017).

Tsighana G/micael and Dr. Eng. Belay Woldeyes did an investigation on sugarcane bagasse ash as partial replacement of cement in concrete production. Bagasse ash was collected from Wonji sugar factory and the ash was sieved with 250 μ m sieve size. M25 grade concrete was designed for the control mix. Sugarcane bagasse ash was replace cement at 5%, 10%, 15% and 20% by weight and workability by slump measure, unit weight of hardened concrete, compressive and water absorption tests were performed. Result indicate that, the workability of concrete decreased as the percentage replacement increased. Result of unit weight showed that, due to the lower density of bagasse ash, the unit weights decreased when cement was replaced. Compressive strength was performed at 7, 14, 21, & 28 days, concrete containing 5% bagasse ash had higher compressive strength at all test ages over the control. In water absorption test, 5% bagasse concrete performed well against water absorption with least percentage water absorbed (Tsighana G/ micael & Prof. Dr. Eng Belay Woldeyes, 2019).

Gizachew Markos Makebo did a review on partial replacement of cement material in Ethiopia. In his literature review work, he tried to see many of the papers worked in Ethiopia on cement replacement in concrete production. The waste materials coffee husk, banana leaf ash, bagasse ash, bone powder, corncobs ash, municipal waste, coal mine, lime sludge,

ground nut shell ash, quarry dust, iron tailing, have pozzolanic properties and can partially replace cement in the range of 10%-15% in normal strength concrete production, the optimum percentage replacement of the material is 10%. And if the percentage replacement of the materials increases the compressive strength becomes decreasing (Gizachew Markos Makebo, 2019).

Divaker. Y, Manjunath and Dr. M.U. Aswath made an attempt to investigate the strength behaviour of concrete with the use of Granite fines as an additive. Concrete were prepared with granite fines as replacement of fine aggregate in 5 different proportions namely 5%, 15%, 25%, 35% and 50% and compressive strength, splitting tensile strength and flexural strength tests were done. The compressive strength was increased by 22% with the use of 35% replacement of fine aggregate with granite fines and the compressive strength was still higher than the control samples strength up to 50% replacement, at 50% replacement granite fines the compressive strength was 38.5Mpa where the control was 37Mpa. The splitting tensile strength was not significantly affected up to 50% replacement. The flexural strength of 10cm x 10cm x 50cm prism without reinforcement increased at 5% replacement by 5.41% but its strength decreased with the replacement beyond 5% but the reduction was insignificant. The flexural strength of beam 15cm x 15cm x 70cm with reinforcement was checked at 25% and 50% replacements, and the result showed that at 25% replacement a 2% increment was observed and at 50% replacement the strength was increased by 32.7%. We can conclude that there was a considerable increment in flexural strength of beams with reinforcement with the use of granite fines (Divakar, Manjunath, Aswath, & Student, 2012).

Mr. G. Raja, and Mr. K. M. Ramalingam were tried to investigate the mechanical properties of normal strength concrete by replacing sand with granite fines. The percentage replacement of granite fines they used were 0, 10, 20, 30, 40, 50 & 100 for M20 mix proportion. Specimens are tested after 28 days of curing for compression strength, flexural strength, and tensile splitting test. The spacemen with 40% replacement of granite fines was achieved higher strength when compared to control specimen (M. G. Raja, 2016).

M. Allam. E. Bakhoun and H. Ezz tried to see the influence of using granite waste on the mechanical properties of green concrete. In their study they tried to partially replaced cement and sand with granite waste and flexural strength test, splitting tensile strength test and pull out test were done. After 28days of curing, results of splitting tensile test, on the concrete cylinders with different proportion of granite waste showed that, at 5% of granite fines waste as a partial replacement of cement, the strength was 20% higher than the control mix, but at 10% replacement the strength dropped to the value equal to the control. By replacing the sand in the concrete mix at the values of the 10%, 17.5% and 25% splitting tensile strength increased by 12%, 15% and 21% respectively, beyond the control mix. The flexural strength of concrete was tested on beams after 28 days of curing. The results showed that the flexural strength of mix containing 5%, 10% and 15% of fine granite waste as a partial replacement of cement were 19%, 30% and 37% respectively lower than the control mix. By replacing the sand with 10% granite granules by weight, the value of the flexural strength was increased by 34% and at 17.5% replacement the value dropped back to the value obtained from the control. At higher percentage of replacement 25% the value of flexural strength were 15% lower than the control mix. The bond strength of mix containing 5% of fines as replacement

of cement was slightly higher by 1%. By replacing the 10% sand with granite the value of bond strength increased by 1%, further increase decreases the bond strength. So it can be conclude that the optimum percentage of cement replacement with granite fine powder was 5% and the optimum percentage of sand replacement with granite granules was 10% and could reach 17.5% (Allam, Bakhoun, Ezz, & Garas, 2016).

R. Kumar, H. Mohamed and M.Haripriya did an experimental study on partial replacement of coarse aggregate by granite waste in place of 20mm sized aggregate. They used M30 grade concrete for the conventional mix and the granite waste were properly cut down to size of coarse aggregate and then they were mixed with the concrete in 10%, 20%, 30%, 40% and 50%. Cubes were casted from these concrete mixes and subjected to curing for 7 and 28 days and their compressive strength were determined. Based on the investigation the compressive strength of concrete was the same with the conventional concrete only at 10%, 20%, and 30% replacement of granite waste. The strength was gradually decrease at 40% and 50% of replacements (Kumar, Mohammed, & Haripriya, 2016).

D. Nagaraju, Dr. S. Sunil did an experimental study on partially replacing of granite powder in fine aggregate. Concrete cubes and cylinders of standard dimension of M20 grade were casted. Four mix ratio were adapted, namely 5%, 10%, 25% and 35% and compressive strength and splitting tensile strength tests are conducted. Findings showed that at 25% replacement of sand with the granite powder, maximum values of compressive and splitting tensile strength were found. With the increase in the percentage of granite powder beyond 35% there will be decrease in the strength of concrete (Nagaraju & Pratap, 2017).

M. Allam, E. Bakhoun, G. Garas et al. were assessed the durability of green concrete containing granite waste powder as partial replacement to sand with various percentage. Physical tests includes slump test, indirect fire test, water absorption and permeability experiment tests were conducted on the concrete samples as indicator for durability. Scanning Electron Microscope (SEM) is also used to investigate the microstructure of concrete by examining the inter-facial transition zone (ITZ). For the experiment, ordinary Portland cement (OPC), locally available fine aggregate with maximum size of 4.75mm, a maximum nominal size of 19mm as coarse aggregate and clean tap water were used for the concrete mix. The granite waste granules particle passed through sieve no. 4.76mm was used as sand replacement. Design mix for 350 grade concrete with two different percentage by weight of granite waste (10% & 17.5%) for sand replacement were prepared. In addition a control samples with 0% replacement were prepared. The workability of the fresh prepared concrete was measured through the slump cone test apparatus. The result revealed that the substitution of granite waste decreased the workability of green concrete. The reduction in compressive strength of the control samples subjected to elevated temperature of 200 and 400 degree celsius was 15% and 23% respectively. As for green concrete containing 10% of granite waste the reduction in compressive strength was 13% and 15% which was considered as less than the value obtained from the control mix. Similarly for 17.5% replacement the result obtained were less by 6% and 17%. Result of the permeability test showed that by replacing sand with granite powder at 10% and 17% replacement ratio the coefficient of permeability was reduced by 6% and 16% respectively than that of the control mix. The water absorption test result showed very similar behaviour to water permeability test result.

The SEM result showed that the 10% replacement mix had fewer pores and the 17% replacement was contains wider shear cracks at the aggregate cement interface. Generally the conclusion of this study was incorporating of fines granite to concrete mix enhanced the some durability related characteristics of concrete (Allam, Bakhoun, Garas, & Ezz, 2016).

D. Chouhan, T. Gupta, R. Sharma investigate the effect of incorporating metakaolin on fresh and harden properties of granite slurry concrete. The concrete mix used for the experiment was M25 grade concrete with water to cementitious material ratio is 0.5 as per IS standard. For this concrete production ordinary Portland cement, locally available river sand and 20mm & 10mm coarse aggregate was used. The granite used was in slurry form and dried at room temperature. Metakaolin used procured from the local suppliers. The cement replacement level of granite and metakaolin were 5% and 10% by weight of cement. Specimens were casted and cured for 28 days. The workability test result showed that the slump value decreased with an increase in replacement level of cement by granite and metakaolin. The compressive strength was enhanced incorporating metakaolin with granite but the maximum value was obtained for the mix containing 10% utilization of metakaolin without granite slurry waste. The flexural results obtained was analogous to that of the compressive strength. Generally, the compressive and flexural strength of concrete increases with the increase in the replacement level of granite slurry. Moreover addition of metakaolin improves the compressive and the flexural strength of concrete as compared with the control samples (Chouhan, Gupta, & Sharma, 2013).

P. Shinde, A. Chavan, Bhosale Gajankush & Dhage also used this granite powder as sand replacement at 0, 10%, 20%, 30%, 40%, 50% & 100% and they did compressive and tensile

strength test. The result showed that the maximum compressive strength was attained at 20% replacement of granite powder, but up to 50% replacement the strength was still above the compressive strength of the control samples. The tensile strength of concrete with 20% replacement of sand with granite powder was maximum and the strength was still higher than the controls up to 40% replacement (Shinde, Chavan, Bhosale, Gajankush, & Dhage, 2018).

Shehdeh, Ghannam, Husam Najm, Rosa Vasconez did experimental study of concrete with granite and iron powder as partial replacement of sand. The percentage replacement used were 0%, 5%, 10%, 15% and 20% for granite as well as for iron powder. The materials used were type I Portland cement, coarse aggregate 10mm to 20mm in size, approximately 2mm diameter sand, water and superplasticizer. Compressive test, splitting tensile test, and flexural test were conducted on concrete cubes, concrete cylinders and beams respectively. The tests was conducted at 7 days and 28 days. Twenty samples for each test were prepared, ten were tested at 7 days and the remaining ten were tested at 28 days. The compressive test result showed that the optimum percentage of granite powder to achieve maximum increase in average compressive strength was 10%. In this case the percentage increase in strength was 36%. For 20% partial replacement of sand with granite powder the increase in the strength was relatively small. Flexural strength test was conducted on 100mm x 100mm x 500mm beam over a span length of 400mm. Result showed that the optimum percentage of granite powder to achieve the maximum increase in flexural strength was 10%. The percentage increase in the flexural strength was 43% in this case. For 20% partial replacement of sand with granite powder the increase in the flexural strength was relatively

small. The tensile strength test was conducted on 15mm (diameter) x 30mm cylinders and the test showed that the optimum percentage of granite powder to achieve the maximum increase in the tensile strength was 15%. Comparing to an optimum value of 10% for compression and flexural strength, it is higher and the percentage increase in this case was 30%. For 20% partial replacement of sand with granite powder the splitting tensile was lower than the control cylinder samples (Ghannam, Najm, & Vasconez, 2016).

K. Vamsi, R. Bhushaiah, S. Mohammad did an experimental investigation on partially replacing cement in concrete with granite powder and fine aggregate with saw dust. In their investigation the granite slurry and saw dust was used to partially substitute cement and sand respectively. Saw dust was replaced the fine aggregate at 3%, 5% and 7% whereas granite slurry was replaced the cement by 10%, 20% and 30%. At 10% of cement replacement with the granite slurry the corresponding saw dust replacement was 3%. Similarly at 20% replacement of cement with granite slurry the corresponding saw dust replacement was 5% and for 30% cement replacement by granite slurry saw dust was replaced sand at 7%. Then compressive and splitting tensile strength test at 7, 14, and 28 days were conducted. The compressive strength at seventh day was almost two times higher than the control mix in all proportioning of granite and saw dust, which indicate good early strength gain. The maximum compressive strength was attained at 10% replacement of granite slurry and at 3% replacement of saw dust. The splitting tensile strength at 7 and 14 days hadn't significant increased. At 10% replacement of cement with granite slurry and 3% replacement of sand with saw dust the maximum tensile strength value was attained (S. mohammad & R. Bhushaiah, 2019).

K. Chiranjeevi, Y. Kumar, P. Poornima investigate strength properties of concrete by using granite powder as an admixture. Concrete was prepared with the granite fines as a replacement of cement in concrete at different proportions namely 2.5%, 5%, 7.5% and 10%. M25 grade concrete was prepared for the above percentage replacement granite and various tests such as compressive, splitting tensile and flexural strength tests were conducted at 7 and 28 days. The materials used for the investigation was Portland pozzolana cement, granite waste with specific gravity 2.98 and its size was less than 90 microns, river sand, coarse aggregate passing through 12.5mm and retained from 4.75mm, local potable water and superplasticizer were used. The 7 day compressive test result showed that, at 7.5% replacement of cement by granite waste the maximum compressive strength value was attained and the percentage increase was 42.47%. The result for the other percentage replacement mix was still higher than the conventional mix. Similarly the 28 days strength gave the same result with the 7 days strength and 7.5% replacement was the optimum percentage replacement for the compressive test result. The splitting tensile strength test result indicate that at 7.5% replacement of granite powder, an optimum value for both 7 & 28 days splitting tensile strength was obtained. Flexural strength also increased at 7.5% of replacement of cement with granite waste. We can conclude that overall increase in the strength was at 7.5% replacement cement with granite waste and to attain the same strength with the conventional concrete 10% substitution with granite fines is still effective (Chiranjeevi et al., 2015).

Srinivasa C. H. and Dr. Venkatesh investigate the fresh and harden properties of ready mix concrete with partially replacing cement with granite powder and using manufactured sand

instead of natural sand. The workability and compressive strength were studied on concrete with partial replacement of cement with granite powder at 10%, 15%, 20%, 25%, 30%, 35% and 40% replacements. Ordinary Portland cement of 53 grade, locally available granite powder, manufactured sand passing 4.75mm, 55% of 20mm and 45% of 12.5mm of the total quantity of coarse aggregate potable water and superplasticizer were used. The workability and compaction factor was good for all mix batches which satisfies the requirements of ready mix pumpable concrete. The compressive strength at 28 days with 20% replacement was the maximum one from which the optimum percentage was established for the target mean strength value. From the investigation it can also conclude that manufactured sand can be used to full extent as alternative to natural sand (Srinivasa, 2015).

Y. Patil, A. Chavan, U. Momin studied the compressive strength of concrete with granite fines as partial replacement of sand. Sand was replaced at 20%, 40% and 60% percentage by weight. The 7 days compressive strength increased by 11.1% for 20% replacement, 23.3% for 40% replacement and 62.5% for 60% of replacement of granite. The 14 days compressive strength increased by 17.21% for 20% replacement, 34.47% for 40% replacement and 56.75% for 60% replacement of granite. The 28 days strength increased by 6.1% for 20% replacement, 29.87% for 40% replacement and 38.49% for 60% replacement. Based on results it is recommended that up to 60 % of natural sand can be replaced with granite fines (Patil, Chavan, Momin, Kadam, & Patil, 2018).

M. Kiran, S. Barmavath, A. Sangeeth, V. Sainath utilized granite waste and recycled plastic of 20mm size in the manufacturing of concrete with partially replacement of conventional cement and coarse aggregate respectively. In the first step granite waste was replaced as

cement in the percentage of 5%, 10%, & 15% in concrete. In the second step, plastic was replaced as coarse aggregate on the percentage of 2%, 3%, & 5%. In the third step, both granite waste and plastic waste were partially replaced in the percentage of 15% and 2%, 3%, 5% as cement and coarse aggregate respectively. Then the produced concrete was tested for physical and mechanical properties. In the granite waste concrete higher compressive strength was obtained at 15% replacement among 5, 10 & 15 percentage replacement. In the plastic concrete relative higher compressive strength was attained at 3% replacement among 2, 3 & 5 percentage replacements. The same result were found for the tensile splitting test result. But in all mix the strength at 28 days was less than the conventional mix. It can be conclude that granite replacement in concrete by cement has advantage in higher early strength because of higher silica content in the granite waste (Kiran et al., 2017).

A study conducted by Dr. T. Felix Kala which focused on the possibility of using locally available granite powder and admixtures in the production of high strength concrete with 28 days strength to the maximum of 60Mpa. The percentage of granite powder added by weight was 0, 25%, 50%, 75% and 100% as replacement of sand in concrete and cement was replaced with 7.5% silica fume, 10% flay ash, 10% slag and the dosage of superplasticizer added was 1% by weight of cement. For the investigation ordinary Portland cement of 43 grade, 19mm sized coarse aggregate and locally available river sand were used. The variation in slump value for different concrete mix was found to be normal when compared to the concrete mix with no admixtures. It is also showed that the slump value increased with the increase in the percentage of granite powder in the concrete mix. The results presented showed that the compressive strength of granite powder concrete was higher than that of

reference mix for all the days of curing. The compressive strength of concrete mixes with admixtures increased in all mixes because of better compatibility than concrete mixes without granite admixtures. A significant increase in compressive strength has been observed in the concrete mix with 25% granite powder together with admixtures (fly ash, slag, silica fume and superplasticizer). It can be seen from the splitting tensile strength test results that the tensile strength decreased with the increase in the percentage of granite powder beyond 25%. The result indicate that the optimum replacement over sand was 25% for all operating conditions. Conversely the compression and splitting tensile test result demonstrated that the strength increase when admixtures were used in all the concrete mixes. The investigation on the effect of granite powder replacement on modules of elasticity were performed at the age of 7, 28 and 90 days. Results showed that similar to the strength properties, modules of elasticity of the concrete mix with 25% granite powder was found to be higher than that of other percentages of granite powder concrete mixes and the control mix in all days of curing. The flexural test result was also showed that the flexural strength for 25% sand replacement by granite powder was increased and significant increase in the flexural strength was observed due to the inclusion of admixtures in the concrete mixes similar to the other strength properties (Kala, 2013).

E. Shamsabadi, M. Ghalehnovi, J. Brito and Ali Khodabakhshian carried out a study to limit the disadvantages related to waste granite powder use through the use of superplasticizer. Reduce workability is the first problem of this replacement and it can be mitigated by using superplasticizer. For this purpose, 19 concrete mixes containing various types of superplasticizer with different content and different percentage replacement of granite

powder were prepared. Fresh concrete density, splitting tensile strength, electrical resistivity, compressive strength and resistance to sulphate attack tests were conducted. The waste granite powder grain size distribution shows the average diameter of cement is lower than that of granite powder. Two commercial superplasticizer were used; a standard one called SPP aqueous solution of modified polycarboxylic polymers and SPL, aqueous solution of lignosulphonate polymers. In addition tap water was used to produce the concrete mix based on ASTM C- 1602. Results shows that the SPP can eliminate the negative effect of granite powder in the slump and greater SPP content leads to much lower negative effect. The density of fresh concrete mix was maximum when 5% of granite powder introduced. At more than 5% replacement the density of concrete decreased due to lower specific gravity of granite than cement. The compressive strength test showed that replacing 5% cement did not significantly change the strength and in some case it even slightly increased it. With 5% replacement ratio, the tensile strength slightly increased but it decreased for higher ratios (Shamsabadi, Ghalehnovi, Brito, & Khodabakhshian, 2018).

Suma Paralada also used granite waste as powder in SCC. Self-compacting concrete is a highly flow able type of concrete that spreads in to the form without the need for mechanical vibrator. Self-compacting concrete is a non-segregating concrete that is placed by means of its own weight. In this study granite powder has been used as the filler material in self-compacting concrete. The result shows that granite powder can be used successfully to achieve self-compacting concrete properties in fresh state. As it is a finer material helps in avoiding segregation (Paralada, 2016).

2.6 Concluding Remarks

In the review part of this paper, an attempt was made to see many of the papers worked on cement replacement in concrete production in Ethiopia as well as other countries. Waste materials such as coffee husk, banana leaf ash, bagasse ash, bone powder, corncobs ash, municipal waste, coal mine, lime sludge, ground nut shell ash, quarry dust, iron tailing have pozzolanic properties and can partially replace cement in the range of 10-15 percent in normal strength concrete production, the optimum percentage replacement of the material is 10%. When the percentage replacement of the materials increases the compressive strength becomes decreasing. All the researchers analyzed only their pozzolanic properties, their effect on compressive strength and percentage of replacement but the durability case was not investigated.

Similarly, there are studies performed on granite waste material, but lots of effort have been done on investigating the strength properties of concrete using granite waste as partial replacement of fine aggregate. There are some researches performed on the strength properties of NSC by partially replacing cement with granite slurry.

This research differ from the other by firstly, the fineness of granite powder used in this research was finer than the powder used by other researchers (finer than 45 μ m). Secondly, unlike the other researches cement replacement by volume is adopted, thirdly, most of the research were focused on strength property investigation, but this research add some durability tests, and the forth and the most important part of this study is the investigation performed on high strength concrete.

3. MATERIALS AND METHODS

3.1 Introduction

The experimental program for this research study is primarily concerned with investigating the potential usefulness of using granite powder in concrete mix. This research aimed to partially introduce granite powder as a natural pozzolanic material just like fly ash and silica fume, which are highly reactive with calcium hydroxide in the presence of moisture and they have the ability to produce additional cementing compounds which results filling the voids in concrete, hence increase the overall strength. To incorporate granite powder in concrete, ASTM C- 618 is used, which is standard specification for coal fly ash and raw or calcined natural pozzolana for use as mineral admixture in concrete.

The experimental program of the current research was carried out to explore the effect of using granite powder as a cement component in concrete and investigating the fresh and harden properties of C20/25 as normal and C55/67 as high strength concrete following the test procedures and specification of the American Standard of Testing and Materials.

All the materials used for this study was locally available. Cement was replaced with granite powder at 0%, 5%, 10%, 15% and 20% by volume in the fresh concrete mixes and different concrete test specimens were casted and cured for strength and durability property investigations.

3.2 Materials

3.2.1 Cement

The cement used for the entire concrete mix design was Type I Portland cement. Commercially available Dangote 42.5R ordinary Portland cement with specific gravity 3.15 was being used. The chemical and physical properties of cement which taken from the factory is presented in the tables below (F.J. Faleye, 2009).

Table 3.1: Physical and chemical properties of Dangote OPC

S. No.	Physical properties	values
1	LOI, loss on ignition (%)	8.5
2	IR, insoluble residue (%)	4.7
3	SSA, specific surface area (m ² /kg)	358
4	Initial Setting time (sec.)	195
5	Specific gravity	3.15

Table 3.2: Chemical oxides composition of Dangote OPC

S. No.	Chemical oxide composition	Percentage by weight
1	CaO	59.6
2	Fe ₂ O ₃	3.22
3	SiO ₂	20.62
4	Al ₂ O ₃	6.01
5	MgO	3.65
6	SO ₃	2.46
7	K ₂ O	0.71

3.2.2 Fine aggregate

The fine aggregate used is locally available river sand which is collected from Dimtu around Hawassa city. The same sand is used for both normal and high strength concrete mix preparation.

Sieve analysis was done for representative samples of the naturally occurring fine aggregate used in the concrete. The analysis is based on the ASTM C-136 standard. Table 3.1 presents average result of sieve analysis of two representative samples. Then it was compared with the standard specification limits of ASTM C 33.

Table 3.3: Sieve analysis results of fine aggregate.

Sieves (mm)	First sample retained mass (kg)	Second sample retained mass (kg)	Average retained mass (kg)	Cumulative mass retained (kg)	Cumulative Percentage mass retained (%)	Cumulative percentage finer by mass (%)	Specification limits	
							lower	upper
4.75	0.02	0.02	0.02	0.02	4.0	96.0	95	100
2.36	0.03	0.03	0.03	0.05	10.0	90.0	80	100
1.18	0.07	0.07	0.07	0.12	24.0	76.0	50	85
0.6	0.16	0.17	0.165	0.285	57.0	43.0	25	65
0.3	0.15	0.15	0.15	0.435	87.0	13.0	5	30
0.15	0.06	0.06	0.06	0.495	99.0	1.0	0	10
0	0.01	0	0.005	0.5	100	0	0	0

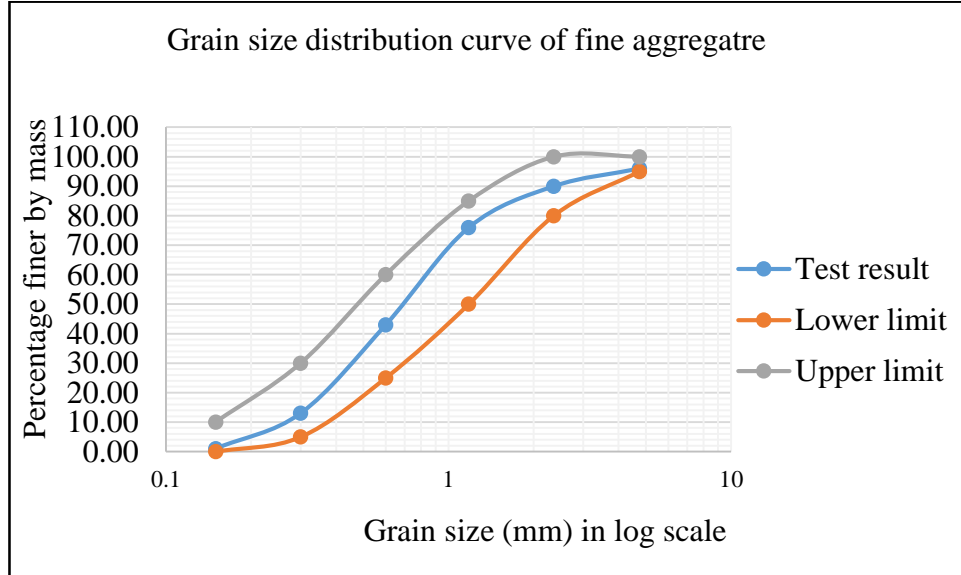


Figure 3.1: Grain size distribution of fine aggregate.

Summary of physical properties of fine aggregate obtained from laboratory test following the ASTM standard is shown in the table below.

Table 3.4: Summary of physical properties of fine aggregate.

S. No.	Physical properties	Values
1	Fineness modules, FM	2.81
2	Silt content (%)	3.57
3	Specific gravity	2.33
4	Bulk unit weight (kg/m ³)	1264.33
5	Absorption (%)	2.041
6	Moisture content (%)	1.67
7	Voids content (%)	43.11

3.2.3 Coarse aggregate

The coarse aggregate is locally available crushed natural stone which was collected from Hawassa city, monopole village. The aggregate used for composing normal strength concrete had nominal maximum aggregate size of 25mm. But for higher strength concrete ACI 211.4R-93 table 4.3.2 suggests maximum aggregate size to be used for different ranges of required cylindrical compressive strength. It suggests 19mm-25mm aggregate size for concrete strength below 9000psi. And 9.5mm-12.5mm for concrete strength above 9000psi. Generally smaller aggregate have provides higher strength potential. So that, in this research, for the design of higher strength concrete the nominal maximum aggregate size used was 19mm.

The average sieve analysis result of two representative sample of coarse aggregate used in the concrete is presented in the table below. The sieves order were chosen based on the specification limits on ASTM C 33.

Table 3.5: Sieve analysis results of coarse aggregate.

Sieves (mm)	First sample retained mass (kg)	Second sample retained mass (kg)	Average retained mass (kg)	Cumulative mass retained (kg)	Cumulative Percentage mass retained (%)	Cumulative percentage finer by mass (%)	Specification limits	
							lower	upper
37.5	0.000	0.000	0.000	0.000	0	100	100	100
25	0.125	0.155	0.140	0.140	2.8	97.2	95	100
12.5	3.155	3.210	3.1825	3.3225	66.45	33.55	25	60
4.75	1.720	1.630	1.675	4.9975	99.95	0.05	0	10
2.36	0.000	0.005	0.0025	5.000	100	0	0	5

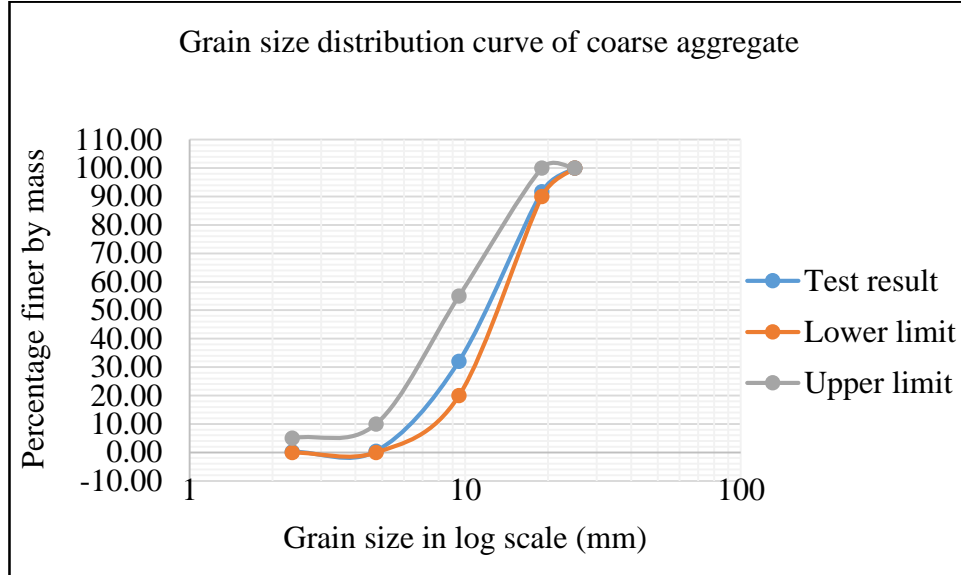


Figure 3.2: Grain size distribution of coarse aggregate.

Summary of physical properties of coarse aggregate obtained from laboratory test following the ASTM standard are shown in the table below.

Table 3.6: Summary of physical properties of coarse aggregate.

S. No.	Physical properties	Values
1	Nominal aggregate size (mm)	25
2	Specific gravity	2.554
3	Bulk unit weight (kg/m^3)	1372.4
4	Absorption (%)	1.42
5	Moisture content (%)	0.5

3.2.4 Water

Water is generally used in concrete making; (1) As mixing water; (2) For curing of concrete and (3) For washing of aggregates. Water may contains impurities. Some of these impurities are sugar, tannic acid, vegetable matter, oil, greases and sulphates, may interfere with the hydration of cement, and thus delay in setting and reducing strength of the concrete. Therefore normal drinkable tap water was used for the entire work in this research.

3.2.5 Granite powder

Granite powder was collected from Addis Ababa Co. A General Trading PLC work shop, which is located around 'Megenagna' village. This granite powder is formed when the polished granite finish (which is imported from China, usually) cut to the desire shape in their work shop. When they cut, bullnose or groove larger granite finish in to smaller and suitable form for market seal, they uses grinding and cutting machines. Through this process the powder is formed and expand in air and then the powder in the air will settle down to ground and washed away by water. The granite powder with water called granite sludge. They remove the granite sludge from the working area by allowing it to flow in to a prepared tanks. In these tanks the granite sludge settled down and the water will be recycled to wash the working area again. When these reservoir tanks reaches their capacity, they clean it by disposing the sludge out there with waste granite finishes. After the sludge is dried out it will get powder form again and that can be easily accessed.

Table 3.7: Physical property of Granite powder

S. No.	Property	Test Result
1	Specific gravity	2.67
2	Particle Size	45µm sieved passed
3	Colour	Grey
4	Moisture content	0.35%
5	Density	2.67g/cm ³
6	Strength activity index	79.5%
7	Water requirement	100.41%

The complete silicate analysis report for the sample granite powder which is done by Geological Survey of Ethiopia is presented in the Table below.

Table 3.8: Chemical composition of granite powder.

S. No.	Chemical oxides composition	Percentage by weight
1	Silica (SiO ₂)	69.12
2	Alumina (Al ₂ O ₃)	17.77
3	Iron (Fe ₂ O ₃)	2.17
4	Calcium oxide (CaO)	1.54
5	Magnesia (MgO)	0.46
6	Soda (Na ₂ O)	2.22
7	Potassium Oxide (K ₂ O)	3.86
8	Manganosite (MnO)	0.04
9	Potassium oxide (P ₂ O ₅)	0.05
10	Titanium dioxide (TiO ₂)	0.14
11	Water (H ₂ O)	0.1
12	Loss on ignition (LOI)	1.24

The basic chemical requirement is that, the sum of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3) should be at least 70%. This can be verified from the complete silicate analysis of granite powder. The sum of the three oxides becomes 89.06%, which confirm the ASTM C-618 requirement.

3.2.6 High Range Water Reducer

High range water reducing Superplasticizer is used to maintain the design workability of high strength concrete mixtures. Naphthalene sulphonate based (SASplast SP60) superplasticizer conforming to ASTM C-494 type F is obtained from SAS Construction Chemicals Ltd. Addis Ababa Ethiopia. The properties of superplasticizer are summarized in the table below.

Table 3.9: Properties of superplasticizer

S. No.	Properties of SP60	Observations
1	Colour	Dark brown liquid
2	Specific gravity (kg/lit.)	1.22 ± 0.03 at 25°c
3	Chemical base	Naphthalene sulphonate
4	Air entrainment	1-2 % depending on dosage
5	Chloride content	Nil

3.3 Experimental Programs

3.3.1 Slump test

Slump test is the simplest test for workability and is the most widely used on construction site. In slump test, the distance that a cone full of concrete slumps down is measured when the cone is lifted from around the concrete. It is done based on ASTM C143, a sample of

freshly mixed concrete is placed and compacted by rodding in the frustum of a cone shaped mould in three layers. Then the mould is raised vertically without twisting it and the concrete allowed to subside. The vertical distance between the original and displaced position of the centre of the top surface of the concrete is measured and recorded as the slump of the concrete (ASTM C143/143M, 1900).



Figure 3.3: Slump apparatus and slump test

3.3.2 Compressive strength test

Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. The strength of concrete specimen is affected by factors like water-cement ratio, degree of compaction and curing temperature. Tests for compressive strength is carried out either on cubes or cylinders. Various standard codes recommends concrete cylinder or concrete cubes as the standard specimen for the test. American Society

for Testing Materials ASTM C39/C39M provides standard test method for compressive strength of cylindrical concrete specimens.

In this research, 150mmx150mmx150mm concrete cube specimens were used for the compressive strength test. The required cubic samples were casted for each replacement of granite powder. The same concrete mix for which workability was determined is filled in to cubical moulds then compacted in three layer in order to remove air bubbles. After 24 hours, the cubes were removed from the mould and cured in water till the required date. After specified curing time the samples are removed from water and the excess water on the concrete surface was wiped. Then placed in the compressive test machine within the respective permissible tolerance period of 7 and 28 days, as per ASTM C39/39M.

Three test specimens were prepared for each selected ages of test. The average of these specimens gives the crushing strength of concrete. As per ASTM C39/39M, if the strength of any specimen varies by more than 15 percent of the average strength, the result of such specimen should be rejected (ASTM C-39, 1901).

For this test, a total of 60 cubic specimens are prepared for normal as well as for higher strength concrete. The detail is presented in the table below.

Table 3.10: Compressive strength test specimens

C20/25 specimens					
Age (days)	Percentage replacement				
	0%	5%	10%	15%	20%
7	3	3	3	3	3
28	3	3	3	3	3

C55/67 specimens					
Age (days)	Percentage replacement				
	0%	5%	10%	15%	20%
7	3	3	3	3	3
28	3	3	3	3	3



Figure 3.4: Compressive strength testing

3.3.3 Flexural tensile strength test

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam to resist failure in bending. As per ASTM standard, it is measured by loading 150mmx150mm concrete beams with span length at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MR) in Mpa and it can be determined by standard test methods ASTM C78 (three point loading) or ASTM C 293 (center point loading).

In this paper, the test specimens were prepared based on ASTM C31 requirements. A 150mmx150mm beam cross section is recommended for concrete with nominal maximum coarse aggregate up to 50mm. The length should be at least 50mm greater than three times the depth of the section. Therefore, 150mmx150mmx600mm dimensioned beam is selected to this test. And these flexural test specimens were casted and hardened in the horizontal position. After 28 days of curing the test is performed as soon as the specimens are removed from moist curing. For this paper, center point loading test is used (ASTM C293). As per the standard, it requires that result of two properly conducted test by the same operator in beams made from the same batch should not differ from each other by more than 12% (ASTM C293, 1902).

Table 3.11: Number of concrete beam specimens.

Concrete types	Percentage replacement				
	0%	5%	10%	15%	20%
C20/25	2	2	2	2	2
C55/67	2	2	2	2	2



Figure 3.5: Concrete beam specimens

3.3.4 Water absorption test

The water absorption by immersion test is done based on ASTM C 642 procedure (ASTM C-642, 1997). The samples were oven dried for 48 hours until the difference between values obtained from two successive values of oven dried mass is less than 0.5% of the lowest value obtained. After final drying, the samples were immersed in water by suspending them by wire mesh. These samples stayed in water for three days till the difference between mass of two successive surface dried sample remain below 0.5% of large value. Then the final mass was measured. After having the final mass of oven dried and surface dried mass, the percentage of water absorption after immersion is calculated as:

$$\text{Absorption after immersion, \%} = \frac{(B - A) * 100}{(A)}$$

Where

A = mass of oven dried sample in air, g

B = mass of surface dried sample in air after immersion, g

Table 3.12: Number of cubes for water absorption test.

Concrete Type	Percentage replacement				
	0%	5%	10%	15%	20%
C20/25	3	3	3	3	3
C55/67	3	3	3	3	3



Figure 3.6: Cube specimens for water absorption test

3.3.5 Sorptivity test

Sorptivity measures the rate of water absorption by hydraulic cement concrete by measuring the increase in the mass of a specimen resulting from absorption of water as function of time when only one surface of the specimen is exposed to water. The water ingress in to the exposed unsaturated surface of concrete by capillary suction during the initial contact with water. The test is performed based on ASTM C1585 test procedure (ASTM C1585, 2007).

This method is intended to determine the susceptibility of an unsaturated concrete to the penetration of water. For this purpose, cylinders of 100mm diameter and 200mm length were casted and cured for 28 days. These cylinders were casted according to the practice of ASTM C31/31M. After final curing time, the parent samples were removed from water and test specimens of size 100mm diameter and 50mm length disc are produced from the 200mm length cylinder by cutting the parent cylinder in to four slices. That measures the water absorption of interior concrete surface. For this test only the middle two disc slices are used rejecting the top and bottom disc specimens. The average result of these two specimen were used to represent the result.

Table 3.13: 100 mm X 50 mm cylindrical test specimens for Sorptivity test.

Concrete Type	Percentage replacement				
	0%	5%	10%	15%	20%
C20/25	2	2	2	2	2
C55/67	2	2	2	2	2



Figure 3.7: Sorptivity test specimens after cutting the parent cylinders.



Figure 3.8: Measuring of mass of specimens.

Sorptivity measures the initial and secondary rate of water absorptions. The initial water absorption is the absorption during one minute and six hours. The secondary water absorption is from day one to day eight.

3.3.6 Chemical attack tests

Cubes of 150 mm from normal and high strength concrete were casted and cured for 28 days. After final day of curing, the specimens were removed from the water and the excess film of water on the surface was cleaned using standard preliminary surface cleaning process and weighed. Then the identified specimens were immersed in chemical solution. The solution was checked periodically. After the prescribed duration, the specimens were removed from the solution. Using weight loss method, percentage weight loss was determined.

3.3.6.1 Sulphate attack

A solution of sodium sulphate was prepared by mixing 5% by weight of sodium sulphate (Na_2SO_4) with potable water. Then the cubes are cured in this solution for 28 days. After 28

days of exposure, the samples were taken out from the solution and the surfaces were dried with dry towel. Finally the surface dried cubes were weighed and results are recorded.

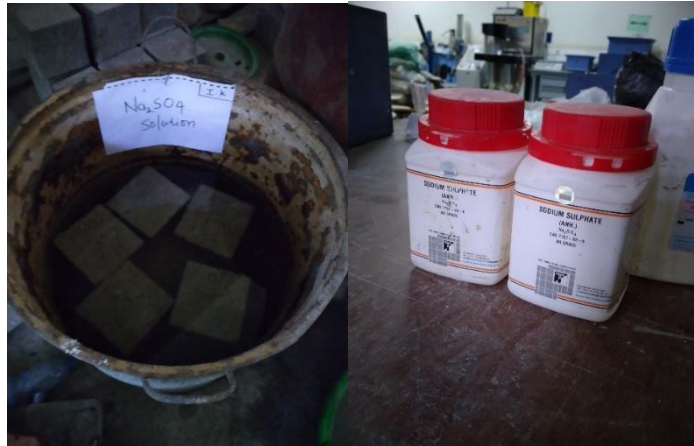


Figure 3.9: Samples in sulphate solution and Na_2SO_4 powder.

3.3.6.2 Chloride attack

A solution of sodium chloride (NaCl) was prepared by mixing 5% by weight of sodium chloride with potable water. After 28 days of exposure, the cubes were taken out and the surfaces were dried. Then final surface dried weights of cubes were found.

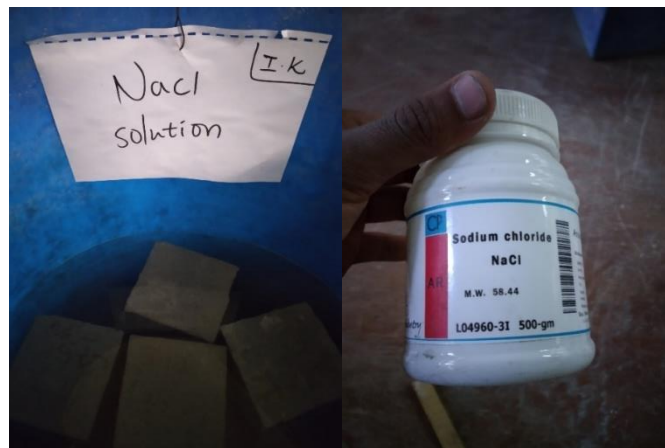


Figure 3.10: Samples in chloride solution and NaCl Powder

4. TEST RESULT AND DISCUSSION

4.1 Introduction

The aim of this chapter is to analysis and discuss the result obtained from the experimental programs in chapter three. Generally, the fresh and hardened properties of both normal and high strength grade concrete are presented, analyzed and briefly discussed in this part.

4.2 Workability of fresh concrete

The result of workability test is presented in the table below,

Table 4.1: Slump height measures of C25 and C67 grade concrete

Percentage replacement	Slump height (cm)	
	C20/25	C55/67
0%	7.5	5
5%	6	4
10%	5	3.5
15%	5	3
20%	2.5	2

From the result obtained, the slump height decreased as the percentage replacement increased in C20/25 and C55/67 grade concrete. Because of the higher surface area of granite powder increased the surface hydration leading to higher water absorption which intern decreased the workability of concrete.

In C20/25 concrete, concrete containing up to 15% granite powder indicate medium workability that can be used for different purposes. A significant decrease in the slump was observed at 20% replacement. Whereas in C55/67 concrete, the slump measures for 0% replacement and 5% replacement were not significantly different. Doing workability test by slump measure for higher strength concrete was not as simple as the one did for normal strength concrete. Because of the high amount of cement and the admixture, the resulting concrete is very sticky. This make the slump test to be less accurate because it doesn't allow to remove the cone gently in the vertical direction without twisting. The concrete stacked to the interior surface of the cone hence it was difficult to detach the cone after the three layer compaction. So that a more accurate workability measure is required to exactly examine the variation in the workability for each percentage replacement of granite powder.

An alternative method of measuring workability called compaction factor test is recommended for such type of concrete in further studies. Because even if the concrete is stacked to the hoppers the standard allows to use rodding to drop the concrete to the next hopper or to the lower cylinder.

4.3 Compressive strength

4.3.1 C20/25 as NSC

Compressive strength test was performed at 7th and 28th days. The 7th day result showed that, for 5% and 10% replacement of cement with granite powder the compressive strength increased by 13% and 9% respectively.

The 28th day compressive strength test result showed that, the average compressive strength was still higher at 5% and 10% replacement by 3.36% and 1% respectively. But relative to 7th day strength increase, the 28th day strength increase is lower. Which indicates that granite powder is better in early strength gain than later strength gain.

Table 4.2: Compressive strength test on C20/25 concrete

Replacements	Cube No.	Compressive strength (Mpa)		Average strength (Mpa)	
		7 th day	28 th day	7 th day	28 th day
0%	1	28.206	36.481	29.576	34.995
	2	30.658	33.233		
	3	28.863	35.270		
5%	4	33.081	35.093	33.357	36.162
	5	36.177	38.867		
	6	30.814	34.526		
10%	7	31.566	34.747	32.209	35.277
	8	33.210	36.867		
	9	32.152	34.218		
15%	10	24.222	28.605	27.696	29.630
	11	28.488	29.350		
	12	30.379	30.934		
20%	13	25.540	28.190	22.870	27.973
	14	20.517	28.292		
	15	22.554	27.437		

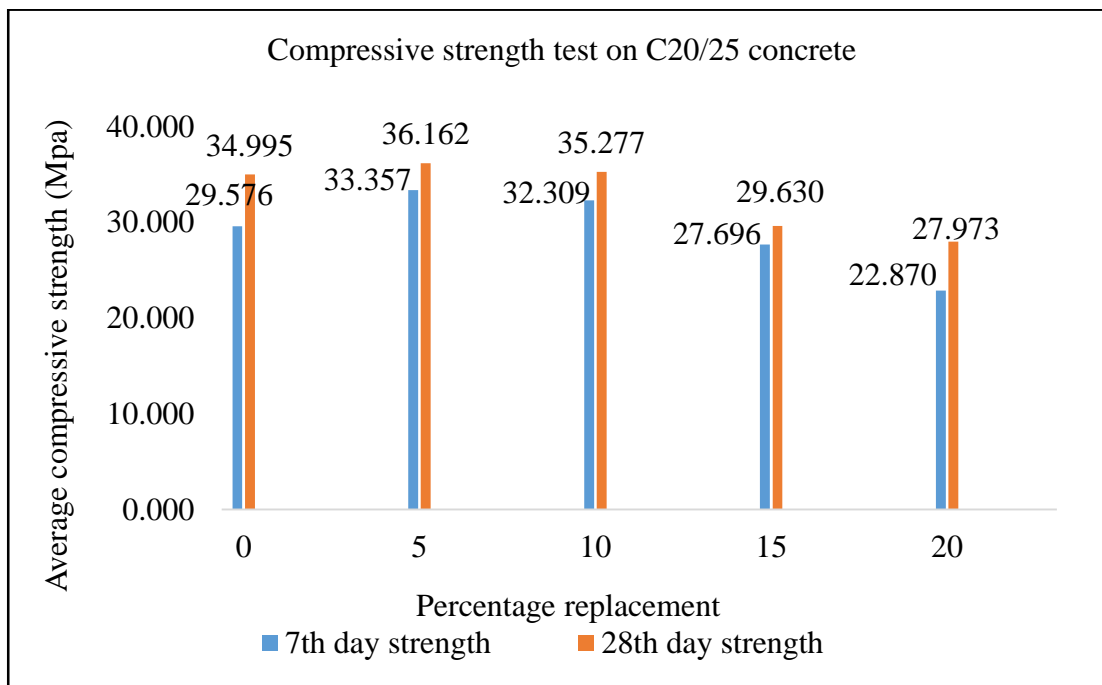


Figure 4.1: Compressive strength test result of C20/25 concrete

The enhancement in strength is due to the behaviour of chemical reaction between calcium hydroxide of cement and granite powder results in the formation of additional CSH gel and the microstructure improvement caused by filling of high fine granite powder. Hence granite powder immensely enhance the concrete matrix.

4.3.2 C55/67 as HSC

Compressive strength tests was done for 7 and 28 days. The 7th day strength test result showed that, the strength increased at 5% replacement by 5.86%. But it decreased for 10%, 15% & 20% by 10.85%, 19.51% & 19.76% respectively.

The 28th day result showed that, concrete cubes containing 5% granite powder was still higher than the control strength. Its strength was increased by 6.78%. For the other replacements, 10%, 15% & 20% the strength decreased by 3.75%, 6.47% & 15.04%

respectively. The decrease in the strength is due to the reduced cement content at higher replacements.

Table 4.3: Compressive strength test on C55/67 concrete

Replacement	Cube No.	Compressive strength (Mpa)		Average strength (Mpa)	
		7 th day	28 th day	7 th day	28 th day
0%	1	57.865	66.468	58.886	67.810
	2	61.261	67.760		
	3	57.533	69.202		
5%	4	64.240	74.960	62.340	72.409
	5	60.109	69.590		
	6	62.671	72.678		
10%	7	52.234	67.044	52.497	65.266
	8	52.057	64.012		
	9	53.199	64.741		
15%	10	47.935	64.178	47.397	63.420
	11	49.695	62.722		
	12	44.562	63.360		
20%	13	49.853	58.731	47.252	57.609
	14	46.465	54.958		
	15	45.439	59.138		

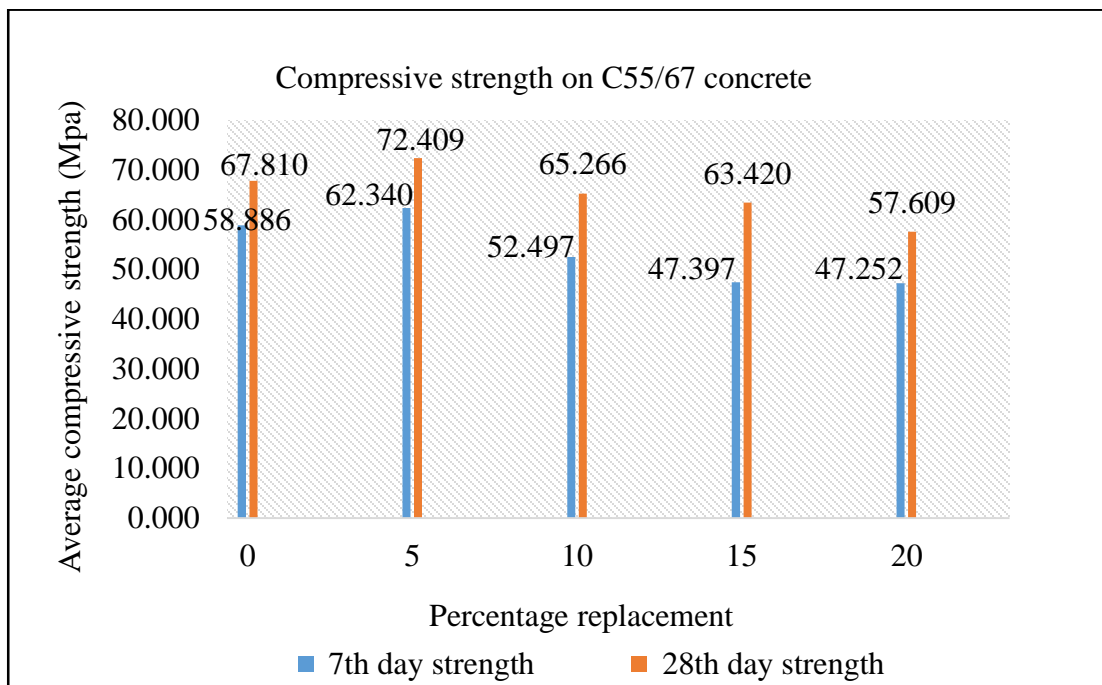


Figure 4.2: Compressive strength test result of C55/67 concrete

The reason for the enhancement is such fine powders chemically react with calcium hydroxide at ordinary temperatures to form compounds having cementitious properties. When using these materials in concrete, the concrete will make efficient use of the hydration products of Portland cement and by consuming calcium hydroxide to produce additional cementing compounds. If concrete containing these products cured properly, the reaction products partially fill in the space originally occupied by mixing water that were not filled by the hydration products of cement, thus lowering the concrete voids and permeability to water and chemicals, hence they increase the overall strength of the concrete.

4.4 Flexural tensile strength

4.4.1 C20/25 as NSC

The flexural strength test was performed at 28 day age. Results showed that, concrete beams containing 5% and 10% granite powder again attained greater strength over the control by 6.34% and 7.94% respectively. The flexural strength decreased by 1% and 1.12% at 15 and 20% replacement.

Table 4.4: Flexural strength test on C20/25 concrete.

Sample No.	Replacement	Maximum load (N)	Length (mm)	Average width at fractured surface (mm)	Average depth at fractured surface (mm)	Modulus of rapture (Mpa)	Average strength (Mpa)
1	0%	31413	500	150	150	6.9807	7.1241
2		32704	500	150	150	7.2676	
1	5%	33654	500	150	150	7.4787	7.5758
2		34528	500	150	150	7.6729	
1	10%	33350	500	150	150	7.4111	7.6897
2		35857	500	150	150	7.9682	
1	15%	31945	500	150	150	7.0989	7.0524
2		31527	500	150	150	7.0060	
1	20%	31185	500	150	150	6.9300	7.0440
2		32211	500	150	150	7.1580	

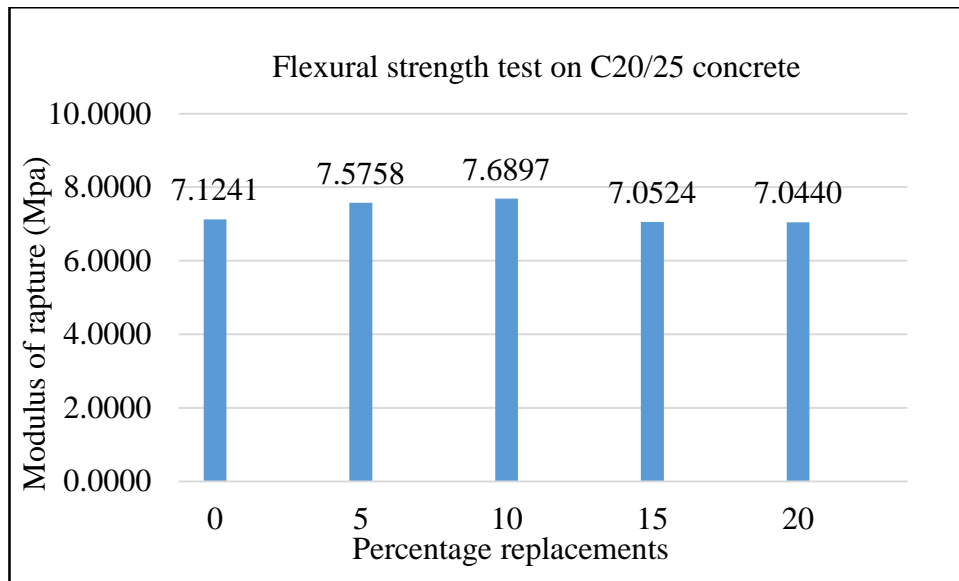


Figure 4.3: Flexural strength test result of C20/25 concrete

4.4.2 C55/67 as HSC

Flexural strength test on HSC beams was done at 28 days. From the test result, the flexural strength was enhanced up to 10% replacement of cement with granite powder. At 5% replacement the flexural strength increased by 6.24% and at 10% replacement the strength increased by 4.90% relative to the control beams. For 15 & 20% replacement the strength decreased by 1.32% & 10.52% respectively. So maximum flexural strength was attained at 5% replacement but up to 10% the strength was still above the control strength.

Table 4.5: Flexural strength test on C55/67 concrete

Sample No.	Replacement	Maximum load (N)	Length (mm)	Average width at fractured surface (mm)	Average depth at fractured surface (mm)	Modulus of rapture, R (Mpa)	Average strength (Mpa)
1	0%	41103	500	150	150	9.2007	9.4708
2		43834	500	150	150	9.7409	
1	5%	44214	500	150	150	9.8253	10.0617
2		46341	500	150	150	10.2980	
1	10%	43948	500	150	150	9.7662	9.9350
2		45467	500	150	150	10.1038	
1	15%	40035	500	150	150	8.8967	9.3399
2		44024	500	150	150	9.7831	
1	20%	38250	500	150	150	8.5000	8.4747
2		38022	500	150	150	8.4493	

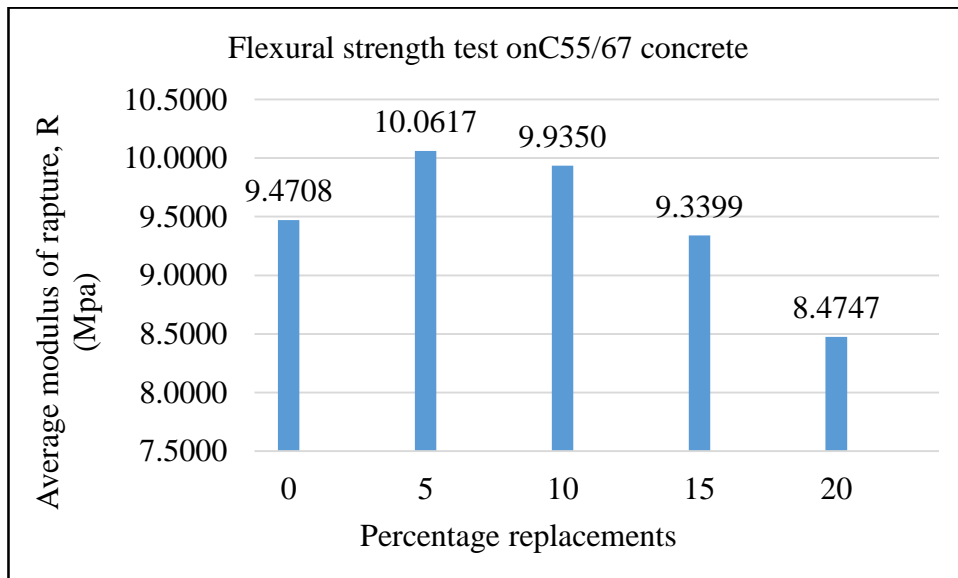


Figure 4.4: Flexural strength test result of C55/67 concrete

4.5 Water absorption

4.5.1 C20/25 as NSC

Water absorption of concrete is considered as one of the most important indicator for its quality and durability. The water absorption test result of C25 concrete showed that, the percentage water absorption by weight decreased for 5% and 10% replacement. Hence concrete containing 5 and 10% granite powder performed well against water absorption. Due to the filling effect of granite micro-sized particles which reduced the volume and conductivity of capillary pores which allows fewer voids to permit water to go through.

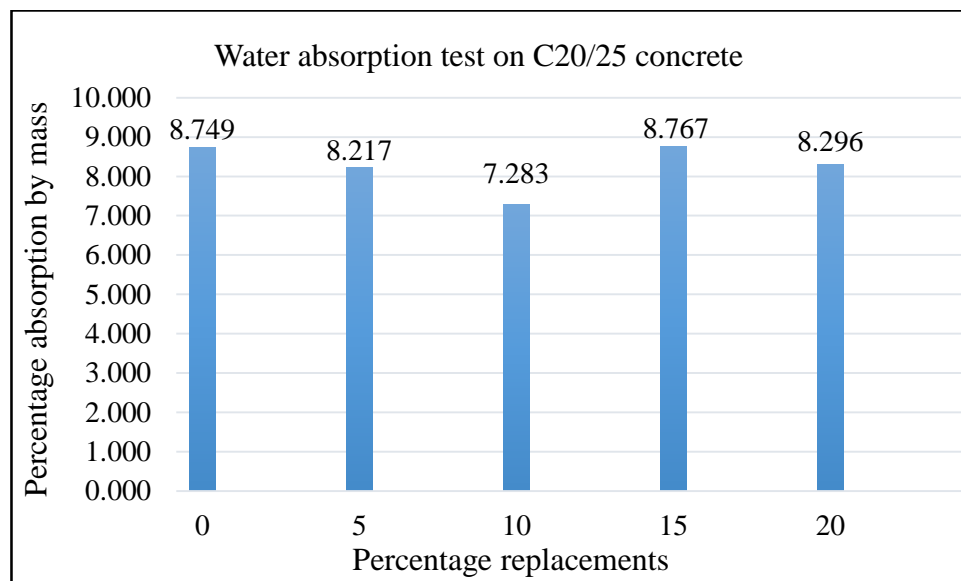


Figure 4.5: Water absorption test result of C20/25 concrete

4.5.2 C55/67 as HSC

Result showed that, the water absorption performance was better for concrete containing 5% granite powder. The percent of water absorption by mass was least at 5% replacement and the absorption increased for other percentages of replacement.

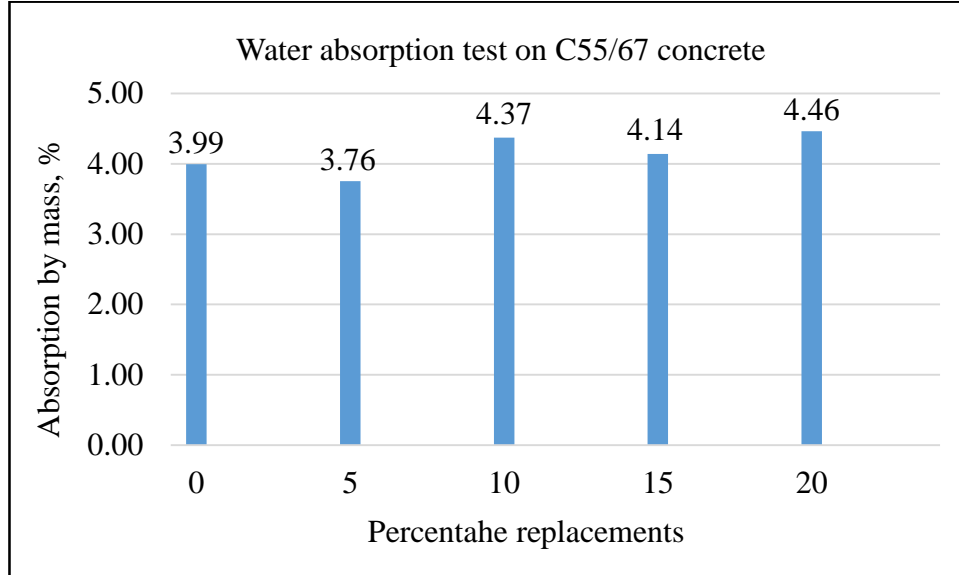


Figure 4.6: Water absorption test result of C55/67 concrete

4.6 Sorptivity

The test has two phases of absorption according to the standard ASTM C 1585. The initial and secondary absorption phase in $\text{mm/s}^{1/2}$. The initial absorption is defined as the slope of the line that best fitted I versus $s^{1/2}$ between one minute and six hour. Whereas Secondary absorption is the slope of the line fitted for the data from day one. The results are compared numerical by using least-square regression method. According to the standard, the numerical result will be valid only for correlation coefficient greater than 0.98. Otherwise the result will no longer representative.

The correlation coefficient was checked for the initial as well as for the secondary absorption data ranges, but the values were greater than 0.98 only for the initial absorptions in C25 and C67 grade concrete. Since the data have no linear relation or it follows a systematic curve in the secondary absorption data ranges, the correlation coefficient were less than 0.98 so the

secondary rate of absorption cannot be determined based on the standard. The numerical method was used only for comparing the initial rate of water absorption in C25 and C67 concrete.

4.6.1 C20/25 as NSC

The result showed that, the initial water absorption was enhanced at 5% GP. Smaller enhancement also seen at 20% replacement.

Table 4.6: Initial rate of water absorption on C20/25

Percentage replacements	Initial absorptions ($\text{mm/s}^{1/2}$)
0%	0.02442
5%	0.01946
10%	0.02681
15%	0.02549
20%	0.02302

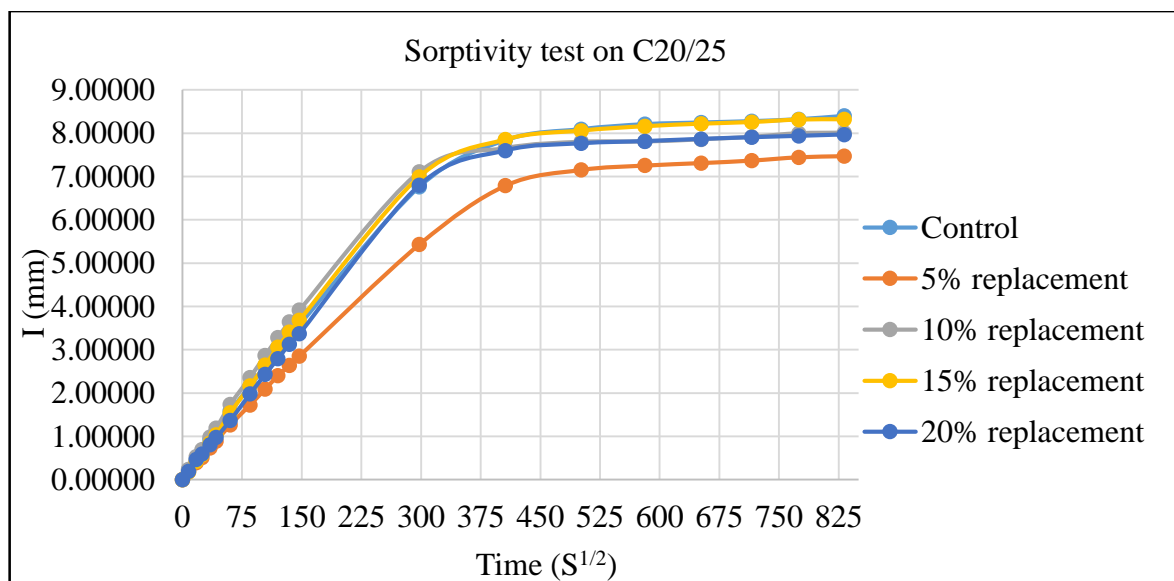


Figure 4.7: Graphical representation of rate of water absorption on C20/25 concrete

4.6.2 C55/67 as HSC

In C67 grade concrete, the initial water absorption was enhanced at 10% replacement. Since the correlation coefficient was less than 0.98 the secondary rate of water absorption cannot be determined numerically.

Table 4.7: Initial rate of water absorption on C55/67.

Percentage replacement	Initial absorptions (mm/s ^{1/2})
0%	0.01739
5%	0.02271
10%	0.01732
15%	0.01825
20%	0.01750

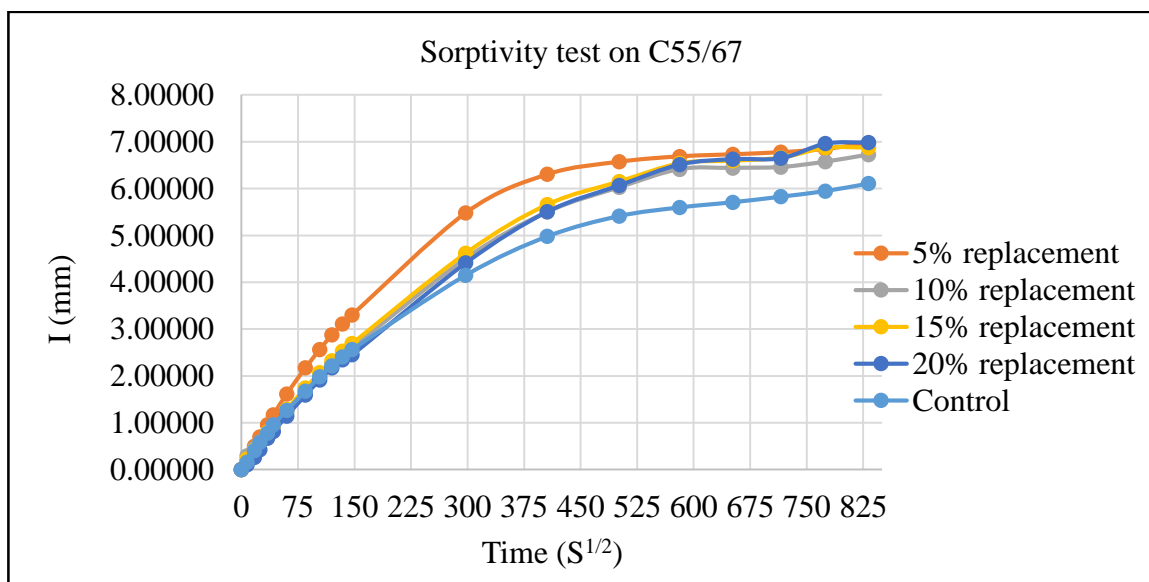


Figure 4.8: Graphical representation of rate of water absorption on C55/67 concrete

4.7 Sulphate attack

4.7.1 C20/25 as NSC

Result of sulphate attack test indicate that, for all replacement of granite powder the performance was better than the control. So adding granite powder in concrete enhance the performance of concrete against sulphate attack.

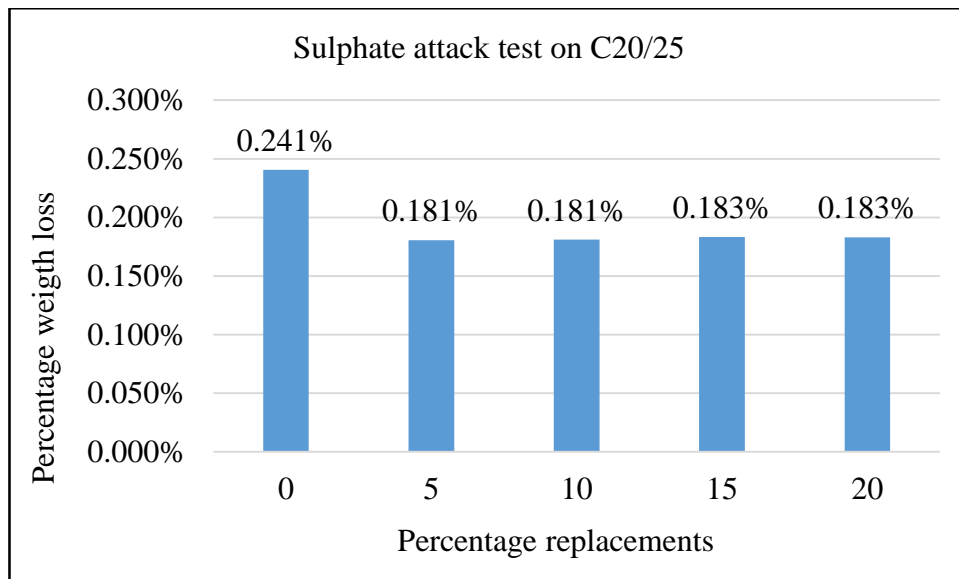


Figure 4.9: Sulphate attack test result of C20/25 concrete

4.7.2 C55/67 as HSC

The performance of concrete containing granite powder under sulphate attack was better than the control concrete.

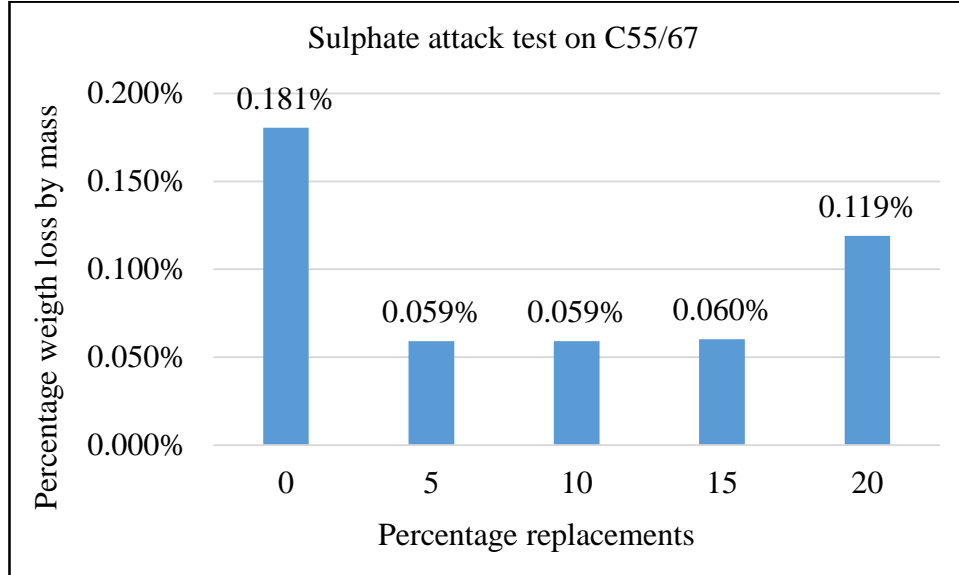


Figure 4.10: Sulphate attack test result of C55/67 concrete

The reason behind the improvement against sulphate attack is that, sulphate salt attacks either C3A, calcium hydroxide or monosulfoaluminate (Afm). Then it form ettringite which is expansive and causes crack. Once the salt have consumed all the CH, then it starts attacking or decalcifies the calcium silicate hydrate (CSH) which is the back bone of concrete strength. One of the best method to stop this effect is reducing C3A of cement, what we are doing here by taking out cement and replacing by granite powder. The other method is reducing the w/c ratio. In higher strength concrete the water-cement ratio is lower that is why weight loss is lesser in HSC than NSC.

4.8 Chloride attack

4.8.1 C20/25 as NSC

The result shows that, adding granite powder in concrete enhance the performance of concrete when the concrete is exposed to chloride solution.

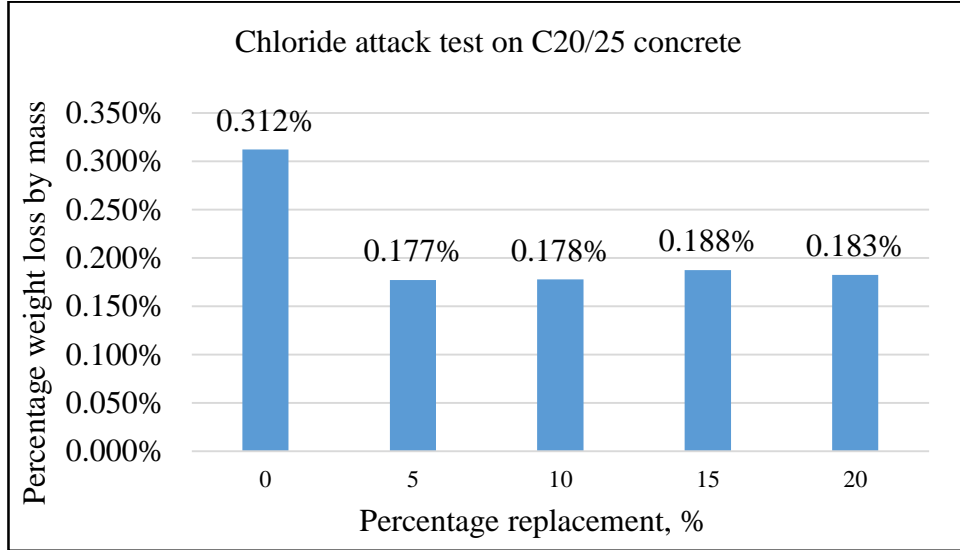


Figure 4.11: Chloride attack test result of C20/25 concrete

4.8.2 C55/67 as HSC

The result showed that, the chloride resistance of concrete was enhanced for all percentage replacement of cement with granite powder. Concrete containing 5% GP retain its original weight after 28 days of exposure in the chloride solution.

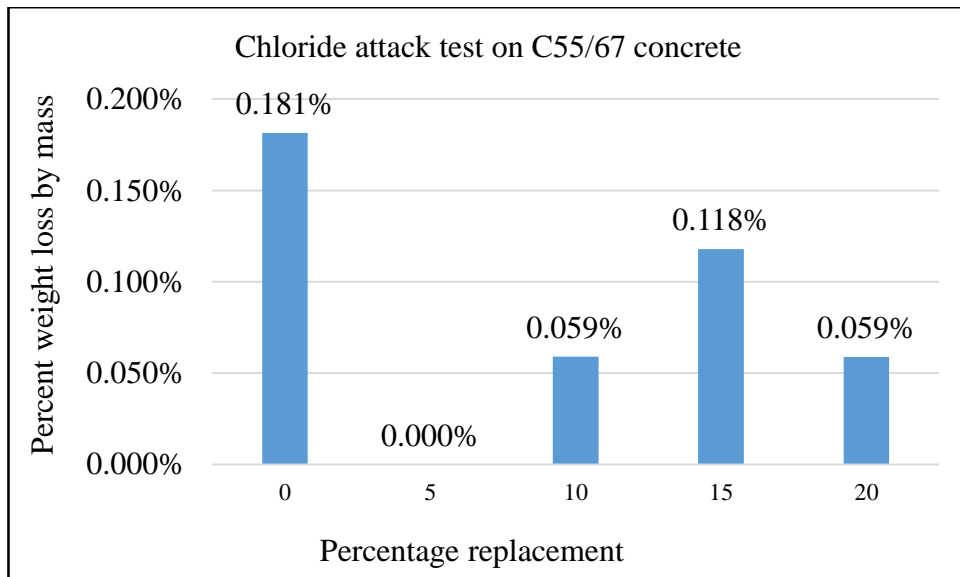


Figure 4.12: Chloride attack test result of C55/67 concrete

5. SUMMARY AND CONCLUSION

5.1 Summary

This research was intended to study the mechanical properties of concrete made by partially replacing cement with granite powder. Granite powder was replaced at 0%, 5%, 10%, 15% and 20% by volume of cement. Then fresh and hardened property of concrete were investigated. Fresh properties of concrete using slump test and hardened properties of concrete were done through strength and durability tests. Compressive strength test and flexural test were performed to evaluate the strength properties. Water absorption test, Sorptivity test, chloride and sulphate attack tests were performed to evaluate the durability properties. These tests were performed on C20/25 grade concrete as normal strength and C55/67 grade concrete as high strength with and without granite powder, then properties were compared and analyzed. The results obtained from the experiment showed reliable data points or facts and promising further research horizon.

5.2 Conclusions

Based on the investigations the following conclusions are made for C20/25 and C55/67:-

5.2.2 C20/25 as NSC

- The workability of concrete decreased as the percentage replacement increased. But up to 15% replacement the concrete shows medium workability that can be used for different purpose.
- Granite powder enhanced the 7th day compressive strength by 13% and 9% at 5% and 10% replacements respectively. The 28th day strength is still higher at 5% and

- 10% replacements by 3% and 1% respectively. From this it can be conclude that granite powder is better in early strength gain than later strength gain.
- The flexural tensile strength was enhanced at 5% and 10% replacements. It increased by 6.34% and 7.94% at 5% and 10% replacements respectively.
- The water absorption was least at 5% and 10% replacements. Due to the filling effect of granite powder, fewer conductivity voids were made at these percentage replacements.
- Rate of water absorption (Sorptivity) shows initial and secondary rate of water absorption. The initial absorption was least at 5%, but there was also little enhancement at 20% replacement. Secondary rate of absorption was enhanced for all percentage replacements, especially after the second day. Hence from this it can be conclude that granite powder had significant effect in improving the quality of concrete against water absorption by capillary suction.
- Weight loss when the concrete exposed to chloride and sulphate attack was smaller in all percentage replacements relative to the control concrete samples.
- Therefore in C20/25 grade concrete, selecting the optimum percentage replacement depends on the condition we encounter. So that for better compressive strength, least rate of water absorption and for better sulphate and chloride attack resistance, 5% replacement is the recommended optimum percentage. For better flexural strength and water absorption performance 10% replacement is recommended.
- In this research, the results obtained were for a single normal strength grade concrete (C20/25), and these results may be the same for the other ranges of NSC.

5.2.3 C55/67 as HSC

- As the percentage replacement increased, the workability of the concrete mixes decreased. But in most mixes, the slump values for 0% and 5% replacement were not significantly different.
- The 7th day compressive strength was improved only at 5% replacements by 5.86% relative to the control strength.
- The 28th day compressive strength was enhanced at 5% replacement by 6.78% relative to the control strength.
- The flexural strength was maximum at 5% replacement, but up to 10% the strength was above the control.
- A denser and best impermeable concrete with least water absorption was made when 5% of the cement was replaced with granite powder.
- Little enhancement in the initial rate of water absorption was seen at 10% replacement, but the secondary rate of water absorption was not improves for all percentage replacements.
- The resistance of concrete to chloride and sulphate attack was boosted up in all replacements relative to the control concrete.
- Therefore, 5% replacement shows improvement on many of tests performed in this research, so the optimum recommended percentage replacement is 5% in this case.
- In this research, the results obtained were for a single high strength grade concrete (C55/67), and these results may be the same for the other ranges of HSC.

References

- A.J.Patel, D. V. M. P. (2015). Review on Partial Replacement of Cement in Concrete. *UKIERI Concrete Congress - Concrete Research Driving Profit and Sustainability*, (December).
- Allam, M. E., Bakhoun, E. S., Ezz, H., & Garas, G. L. (2016). Influence of Using Granite Waste on the Mechanical Properties of Green Concrete. *ARPJ Journal of Engineering and Applied Sciences*, 11(5), 2805–2811.
- Allam, M. E., Bakhoun, E. S., & Garas, G. L. (2014). Re-Use of Granite Sludge in Producing Green Concrete. *ARPJ Journal of Engineering and Applied Sciences*, 9(12), 2731–2737.
- Allam, M. E., Bakhoun, E. S., Garas, G. L., & Ezz, H. (2016). Durability of Green Concrete Containing Granite Waste Powder. *International Journal of Engineering & Technology*, 8(5), 2383–2391. <https://doi.org/10.21817/ijet/2016/v8i5/160805042>
- ASTM C-39. (1901). Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. In *American Society for Testing and Materials* (pp. 1–5).
- ASTM C-642. (1997). Standard Test Method for Density , Absorption , and Voids in Hardened Concrete. In *American Society for Testing and Materials* (pp. 1–3).
- ASTM C143/143M. (1900). Standard Test Method for Slump of Hydraulic - Cement Concrete. In *American Society for Testing and Materials* (pp. 1–3).
- ASTM C1585. (2007). Standard Test Method for Measurement of Rate of Absorption of

- Water by Hydraulic. In *American Society of Testing and Material* (pp. 1–6).
- ASTM C293. (1902). Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading). In *American Society for Testing and Materials* (pp. 1–3).
- ASTM C618. (1998). ASTM c-618-98, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for use as a Mineral Admixture in Concrete. In *American Society for Testing and Materials* (pp. 301–303).
- Awol Abrar. (2011). *Using Marble Waste Powder in Cement and Concrete Production*. Addis Ababa University.
- Berhanu Negesse & Dr.- Ing Abebe Dinku. (2018). *Utilization of Waste Marble Powder as a Partial Replacement of Cement in HCB Production*. Addis Ababa University.
- Bililign Firdawek, D. T. A. (2019). *Evaluation of the Performance of Concrete with Partial Replacement of Cement by Lime and Pumice at Elevated Temperature*. Addis Ababa Science and Technology University.
- Chiranjeevi, K., Kumar, Y. Y., & Poornima, P. (2015). Experimental Study on Concrete with Waste Granite Powder as an Admixture. *International Journal of Engineering Research & Applications*, 5(6), 87–93.
- Chouhan, D. S., Gupta, T., & Sharma, R. K. (2013). Fresh and Hardened Properties of Granite Slurry Concrete Incorporating Metakaolin. *International Journal for Innovative Research in Science & Technology*.

- Divakar, Y., Manjunath, S., Aswath, M. U., & Student, P. G. (2012). Experimental Investigation on Behaviour of Concrete with the Use of Granite Fines. *International Journal of Advanced Engineering Research and Studies*, 1(4), 1–4.
- Dr. Belachew Asteray & Million Yehualashet. (2019). *Experimental Investigation on Mechanical Properties of High -Performance Concrete With Partial Replacement of Cement by Fly Ash*. Addis Ababa Science and Technology University.
- F.J. Faleye, S. O. and O. O. (2009). Chemical and Physical Analyses of Selected Cement Samples in Nigerian Market. *Bangladesh Journal of Scientific and Industrial Research*, 1(44), 44–45. <https://doi.org/10.3329/bjsir.v44i1.2712>
- Fitsum Nigussie & Dr. Essayas G/ youhannes. (2017). *Analysis of Mechanical Properties of Cellular Lightweight Concrete Containing Bagasse Ash*. Addis Ababa University.
- G. Ediward Nawy. (2009). *Reinforced Concrete (Fundamental Approach)*.
- Ghannam, S., Najm, H., & Vasconez, R. (2016). Experimental Study of Concrete Made with Granite and Iron Powders as Partial Replacement of Sand. *Journal of Sustainable Materials and Technologies*, 9, 1–9. <https://doi.org/10.1016/j.susmat.2016.06.001>
- Gizachew Markos Makebo. (2019). Partial Replacement of Cement Material in Ethiopia : A Review. *International Research Journal of Engineering & Technology (IRJET)*, 06(10), 1002–1005.
- Hawaz Abrham, Quezon Emer Tucay, & Mamuye, B. (2018). Effects of Varying Dosage Replacement of Cement Content by Animal Bone Powder in Normal Concrete Mix

Production. *Americal Journal of Civil Engineering and Architecture*, 6(4), 133–139.

<https://doi.org/10.12691/ajcea-6-4-1>

Hordofa, H. (2019). *Experrmmntal Investigation on Eggshell Powder Blended Concrete*.

Addis Ababa Science and Technology University.

John M. Scanion, G. R. M. (1985). ACI Standard Practice for Selecting Proportions for

Normal, Heavyweight, and Mass Concrete. In *ACI 211.1-81* (pp. 438–513).

Kala, D. T. F. (2013). Effect of Granite Powder on Strength Properties of Concrete.

International Journal of Engineering & Science, 2(12), 36–50.

Kiran, M. V, Barmavath, S., Sangeetha, A., Gopi, K., V, V. R., Sainath, T., & S, K. P.

(2017). Compressive Strength and Tensile Strength of Granite Waste, Plastic Waste Concrete by Replacing Partially. *International Journal of Inovative Research in Science, Engineering & Technology*, 6(4), 6142–6163.

<https://doi.org/10.15680/IJIRSET.2017.0604264>

Kumar, R. S., Mohammed, H., & Haripriya, M. (2016). An Experimental Study on Partial

Replacement for Coarse Aggregate by Granite Waste. *International Journal of Inovative , Science, Engineering & Technology*, 3(3), 349–353.

M. G. Raja, M. K. M. R. (2016). Experimental Study on Partial Replacement of Fine

Aggregate by Granite Powder in Concrete. *International Journal for Inovative Research in Science & Technology*, 2(12), 202–209.

Macgregor, J. K. (2009). *Reninforced Concrete Mechanics & Design*.

- Mass, G. R., Alonzo, O., Bell, L. W., Bennett, J. E., Boyle, M., Crocker, D. A., ... White, D. J. (1998). Guide for Selecting Proportions for High-Strength Concrete with Portland Cement and Fly Ash. In *ACI 211.4R-93* (Vol. 93).
- Muhannad Ismeik. (2009). Effect of Mineral Admixtures on Mechanical Properties of High Strength Concrete Made with Locally Available Materials. *Jordan Journal of Civil Engineering*, 3(1), 78–90.
- Nagaraju, D., & Pratap, D. s. . sunil. (2017). An Experimental Study on Partially Replacment of Granite Powder in Fine Aggregate. *International Journal of Research in Advanced Engineering Technology*, 6(1), 310–319.
- Paralada, S. (2016). Use of Granite waste as Powder in SCC. *International Journal of Engineering Research & Technology*, 03(02), 1129–1135.
- Patil, Y., Chavan, A. R., Momin, U. H., Kadam, H. P., & Patil, S. N. (2018). Studying the Compressive Strength of Concrete with Granite as Partial Replacement to Sand. *International Journal of Engineering & Technology*, 05(04), 4339–4342.
- Popovics, S. (1992). *Concrete Materials*.
- S. mohammad, K. V., & R. Bhushaiah, K. K. (2019). Partial Replacement of Cement in Concrete with Granite Powder and Fine Aggregate with Saw Dust. *International Journal of Innovative Technology and Exploring Engineering*, 06(03), 3210–3222.
- Sergii Tolmachov, Belichenko Olena, & Zakharov Denis. (2017). Influence of Additives on Flexural Strength of Concrete. *MATEC Web Conferences*, 116, 1–5.

<https://doi.org/10.1051/mateconf/201711601019>

Shah, S. P. B., Gohil, S. P. D., Chavda, S. H. J., & Khediya, S. T. D. (2015).

Advancements in Concrete Technology. *American Journal of Engineering Research (AJER)*, 4(12), 36–40.

Shamsabadi, E. A., Ghalehnovi, M., Brito, J. De, & Khodabakhshian, A. (2018).

Performance of Concrete with Waste Granite Powder and the Effect of Superplasticizers. *MDPI*, 8, 1–20. <https://doi.org/10.3390/app8101808>

Shetty, M. S. (2019). *Concrete Technology Theory and Practice*.

Shinde, P. S. S., Chavan, A. D., Bhosale, A. P., Gajankush, D. C., & Dhage, V. D. (2018).

To Study the Effect of Granite Powder on Concrete. *International Journal for Research in Applied Science & Engineering Technology*, 6(Iii), 2454–2456.

Srinivasa, C. H. & D. V. (2015). Optimization of Granite Powder used as Partial

Replacment to Cement in the Design of Ready Mix Concrete of M20 Grade using IS1026:2009. *International Journal of Engineering & Technology*, 4(01), 104–111.

T. Hirschi, H. Knauber, M. Lanz, J. Schrabback, C. Spirg, U. W. (2005). *Concrete Handbook*.

Tsigehana G/ micael & Prof. Dr. Eng Belay Woldeyes. (2019). *Sugarcane Bagasse Ash as Partial Replacement of Cement in Concrete Production*. Addis Ababa University.

Appendices

Appendix A: Photos showing collection of granite powder, its specific gravity and chemical test results.



Figure A 1: Granite sludge in reservoir tank



Figure A 2: Collection of granite powder

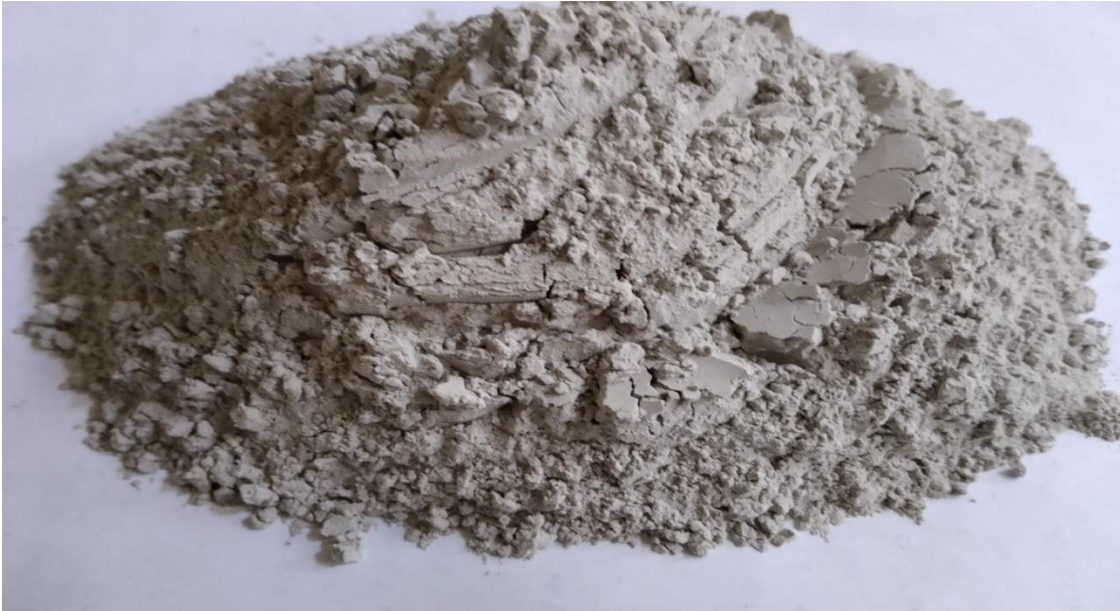


Figure A 3: Granite powder used in concrete mixes



Figure A 4: Granite powder finer than 45 μ m



Figure A 5: Granite powder wastage in other workshop

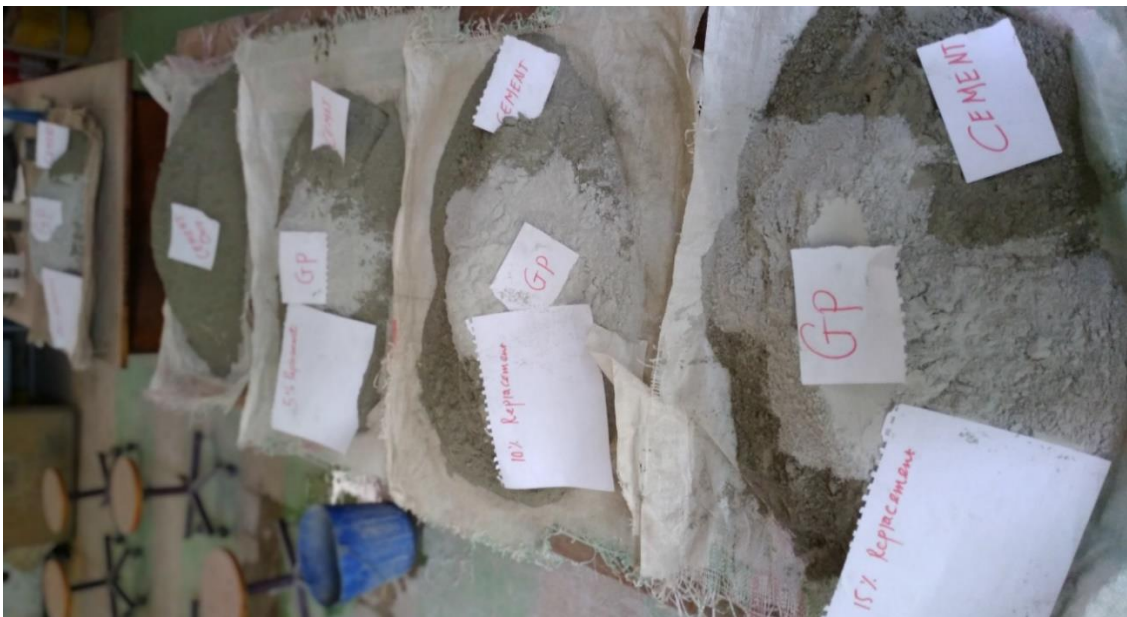



Figure A 6: Mixing of cement and granite powder during replacement


Geological Survey of Ethiopia
Mineralogy & Geotechnical Laboratory Directorate
Result Form

Directorate: Mineralogy and Geotechnical Laboratory Directorate Lab section: Mineralog Physical

Client/Originator Name: Issayas Keshbede Geo. Pre. No of Samples: 1 Sample No.

Client Category: Survey Area Ref: AA Lab No.:

File name: 0339/20 PXT Preparation required:

Sample Type: Rack Powder

Type of Analysis: Specific Gravity Date Submitted: 14/05/20

Cell No.	Lab No.	Pyconometer No.	Mass of pyconometer in g	Mass of test solution in the pyconometer without test sample in g	Density of test solution in g/cm ³	Mass of pycnometer & test sample in g	Mass of test sample in g	Mass of pycnometer, test sample and test solution in g	Volume of test solution in g/cm ³	Specific Gravity in g/cm ³	Average
GP	0339/20	60/60	29.246	78.9452	1.0000	37.3409	8.0949	84.0373	3.0028	2.60	2.67
		29/29	28.19	78.0836	1.0000	37.1745	8.9845	83.0597	3.3784	2.65	

Described by / Analysis: AP Checked by: Abdu Ebrahim Date Completed: 24/01/20




Figure A 7: Specific gravity test result of GP



GEOLOGICAL SURVEY OF ETHIOPIA		Doc Number: GLD/F5.10.2	Version No: 1
GEOCHEMICAL LABORATORY DIRECTORATE			Page 1 of 1
Document Title: Complete Silicate Analysis Report		Effective date: May, 2017	

Customer Name:- Issayas Kebede.
 Issue Date: -05/02/2020

Sample type:- Granite powder
 Request No:- GLD/RQ/073/20
 Date Submitted: - 23/01/2020
 Report No:- GLD/RN/49/20
 Sample Preparation: - 200 Mesh
 Number of Sample:- One (1)

Analytical Result: In percent (%) Element to be determined Major Oxides & Minor Oxides
 Analytical Method: LiBO₂ FUSION, HF attack, GRAVIMETRIC, COLORIMETRIC and AAS

Collector's code	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	TiO ₂	H ₂ O	LOI
GP	69.12	17.77	2.17	1.54	0.46	2.22	3.86	0.04	0.05	0.14	0.10	1.24

Note: - This result represent only for the sample submitted to the laboratory.

Analysts
 Yirgalem Abriham
 Tizita Zemene
 Nigist Fikadu

Checked By

 for Yohannes Getachew

Approved By

 Gosa Haite



Quality Control

 Negash Worku

Figure A 8: Chemical test result of GP

Appendix B: Photos on collecting materials for concrete production



Figure B 1: Coarse aggregate quarry



Figure B 2: Dangote 42.5R grade cement

Appendix C: Material tests for concrete proportioning

After collecting all the materials, tests were done for fine aggregate and coarse aggregates.

Appendix C 1: Test on fine aggregate



Figure C 1: Sieve analysis, specific gravity & silt content tests on sand

Table C 1: Unit weight and void content of fine aggregate

Fine aggregate - loose unit weight				
Dry loose unit weight (the sample was oven dry for 24 hrs. at 110 ± 5 degree celcius)				
	Description	mass (kg)	unit wt. of sand (kg/m^3)	% of voids
1	mass of empty measure	7.56	1210.191	45.549
2	Mass of measure + loos mass	9.46		
3	volume of measure (m^3)	0.00157		
Fine aggregate - dry rodded unit weight				
Dry rodded unit weight (the sample was oven dry for 24 hrs. at 110 ± 5 degree celcius)				
	Description	mass (kg)	unit wt. of sand (kg/m^3)	% of voids
1	mass of empty measure	7.56	1318.471	40.677
2	Mass of measure + rodded mass	9.63		
3	volume of measure (m^3)	0.00157		
% void $(S*W-M)/S*W$ where, S=bulk sp. Gr (OD) W = unit wt. of water = $998\text{kg}/\text{m}^3$ M = bulk density		To incorporate these values in to mix design it is better to averaging them		
		unit wt. of sand (kg/m^3)		% of void
		1264.33		43.11

Table C 2: Specific gravity and water absorption test on Sand

Fine aggregate						
ASTM C- 128, sample size taken 0.5kg SSD sample (after soaking the sample for 24hrs)						
	descriptions	mass (kg)	Bulk sp. Gr(OD)	Bulk sp. Gr (SSD)	Apparent Sp. Gr	Absorption, %
1	mass of SSD sample (S)	0.5	2.333	2.381	2.450	2.041
2	mass of sample + physcnometer + water (C)	1.59				
3	mass of physcnometer + water (B)	1.3				
4	mass of OD sample (A)	0.49				
Note	Sp. Gr(OD) = A/(B + S -C)		Total moisture content of sand after washing		1.670%	
	Sp. Gr (SSD) = S/(B +S-C)					
	Apparent Sp. Gr = A/(A+B-C)					
	Absorption = (S-A)*100/A					

Table C 3: Silt content test

Silt content of sand before washing				
Sample	height of silt in the sampler tube (ml)	height of silt + sand in the sampler tube (ml)	percentage of silt	average % silt content
1	5	105	4.76%	4.76%
2	5	105	4.76%	
Silt content of sand after washing				
Sample	height of silt in the sampler tube (ml)	height of silt + sand in the sampler tube (ml)	percentage of silt	average % silt content
1	5	140	3.57%	3.57%
2	5	140	3.57%	

Table C 4: Sieve analysis test on sand

Fine aggregate									
sample size= 0.5kg									
No	Sieve (mm)	1st sample retained mass(kg)	2nd sample retained mass(kg)	Average retained mass (kg)	cumulative mass retained	cumulative mass percentage retained	cumulative percentage finer by mass	Specification Limits	
								Lower	Upper
1	4.75	0.020	0.020	0.020	0.020	4.00	96.00	95	100
2	2.36	0.030	0.030	0.030	0.050	10.00	90.00	80	100
3	1.18	0.070	0.070	0.070	0.120	24.00	76.00	50	85
4	0.6	0.160	0.170	0.165	0.285	57.00	43.00	25	60
5	0.3	0.150	0.150	0.150	0.435	87.00	13.00	5	30
6	0.15	0.060	0.060	0.060	0.495	99.00	1.00	0	10
pan	0	0.010	0.000	0.005	0.500	100.00	0.00	0	0
sum		0.500	0.500	0.500	FM	2.81	note: comparision with the specification limit		

Appendix C 2: Test on coarse aggregate



Figure C 2: Washed aggregate and specific gravity test on coarse aggregate

Table C 5: Unit weight test on 25mm size coarse aggregate

Coarse aggregate - loose unit weight				
Dry loose unit weight (the sample was oven dry for 24 hrs. at 110 ± 5 degree celcius)				
	description	mass (kg)	Unit wt. (kg/m3)	% of voids
1	mass of empty measure	14.31	1310.019	48.604
2	Mass of measure + loos mass	21.24		
3	volume of measure (m3)	0.00529		
Coarse aggregate - dry rodded unit weight				
Dry rodded unit weight (the sample was oven dry for 24 hrs. at 110±5 degree celcius)				
	description	mass (kg)	Unit wt.	% of voids
1	mass of empty measure	14.31	1434.783	43.710
2	Mass of measure + rodded mass.	21.9		
3	volume of measure (m3)	0.00529		
<p align="center"> % void $(S*W-M)/S*W$ where, S=bulk sp. Gr (OD) W = unit wt. of water = 998kg/m3 M = bulk density </p>		Average values		
		unit wt. (kg/m3)		% of void
		1372.40		46.16

Table C 6: Unite weight test on 19mm size aggregate

Coarse aggregate - loose unit weight				
Dry loose unit weight (the sample was oven dry for 24 hrs. at 110 ± 5 degree celcius)				
	description	mass (kg)	Unit wt. (kg/m ³)	% of voids
1	mass of empty measure	14.31	1285.444	48.604
2	Mass of measure + loos mass	21.11		
3	volume of measure (m3)	0.00529		
Coarse aggregate - dry rodded unit weight				
Dry rodded unit weight (the sample was oven dry for 24 hrs. at 110 ± 5 degree celcius)				
	description	mass (kg)	unit wt.	% of voids
1	mass of empty measure	14.31	1434.783	43.710
2	mass of measure + rodded mass	21.9		
3	volume of measure (m3)	0.00529		
% void $(S*W-M)/S*W$ where, S=bulk sp. Gr (OD) W = unit wt. of water = 998kg/m ³ M = bulk density		Average values		
		unit wt. (kg/m ³)		% of void
		1360.11		46.16

Table C 7: Specific gravity and water absorption test on 25mm & 19mm size coarse aggregates and found the same

Coarse aggregate						
ASTM C-127, sample size taken 5kg, SSD (after soaking the sample for 24 hrs.)						
	Descriptions	mass (kg)	Bulk sp. Gr(OD)	Bulk sp. Gr (SSD)	Apparent Sp. Gr	Absorption , %
1	weight of SSD sample (B)	5	2.554	2.591	2.651	1.420
2	weight of sample in water (C)	3.07				
3	weigh of OD sample (A)	4.93				
Note	Sp. Gr (OD) = A/(B-C)	Total moisture content of aggregate after washing		0.50%		
	Sp. Gr (SSD) = B/(B-C)					
	Apparent Sp. Gr = A/(A-C)					
	Absorption = (B-A)*100/A					

Table C 8: Sieve analysis for 25mm size coarse aggregate

Coarse aggregate									
sample size= 5kg									
No	Sieve (mm)	1st sample retained mass(g)	2nd sample retained mass(g)	Average retained mass (kg)	cummulative mass retained	cummulative mass percentage retained	cummulative percentage finer by mass	Specification Limits	
								Lower	Upper
1	37.5	0.0000	0.0000	0.0000	0.0000	0.00	100.00	100	100
2	25	0.1250	0.1550	0.1400	0.1400	2.80	97.20	95	100
3	12.5	3.1550	3.2100	3.1825	3.3225	66.45	33.55	25	60
4	4.75	1.7200	1.6300	1.6750	4.9975	99.95	0.05	0	10
5	2.36	0.0000	0.0050	0.0025	5.0000	100.00	0.00	0	5

Note: the nominal aggregate size was 25mm, based on ASTM C136 for nominal maximum aggregate size of 25mm the sample for the analysis shall be 10kg. But the sieving was not good for such mass, so the mass reduced to 5kg.

Table C 9 : Sieve analysis for 19mm size coarse aggregate

Coarse aggregate (nominal max. size = 19mm)									
sample size= 5kg									
No	Sieve (mm)	1st sample retained mass(kg)	2nd sample retained mass(kg)	Average retained mass (kg)	cummulative mass retained	cummulative mass percentage retained	cummulative percentage finer by mass	specification limits	
								lower	upper
1	25	0.0000	0.0000	0.0000	0.0000	0.00	100.00	100	100
2	19	0.3850	0.4500	0.4175	0.4175	8.33	91.67	90	100
3	9.5	2.9500	3.0200	2.9850	3.4025	67.91	32.09	20	55
4	4.75	1.6450	1.5250	1.5850	4.9875	99.55	0.45	0	10
5	2.36	0.0200	0.0050	0.0125	5.0000	99.80	0.20	0	5

Appendix C 3: Summary of test results

After doing all the tests, the properties are finalized in the table below.

Table C 10: Summary of properties of aggregates

Test result of aggregates		
Coarse Aggregate 1		
No	Test description	Values
1	Nominal maximum size (mm)	25
2	Specific gravity (OD)	2.554
3	Bulk unit weight (kg/m ³)	1372.4
4	Absorption, %	1.42
5	Moisture content, %	0.5
Coarse Aggregate 2		
1	Nominal maximum size (mm)	19
2	Specific gravity (OD)	2.554
3	Bulk unit weight (kg/m ³)	1360.11
4	Absorption, %	1.42
5	Moisture content, %	0.5
Fine Aggregate		
1	Fineness modules, FM	2.81
2	Silt Content, %	3.57
3	Specific Gravity (OD)	2.33
4	Bulk unit weight (kg/m ³)	1264.33
5	Absorption, %	2.041
6	Moisture content, %	1.67
7	Voids content, %	43.11

Appendix C 4: Mix design

Mix proportion for normal strength concrete, C20/25

C20/25 is a Euro code designation, 20Mpa is the characteristic cylindrical strength and 25Mpa is the characteristic cubic strength.

The mix design is based on ACI 211.1-81 section (John M. Scanion, 1985).

Target mean strength

When data are not available to establish a standard deviation, according to ACI report 318 for specified cylindrical compressive strength less than 20.5Mpa, the target mean strength will be increased by 6.9Mpa. Therefore, the target mean strength in our case will be 26.9Mpa.

Selection of slump

The slump value is 75-100mm

Choice of maximum nominal aggregate size

From the sieve analysis, the nominal max aggregate size is 25mm. But to get more precise data 28mm sieve was inserted b/n 37.5mm and 25mm and there was retained mass there. So that the nominal maximum size become 28mm.

Estimation of mixing water

Assuming the concrete will not be exposed to freezing and thaw condition or air entraining admixture is no longer used in the concrete, so the concrete is non air entrained.

The quantity of mixing water per unit volume of concrete can be determined from ACI 211.1-81 table A1.5.3.3 using the following information:

- For slump value between 75-100mm
- For nominal aggregate size of 28mm and
- For non-air entrained concrete.

From the table the relation is like:

$$25mm = 193kg$$

$$28mm = x$$

$$37.5mm = 181kg$$

Using linear interpolation the quantity of water become **190.132 kg**.

Selection of water cement ratio.

From ACI 211.1-81 table A1.5.3.4 (a), using the cylindrical compressive strength of 26.9Mpa and non-air entraining concrete, the water cement ratio by weight is **0.58**.

Estimation of cement content per meter cubic of concrete.

From the data obtained from step 3 & 4, the quantity of cement can be calculated easily:

$$w/c = 0.58 \rightarrow wt.ofcement = \frac{wt.ofwater}{w/c} = \frac{190.132}{0.58} = 327.81kg$$

The weight of cement become **327.81 kg**.

Estimation of volume of dry-rodded coarse aggregate per unit volume of concrete.

From ACI 211.1-81, Table A1.5.3.6 the volume can be determined using the following data:

- Fineness modulus of sand, FM = 2.81=2.8
- Nominal maximum aggregate size = 28mm

Using linear interpolation,

$$25mm = 0.67$$

$$28mm = x$$

$$37.5mm = 0.71$$

For 28mm max aggregate size, the volume of coarse aggregate is $0.6796m^3$. We have dry rodded bulk density of coarse aggregate, which is **1372.40 kg/m³**, so the weight can be easily calculated as:

$$wt.ofC.A = 1372.40kg / m^3 * 0.6796 = 932.68kg$$

Weight of coarse aggregate become **932.68 kg**.

Estimation of weight of fine aggregate.

Volumetric method

Calculating solid volume of ingredients.

(From table A1.5.3, for 28mm aggregate size, introduce 1.38% (by interpolation) entrapped air in volumetric calculation.)

$$cement = \frac{327.81}{3.15 * 1000} = 0.10406m^3$$

$$water = \frac{190.13}{1000} = 0.19013m^3$$

$$air(entrapped) = 0.01380m^3$$

$$coarseaggregate = \frac{932.68}{2.554 * 1000} = 0.36518m^3$$

Volume of sand

$$fineaggregate = 1m^3 - (0.10406 + 0.19013 + 0.01380 + 0.36518)m^3 = 0.32683m^3$$

Adjustment to weight of aggregates due to its moisture content.

Coarse aggregate

Total moisture content = 0.5%

Weight of coarse aggregate (dry) = 932.68kg

So that to use the coarse aggregate in its natural state the weight is adjusted like:

$$wetweight = 932.68 * (100 + 0.5) / 100 = 937.34kg$$

Weight of coarse aggregate = **937.34 kg**

Fine aggregate

Total moisture content = 1.67%

Weight of sand (dry) = 761.51 kg (taken from volumetric basis estimation)

So that to use the fine aggregate as it is, the weight should be adjusted like:

$$Wet weight = 761.51 * (1.0167) = **774.22kg**$$

Adjustment to quantity of water due to free moisture in aggregates.

Weight of water = 190.13kg, calculated previously.

Adjustment the weight of water due to the moisture in coarse aggregate.

Water absorption (required to maintain SSD state) = 1.42%

Total moisture content = 0.5%

Weight of coarse aggregate (dry) = 932.68kg

$$\text{Free moisture} = \text{Total moisture} - \text{Absorbed}$$

Since the moisture content is less than even the absorption, it need additional quantity

$$\text{of water} = \frac{(1.42 - 0.5) * 932.68}{100} = 8.58\text{kg}(\text{additional})$$

Adjustment the weight of water due to the moisture in fine aggregate

Water absorption = 2.04%

Total moisture content = 1.67%

Weight of fine aggregate (dry) = 761.51kg

$$\text{Free moisture} = \text{Total moisture} - \text{Absorbed}$$

Since the moisture content is greater than the absorption, the free quantity of water is

$$\frac{(1.67 - 2.04) * 761.51}{100} = 2.81\text{kg}(\text{additonal}) \text{ should be deducted from the previous}$$

estimated quantity of water.

Adjusted quantity of water

$$\text{Net water quantity} = 190.13 + 8.58 + 2.81 = 201.52\text{kg}$$

Summary

Summary of weights:

Dry weight

Wt. of cement = 327.81 kg

Wt. of water = 190.13 kg

Wt. of C.A = 932.68 kg

Wt. of F.A = 761.51 kg

Batch weight

Wt. of cement = 327.81 kg

Wt. of water = 201.52 kg

Wt. of C.A = 937.34 kg

Wt. of F.A = 774.22 kg

per 1 m³ of concrete.

Mix design for high strength concrete C55/67

C55/67 is a Euro code designation, 55Mpa is the characteristic cylindrical strength and 67Mpa is the characteristic cubic strength.

(The mix proportion is done based on ACI 211.4R-93. (Mass et al., 1998))

Selection of slump.

From Table 4.3.1, the recommended slump for concrete with HRWR (superplasticizer) before adding the HRWR is between 1 and 2in. (25mm to 50mm).

Selecting nominal maximum coarse aggregate size.

ACI 211.4R-93 table 4.3.2, suggests the maximum aggregate size for different ranges of required cylindrical compressive strength. It suggests 19mm -25mm aggregate size for concrete strength below 9000psi (62Mpa) and 9.5mm-12.5mm for concrete strength above 9000Psi (62Mpa). Generally smaller sized aggregate have provides higher strength potential. So that in this case, 19mm aggregate size is preferred to use to attain 55Mpa cylindrical strength.

Selecting optimum coarse aggregate content.

From table 4.3.3, for 19mm max aggregate size and FM between 2.5 & 3.2 the recommended fraction of coarse aggregate per unit volume of concrete is 0.72. Hence, the weight of coarse aggregate will be:

$$\text{weight of coarse aggregate} = 1360.11\text{kg} / \text{m}^3 * 0.72\text{m}^3 = 979.279\text{kg}$$

Hence, the weight of dry coarse aggregate is **979.27 kg**.

Estimating mixing water and air content.

Based on a slump of 25-50mm and 19mm maximum size coarse aggregate, the required mixing water chosen from table 4.3.4 is 285lb/yd³ (**169kg/m³**) and the entrapped air content for mixtures made using HRWR is 1.5%. This is based on the assumption there is 35% voids in sand.

$$\text{mixing water adjustment} = (V - 35) * 8lb / yd^3$$

$$\text{mixing water adjustment} = (43.11 - 35) * 8 = 64.88lb / yd^3 = 38.49kg / m^3$$

The total quantity of mixing water become 169+38.49 = **207.49 kg** per unit cubic meter of concrete.

Selecting the W/(c+p) ratio.

When production is on the basis of laboratory trial batches, the required average strength for may be determine from the equation:

The cylindrical compressive strength we going to design is 55Mpa (= 55*1000/6.89=7982.58Psi)

$$f_{cr} = \frac{(f_c + 1400)}{0.9} \text{ (psi)}$$

$$f_{cr} = \frac{(7982.58 + 1400)}{0.9} = 10,425.08 \text{ psi}$$

From table 4.3.5(b), the recommended maximum water cement ratio for concrete made with HRWR, 19mm nominal max aggregate size and the required field strength of 10425.08psi at 28 day is **0.283** (by interpolation).

Estimating content of cementitious material.

The weight of cementitious material per unit cubic meter of concrete can be determined by dividing the amount of mixing water to w/c ratio.

$$\text{weight of cement} = \frac{207.49}{0.283} = 733.18\text{kg}$$

Weight of cement is **733.18 kg**.

Estimating weight of sand.

Using absolute volume method,

Absolute volume of

$$\text{cement} = \frac{733.18}{3.15 * 1000} = 0.2327\text{m}^3$$

$$\text{water} = \frac{207.49}{1000} = 0.2075\text{m}^3$$

$$\text{C.A} = \frac{979.27}{2.554 * 1000} = 0.3834\text{m}^3$$

$$\text{air} = \frac{1.5}{100} * 1 = 0.0150\text{m}^3$$

$$\text{volume of sand} = 1 - (0.2327 + 0.2075 + 0.3834 + 0.0150) = 0.8386\text{m}^3$$

$$\text{weight of sand} = 0.1614 * 1000 * 2.33 = 376.06\text{kg}$$

Weight of dry sand is **376.06 kg**.

Adjustment to aggregate's weights due to its moisture content (batch weight).

Coarse aggregate

Total moisture content = 0.5%

Weight of coarse aggregate (dry) = 979.27kg

So that to use the coarse aggregate in its natural state the weight is adjusted like:

$$\text{wetweight} = 979.27 * (100 + 0.5) / 100 = 984.17\text{kg}$$

The wet weight of coarse aggregate **is 984.17 kg**

Fine aggregate

Total moisture content = 1.67%

Weight of sand (dry) = 376.06 kg

So that to use the fine aggregate as it is, the weight should be adjusted like:

$$\text{Wet weight} = 376.06 * (1.0167) = \mathbf{382.34 \text{ kg}}$$

Adjustment to quantity of water due to moisture in aggregates.

Weight of water = 207.49kg

Adjustment due to the moisture in coarse aggregate.

Water absorption (required to maintain SSD state) = 1.42%

Total moisture content = 0.5%

Weight of coarse aggregate (dry) = 979.27kg

$$\text{Free moisture} = \text{Total moisture} - \text{Absorbed}$$

Since the moisture content is less than even from the required for the absorption, it

need additional water of quantity $\frac{(1.42 - 0.5) * 979.27}{100} = 9\text{kg}(\text{additional})$.

Adjustment due to the moisture in fine aggregate

Water absorption = 2.04%

Total moisture content = 1.67%

Weight of fine aggregate (dry) = 376.06 kg

Free moisture = Total moisture – Absorbed

The additional quantity of water required in sand is:-

$$\frac{(1.67 - 2.04) * 376.06}{100} = 1.391\text{kg}$$

Adjusted quantity of water

Net water quantity = 207.49 + 9 + 1.391 = 217.88kg

Summary of weights

Thus the batch weight of ingredients are corrected to account for moisture contribution by aggregate and the free moisture content. So the weight of the ingredients to produce 1m³ of concrete are:

Dry weights
cement = 733.18kg
water = 207.49kg
C.A = 979.27kg
F.A = 376.06kg

Batch weights
cement = 733.18kg
water = 217.88kg
C.A = 984.17kg
F.A = 382.34kg