JIMMA UNIVERSITY

SCHOOL OF GRAUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTION ENGINEERING AND MANAGEMENT

INVESTIGATION OF CEMENT REPLACEMENT WITH HIGH CONTENT OF PUMICE ON MECHANICAL PROPERTY OF CONCRETE: A CASE OF C-25 GRADE OF CONCRETE

A Thesis Submitted to the School of Graduate Studies of Jimma University of Jimma Institute of Technology, in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Civil Engineering (Construction Engineering and Management).

By:

Dawit Beyene

February, 2017

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Main Advisor: Eng'r Elmer C.Agon (Ass. Prof.)

Co - Advisor: Eng'r Abebe Eshetu (MSc.)

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DECLARATION

I, the undersigned, declare that this thesis entitled “**Investigation of cement replacement with high content of pumice on mechanical property of concrete: a case of c-25 grade of concrete**” is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for theses have been duly acknowledged.

Candidate:

DAWIT BEYENE

Signature______________________________

As Master research Advisors, we hereby certify that we have read and evaluated this MSc. research prepared under our guidance, by DAWIT BEYENE entitled: “**Investigation of cement replacement with high content of pumice on mechanical property of concrete: a case of c-25 grade of concrete**” We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

	Signature	Date
1. Engr. Elmer C.Agon Advisor	______________	_______________
2. Eng’r. Abebe Eshetu (MSc.) Co- Advisor	______________	_______________

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CEMENT REPLACEMENT WITH HIGH CONTENT OF PUMICE ON MECHANICAL PROPERTY OF CONCRETE

ABSTRACT

Pumice is a textural term for a volcanic rock that is solidified frothy lava typically created when superheated, highly pressurized rock is violently ejected from a volcano. It can be formed when lava and water are mixed. In view of environmental and sustainability concerns associated with the production of cement, the use of pozzolanas to replace part of Portland cement is receiving a lot of attention. The partial replacement of ordinary Portland cement by pozzolanas are known to improve the mechanical strength, resistance to sulphates and reduces pore sizes of concrete.

The objective of this research is to investigate cement replacement with high content of pumice on mechanical property of concrete. For this study pumice natural pozzolona sample is collected and their chemical and physical properties were studied and the experiments were performed on C-25 grade of concrete mix with 0.51 water cement ratio with slump of 25-100mm. Concrete Cubes were casted from each batch of the mix by varying percentage of pumice as replacement of cement 0%, 30%, 40%, and 50% whereas all other parameters keeping as constant. A total of 24 cubs and 24 beams samples were prepared for testing at age of 7th and 28 days for four percentage of pumice.

The result of this research was show that, at 0%, 30, 40%, and 50% replacement of cement with pumice have a compressive strength of 21.41Mpa, 18.44Mpa, 12.69Mpa, and 9.76Mpa respectively at the age of 7 day of curing and 33.8Mpa, 31.73Mpa, 29.35Mpa and 26.4Mpa respectively at the age of 28 day of curing. On the other hand, 0%, 30, 40%, and 50% replacement of cement with pumice have a flexural strength 3.84Mpa, 3.59Mpa, 3.28Mpa and 2.95Mpa respectively at the age of 7 day of curing and 3.97Mpa, 3.68Mpa, 3.61Mpa and 2.94Mpa at the age of 28 day of curing. In addition to this, the concrete mix having a slump value 65mm, 65mm, 60mm, and 60mm for 0%, 30%, 40%, and 50% replacement of cement with pumice respectively. The compressive and flexural strength of concrete shows reduction due to increment of percentage of pumice but all percentage of the replacement of cement with pumice satisfy the specified compressive strength of concrete (fc). Hence it is recommended to replace until 50% replacement of cement with pumice.

Keywords: pumice, compressive strength, flexural strength and workability of concrete.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

ACRONOMY

ACI- American Concrete Institute

ASTM- American Society for Testing and Materials

BS- British Standard

ES - Ethiopian Standard.

FM - Fineness Modulus

SSD - Saturated and surface dry

Kg - kilogram

Cu - Coefficient of Uniformity

Cc - Coefficient of Curvature.

Kg/m3- kilogram per cubic meter

KN - kilo Newton

m3 - Meter cubic

Max -Maximum

Min - Minimum

MPa - Mega Pascal

W/c - Water to cement ratio

GHG-Greenhouse gas

OPC-ordinary Portland cement

PPC- Portland pozzolnic cement

CO2-carbon di oxide

C-S-H- calcium silicate hydrates

CHAPTER ONE

INTRODUCTION

1.1 Background

Concrete is the world's most utilized construction material [1]. The need for infrastructural development in both the developing and developed countries has placed a great demand on ordinary portland cement (OPC), traditionally, the main binder in the manufacture of concrete. Despite the advantages of concrete as a construction material, the production of cement comes at a great cost to the environment [1]

In view of environmental and sustainability concerns associated with the production of cement, the use of pozzolanas to replace part of Portland cement is receiving a lot of attention. Replacing portland clinker either partially or entirely is also being investigated as an alternative to carbon dioxide emissions [1].

From 1880 – 1996, the world's annual consumption of Portland cement rose from 2 million tons to 1.3 billion ton. This was associated with major environmental cost include: a) cement manufacturing is the third largest CO2 producer and for over 50% of all industrial CO2 emissions (for every 1 ton of cement produced, 1.25 tons of CO2 is released in the air); b) 1.6 tons natural recourse is consumed to produce 1 ton of cement. This calls for the use of other alternative sustainable binders. One of the most promising materials is Pozzolanic materials [13].

Up to 70% of Portland cement can be replaced by using materials such as primarily fly ash, slag, silica fume, natural pozzolanas, rice-husk ash, wood ash, and agricultural products ash [1]. Artificial pozzolanas used in modern commercial cement are derived from fly ash produced by coal burning plants; incineration of municipal solid waste etc… [2].

Pozzolanic materials do not possess any cementing properties of their own, but they contain silica and alumina in reactive form. Ancient Romans produced exceptional cement by mixing pozzolanic materials with lime to build structures some of which are standing today [2].

Pozzolanic materials chemically react with calcium hydroxide in the presence of water to form compounds possessing cementitious properties [2].

The pozzolanic reactions are silica reactions in the presence of calcium hydroxide and water to produce calcium silicate hydrates(C-S-H) [4, 5]. C-S-H creates a denser microstructure that increases strength, reduces the permeability of concrete and improves its resistance to chemical attack.

The partial replacement of ordinary portland cement by pozzolanas are known to improve the resistance of concrete to sulphates [6]. As additives in modern cements pozzolanas improve mechanical strength and provide resistance to physical and chemical weathering [2]. The addition of pozzolanas reduces pore sizes and porosity leading to increased strength [6].

The raw materials of the natural Pozzolanic materials are available and distributed over a wide area of the Ethiopian rift valley. There are many locations for natural pozzolanas in Ethiopia.

The East African rift valley originated during Late Tertiary with expansive out pouring of lava and pyroclastic flow forming pumicite and pumicious ash in the Main Ethiopian Rift Valley (MERV).

Although, there are a lot of occurrences of pumice in the MERV, the best known deposits are Gari Baldi Pass, Koka, Dere, Bishoftu, Modjo, Alemtena and Meki . Fentale, Lake Verdi and Kinbibit are not studied well [7]. Occurrences are also found in Adami-Tulu and Langano.

Pumice is a textural term for a volcanic rock that is solidified frothy lava typically created when superheated, highly pressurized rock is violently ejected from a volcano. It can be formed when lava and water are mixed. This unusual formation is due to the simultaneous actions of rapid cooling and rapid depressurization [8]. The depressurization creates bubbles by lowering the solubility of gases (including water and CO_2) dissolved in the lava, causing the gases to rapidly exsolve (like the bubbles of CO_2 that appear when a carbonated drink is opened). The simultaneous cooling and depressurization freezes the bubbles in the matrix and creates vesicles.

Pumice is actually a kind of glass and not a mixture of minerals. Pumice is a light colored highly vesicular glass generally composed of 60-70% SiO_2, 12- 14% Al_2O_3, 1-2% Fe_2O_3 and alkali oxides [10]. Pumice has generally a specific gravity of <1%. There for this research focus study mechanical properties of high content pumice (N class-fly ash) concrete. Laboratory experimentation were carry out to investigate the mechanical property of high content pumice concrete. Then, based on the experimental results conclusion and recommendations have been forwarded.

1.2 Research questions

1. What are the chemical composition and physical property of pumice?
2. Does have effect on workability of the concrete due to replacement of cement with high content of pumice?
3. What will happen the compressive and flexural strength of concrete with replacement of cement with high content of pumice?

1.3 Objective of the study

1.3.1 General objective of the study

- The objective of this study was to investigate cement replacement with high content of pumice on mechanical property of concrete.

1.3.2Specific Objective of the Study

- To identify the physical properties and chemical composition of pumice.
- To identify the workability of concrete with partial replacement of cement with high content of pumice.
- To identify compressive and flexural strength of concrete with replacement of cement with high content of pumice through laboratory test.

1.4 Statement of the problem

The importance of Cement as a binding material is increased with the onset of the development and the physical renaissance. Now concrete is an important material for building construction, the present annual world production of concrete is above billion cubic meters. Due to this highly demand of OPC (for concrete and other purpose of construction) it became expensive and scarce commodity and greenhouse gas emission and this has severely limited the construction of affordable housing in much of the third world.

This large demand needs another alternative material from two points of view, economically and availability [1]. In Ethiopia cement industry will be one of the fastest growing, also causing the vast majority of GHG emissions. Since cement production and consumption are directly related to almost all economic activities, they closely follow economic trends. Ethiopian cement production will increase 10 fold from 2.7 Mt in 2010 to 27 Mt in 2015 and more than 65 Mt in 2030 [53]. As the result, overall industrial emissions are projected to grow by 16% per year from 4Mt CO2 equivalents today to 71 Mt in 2030. The fact that the product is essential to the society; however, the manufacturing process has huge environmental impacts that must be addressed. The GHG emissions in the case of Ethiopian industries, specifically cement industry are the major GHG emitters and special attention is required on this specific sector. One of the strategies towards GHG mitigation in cement industry is involved in the use of alternative raw materials or commonly known as clinker substitution. Checking the mechanical property of as concrete partial replacement of Portland cement with pumice is the main concern of this study. This give an opportunity minimize Portland cement production as Production of Portland cement have an effect on the environment.

1.5 Scope and Limitation of the Study

The scope of the study focuses on meki quarry site source of pumice which are mainly uses in the production of Portland pozzolena cement in Ethiopia. Moreover, the focus of research has been limited to the mechanical properties of high content pumice concrete for C-25 grade of concrete.

1.6 Significance of the study

With regard to high importance of sustainable development based on using green construction materials, many attempts have been made to adopt different strategies to implement sustainability in concrete industry. According to the World Commission on Environment and Development of the United Nations, sustainability is "meeting the needs of the present without compromising the ability of the future generations to meet their own needs". To encourage concrete industry to implement sustainability aspects in its products and services, different organizations have published guidelines and specifications. Natural pozzolenic materials are used as a mineral addition in concrete to improve its strength and durability characteristics. Pumice is one of the natural pozzolonic material can be used either as a partial replacement of cement or as a partial replacement of aggregates and as supplementary addition to achieve different properties of concrete. The research conduct on the study of mechanical properties of concrete with replacement of cement with high content pumice. So by knowing the mechanical properties of concrete with pumice is important on the use of concrete with pumice in construction industry and minimizing the cost of the project as pumice is cost advantage comparing with cement and also reduce carbon di oxide emission to the environment for production of OPC.

CHAPTER TWO

LITERATURE REVIEW

2.1 Definition of Pozzolana

Pozzolana is defined as a siliceous or alumino-siliceous material that, in finely divided form and in the presence of moisture, chemically reacts at ordinary room temperature with calcium hydroxide, released by the hydration of Portland cement, to form compounds possessing cementitious properties [9]. Pozzolanic materials can be used either as an addition to the cement in the manufacturing process or as a replacement for a portion of the cement in the mortar and concrete production.

Pozzolanas can be classified as natural and artificial. The basic classification into natural and artificial has no real or engineering purpose. With respect of economy and performance, it does not matter whether the source is natural‖ or not [10]. Natural pozzolanas are of two types: the true natural pozzolanas and the pseudo natural pozzolanas.

The true natural pozzolanas are ashes and lavas originating from alkalitrachytic, leucitic, leucotephritic and hauynophric types of magma. These ashes result from explosive eruptive volcanoes and are forced to solidify as a pyroclastic glass (glass fragments formed by rapid quenching of magma produced by volcanic explosions [11]. In the pseudo natural pozzolanas, the pyroclastic glassy minerals in the original lava have undergone hydrothermal alteration (auto-metamorphism) leading to zeolitization and sometimes argillization [11].

Artificial pozzolanas are those materials in which the pozzolanic property is not well developed and hence usually have to undergo pyro-processing before they become pozzolanic [12]. Artificial pozzolanas include materials such as flyash, blast furnace slag, surkhi (burnt clay), siliceous and opaline shales, spent oil shale (used in Sweden to make gas concrete‖), rice husk ash, burnt sugar cane stalks and bauxite waste [12].

The general term pozzolana is used to designate natural as well as industrial co-products that contain a percentage of vitreous silica. This vitreous (amorphous) silica reacts at ambient temperature with the lime produced by the clinker minerals to form hydrated calcium silicates (C-S-H) [13].

2.2 Portland cement

Cement is defined as a powdered material that chemically reacts with water and therefore attains the property of setting and hardening [39]. This property makes the cement hydraulic. Portland cement is made by heating raw materials with an appropriate chemistry, usually mixture of limestone and clay, to a temperature between 1400oC and 1600oC, where the two materials interact chemically to form the calcium silicates. Partial fusion occurs, and nodules of clinker are produced. The clinker is mixed with a few percent of calcium sulphate and finely ground, to make the cement.

Limestone + Clay ⟶ Clinker + 2%gypsum ⟶ Portland cement

Some modern cement specifications, EN 197-1, also permit adding up to 5% limestone in the course of clinker grinding. The calcium sulphate, which is commonly described as gypsum, controls the rate of set and influences the rate of strength development. The clinker chemically has a composition of CaO, SiO2, Al2O3, and Fe2O3, all constituting about 80% of Portland cement. The other significant minor oxides are MgO, SO3, K2O and Na2O [39]. Cement clinker particles are multiphase solids. Each phase has a specific reaction with water to produce a range of hydration products. Alite (C3S) is the most important constituent of all normal Portland cement clinkers and it constituents 50-70% of the total composition of the clinker. It is tricalcium silicate (Ca3SiO5) modified in composition and crystal structure by ionic substitutions. It reacts relatively quickly with water, and is the most important of the constituent phases for strength development up to 28 days. Belite (C2S) constitutes 15-30% of normal Portland cement clinkers. It is dicalcium silicate (Ca2SiO4) and normally presents wholly or largely as β polymorph. It reacts slowly with water, thus contributing later-age strength beyond 28 days [39].

Aluminate constitutes 5-10% of most normal Portland cement clinkers. It is tricalcium aluminate (3CaO.Al2O3), substantially modified in composition and sometimes also in structure by ionic substitutions. It reacts rapidly with water, and can cause undesirably Ferrite makes up 5-15% of normal Portland cement clinkers. It is tetracalcium aluminoferrite (Ca2AlFeO5), substantially modified in composition by variation in Al/Fe ratio and ionic substitutions. The rate at which it reacts with water appears to be somewhat variable, perhaps due to differences in composition or other characteristics, but in general is high initially and low or very low at 28 days.

Table 2.1 shows the compositions of phases in Portland cement clinker.

Table 2- 1. Compositions of phases in Portland cement clinker.

(Source: Taylor, 1997)

Phase	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	Mn_2O_3	Fe_2O_3
Alite	0.1	1.1	1	25.2	0.1	0.1	0.1	71.6	0	0	0.7
Belite	0.1	0.5	2.1	31.5	0.1	0.2	0.9	63.5	0.2	0	0.9
Aluminate (Cubic)	1	1.4	31.3	3.7	0	0	0.7	56.6	0.2	0	5.1
Ferrite	0.1	3	21.9	3.6	0	0	0.2	47.5	1.6	0.7	21.4
Aluminate (Orthorhombic)	0.6	1.2	28.9	4.3	0	0	4	53.9	0.5	0	6.6
Aluminate (Low Fe)	0.4	1	33.8	4.6	0	0	0.5	58.1	0.6	0	1
Ferrite (Low Al)	0.4	3.7	16.2	5	0	0.3	0.2	47.8	0.6	1	25.4

2.2.1 Hydration of Portland cement

The chemical reaction between cement minerals and water is mainly by hydration. The active cement components are tricalcium aluminate (3CaO·Al2O3 or C3A); tetracalcium-aluminoferrite (4CaO·Al2O3·Fe2O3 or C4AF); tricalcium silicate (3CaO·SiO2 or C3S) and dicalcium silicate (2CaO·SiO2 or C2S). The factors responsible for the mechanical properties of concrete are the extent of hydration of cement and the resultant microstructure of the hydrated cement. In contact with water, the C3A and C4AF react almost instantaneously leading to the setting of the cement. Both the C3A and the C4AF react with calcium sulphate to produce ettringite (3CaO·Al2O3·3CaSO4·32H2O). The overall non-stoichiometric reaction and their product can be represented as:

3CaO.Al2O3+ 3CaSO4.2H2O + 26H2O = 3CaO.Al2O3.3CaSO4.32H2O

C3A gypsum ettringite (AFt)

This hydrates further to form a solid solution of the low-sulphate sulphoaluminate $3CaO \cdot Al_2O_3 \cdot CaSO_4 \cdot 12H_2O$ usually existing in a solid solution with C_4AH_{13}.

$$2(3CaO.Al_2O_3) + 3CaO.Al_2O_3.3CaSO_4.32H_2O + 4H_2O = (3CaO.Al_2O_3.CaSO_4.12H_2O)$$

ettringite (AFt) (AFm)

Concurrently, C_3S and C_2S react with water, albeit more slowly producing afwillite ($3CaO \cdot 2SiO_2 \cdot 3H_2O$) and lime, $Ca(OH)_2$. This process continues up to more than one year and leads to hardening of the cement paste though there are bound to be unhydrated cement cores according to [39]. The overall non-stoichiometric reactions that lead to hardening of the cement products can be represented as:

$$2(3CaO.SiO_2) + 7H_2O = 3CaO.2SiO_2.4H_2O + 3Ca(OH)_2$$

$$2(2CaO.SiO_2) + 5H_2O = 3CaO.2SiO_2.4H_2O + Ca(OH)_2$$

The afwillite and the lime produced by these reactions remain in solution and in the presence of water, further hydrolyze to produce more lime in solution. The lime thus produced is a source of weakness in cement products, especially concrete for several reasons. The free lime has a low strength and poor stability leading to lower strength and less durability of cement paste and concrete [39]. The free lime, on account of its low stability, is also easily attacked by sulphate solutions. Additionally, by a preferential growth in one direction in the presence of water, the free lime crystals may cause unsoundness in cement products especially in mass concrete leading to disruptions and failure of structures, several years after setting [39].

2.3 Pozzolanic Classification According to the Codes

ASTM – C 618-93 categorizes natural pozzolans and fly ashes into the following three categories:

1. Class N Fly ash: Raw or calcined natural pozzolans such as some diatomaceous earths, opaline chert and shale, stuffs, volcanic ashes and pumice come in this category. Calcined kaolin clay and laterite shale also fall in this category of pozzolans.

2. Class F Fly ash: Fly ash normally produced from burning anthracite or bituminous coal falls in this category. This class of fly ash exhibits pozzolanic property but rarely if any, self-hardening property.

3. Class C Fly ash: Fly ash normally produced from lignite or sub- bituminous coal is the only material included in this category. This class of fly ash has both pozzolanic and varying degree of self cementitious properties. (Most class C fly ashes contain more than 15 % CaO. But some class C fly ashes may contain as little as 10 % CaO).

2.4 chemical and physical requirements of pozzolona

Table 2- 1 Requirements for fly ash and natural pozzolans for use as a mineral admixture in Portland cement concrete as per ASTM C 618-93.

Requirements	Classification of pozzolona		
	N	F	C
1 Chemical Requirements			
$SiO_2 + Al_2O_3 + Fe_2O_3$, min %	70.0	70.0	50.0
SO_3, max %	4.0	5.0	5.0
Moisture content, max %	3.0	3.0	3.0
Loss on ignition, max %	10.0	6.0	6.0
2 Physical Requirements			
Amount retained when wet sieved on 45 m. Sieve, max %	34	34	34
Pozzolanic activity index, with Portland cementat 28 days, min % of control	75	75	75
Pozzolanic activity index, with lime, at 7 days, min (MPa)	5.5	5.5	-
Water requirement, max % of control	115	105	105
Autoclave expansion or contraction, max %	0.8	0.8	0.8
Specific gravity, max variation from average.	5	5	5

Percentage retained on 45 sieve, max variation, and percentage points from average.	5	5	5

Table 2- 2 Chemical Requirements

S. No.	**Characteristics**	**Requirement (%)**
1	Silicon dioxide (SiO_2) + aluminium oxide (Al_2O_3) + ironoxide (Fe_2O_3), percent by mass, Min.	70.0
2	Silicon dioxide (SiO_2), percent by mass, Min.	35.0
3	Magnesium oxide (MgO), percent by mass,Max.	5.0
4	Total sulphur as sulphur trioxide (SO_3), percent by mass, Max.	2.75
5	Available alkalis as sodium oxide (Na_2O), percent by mass, Max.	1.5
6	Loss on Ignition, percent by mass, Max.	12.0
7	Moisture content, percent by mass	3.0

2.5 The pozzolanic Reaction and importance

The comparison between Normal Portland cement and pozzolanic Portland cement can be helpful in knowing the difference of their behaviour about the reaction of C-S-H production.

Normal Portland cement reaction

$$C_3S + H \rightarrow C - S - H + CH$$

Pozzolonic Portland cement reaction

$$\text{pozzolan} + CH + H \rightarrow C - S - H$$

The reaction between pozzolan and calcium hydroxide is called pozzolanic reaction. The importance of pozzolanic cements is mostly because of three reasons. First, this reaction is slow though the rate of heating and strengthening will be slow. Second, this reaction use lime instead of producing lime which has important effect on the resistance of hydrated paste against acidic environments. Third, observing the distribution of pores in hydrated cements shows that the products of this reaction are very effective in filling large capillary areas though improves the strength and permeability of the system.

2.6 Pozzolanic Reaction's Origin

One theory is based on assuming the existence of zeolites in pozzolans as reason of reaction between pozzolan and lime. It means that there are some known zeolite minerals which tend to attract lime with the mechanism of ion replacement. The pozzolanic reaction can be explained due to solubility of feldspar shape materials in lime solution. He realized that the four-side units of silica are in a situation in these materials that oxide ions present in all four sides, though the oxide ion will change to hydroxide ion on surface.

$$2O^{2-} + 2H^{+} \rightarrow 2(OH)^{-}$$

This reaction will cause silica to enter lime solution and react with calcium ions and produce non-solved hydrated calcium silicate. Therefore, exiting one unit of silica from surface causes the other silica unit to be in contact with solution and the mechanism will repeat. It is mentioned in Dron theory that this mechanism will happen in pyroclastic Pozzolans easier than other kinds because of weaker internal connections in four sides silica blurs and in zeolite pozzolans because of porosities and permeation of lime solution inside, it will happen more rapid.

Takemoto and Uchikawa [15] understood that in very alkaline solution of lime, pozzolanic particles are attacked with protons. Therefore the surface will have negative charge and attracts Ca2+ and causes the pozzolan alkaline solved in liquid phase and Ca2+ in surface of particle will react with silica and alumina and form a layer which thickened during time. Osmotic pressure due to difference of density between inside and outsides caused this to be broken. As a result, the properties of concentration of hydrated calcium aluminate and hydrated calcium silicates causes the hydrated calcium aluminate to settle outside of pozzolan whereas hydrated calcium silicates stay on the surface of pozzolans.

2.7 Pozzolan’s Structure

Generally, the structure of pozzolan is transparent alumina silicate having some part, which is remained in soot, or material left over from burning organic materials and mostly in the shape of very fine particles to the particles with the size of 1mm can be seen. The remained ash has the properties of pozzolan and has the ability of reaction against calcium hydroxide and also has a good ability to form like Portland cement.

The chemical analysis of pozzolan shows that non-homogeneity of its quality is related to the value of calcium oxide. More than 45% of calcium oxide (CaO) is accessible in waterways or lava flow and the significant point is the value of calcium oxide which is less than 10% in most of the cases [16].

Generally, pozzolans contain 50% to 70% silica (SiO_2), 20% to 35% alumina (Al_2O_3), 3% to 10% hematite (Fe_2O_3), 2% to 7% lime (CaO), 1% to 7% magnesium oxide (MgO), and 1% to 5% potassium oxide (K_2O). The detrimental parts of pozzolans are organic materials and clays which have inverse effect on pozzolanic cement paste’s strength and stop it to set.

2.8 Effective Factors on Pozzolanic Reactions

Costa and Massaza [17] in a research on Italian pozzolans show that it is probable that the compressive strength of mortar is related to the value of SiO_2+Al_2O_3 in long term but the primary strength (in 7 days) and its react with lime is mostly related with special surface. The finer size of the particles causes them to have more pozzolanic reactions. Chatterjee and Lahiri [18] show that there is no general relation between reactions of pozzolans which is measured with strength of mortars and their special surface. They show for some special pozzolans that the strength increases with increasing of fineness, even though this increment was very small.

2.9 Pozzolanic Reaction Measurement

There are three types of tests to measure the pozzolanic reactions: Chemical, physical and mechanical. The relation among methods used in the test of these three groups is weak [19]. Yet Price insists that mechanical test is the best way of measuring pozzolans [20]. The mechanical method is mentioned in many codes. The American standard of ASTM C618-73 [45] for natural pozzolans and virtual pozzolans of fly ash presents two indexes which are related to detecting the pozzolanic reaction when lime is used. In the case of mixtures with pozzolanic Portland cements the pozzolanic reaction index is presented as the ratio of mortar's compression of pozzolan-cement in respect to that of control mixture of pure cement.

2.10 Concrete properties made by pozzolanic portland cement

2.10.1 Introduction

Generally, pozzolan reacts with lime.In other word, lime can be either straightly as a mixture of pozzolan and lime or as a subsidiary product of Portland cement hydration. For mixture of lime and pozzolan, presence of pozzolan will make hydraulic properties for the mixture, i.e. decreases setting time, increases the strength, and intensively increases durability of concrete [21].

Lime and pozzolan react in the mixture of pozzolanic portland cement, because lime is the product of hydration of C3S and C2S in cement, though it is probable that many of strengthened concrete's properties change due to adding pozzolanic materials. Some of these effects are according to physical factors such as fineness of pozzolan particles, shape of particles, and so on. The effect on strength and permeability of strengthened concrete, resistance against thermal cracks, reaction between silica and alkaline, and sulfate attacks are some of the signs of pozzolanic cements. Pozzolans are sometimes used to decrease the internal temperature of concrete.

Some of the pozzolans are used to neutralize or decrease the expansive ability of concretes due to alkaline reacts of particles. Whenever using of active particles in concrete is inescapable, the cement with low alkaline property or standard pozzolan due to ASTM C441 [46] can be used to avoid expansion.

2.10.2 Compressive Strength

It is clear that lime and pozzolan reaction in the mixture of pozzolanic portland, because lime is the product of C3S and C2S hydration. There are some signs that these reactions between pozzolan and portland cement starts in early setting time. Strength growing in pozzolanic portland cement at the beginning for a specific pozzolan is related to the amount of replaced cement with pozzolan. In many countries, it is allowed to replace up to 40% of hydraulic cement with pozzolan with the condition of reaching needed compressive strength [22]. In this research, the replaced amount of cement with pozzolan is up to 50%.

Strength growing is a function of process of filling the pores. This filling is with the products of hydration. Some researchers have previously done works in the case of effects of using pozzolan in different percentages on concrete strength. In one part of this present research, the effect of using pozzolan on the strength of concrete was observed [23].

Using micro silica is observed by some researchers. These researches show that portland cement replacement with silica soot in concrete can improve compressive strength. Of course using silica soot with plasticizer or super plasticizer will be more effective [24].

2.10.3 Heat of Hydration

Totally, the hydration heat in early age concretes with portland cement is more than concrete with pozzolanic portland cement, but pozzolanic reaction is also exothermic. As [25] says, “Total released heat during hydration is basically more than reckoned heat for just using cement”. He also mentioned that these properties in mass concrete like dams is suitable, because released heat should be controlled before concreting one block on another. Davis proposed to increase replaced amount of cement with pozzolan to achieve 50% less released heat amount. [26] Also has done experiences in this category which show intense hydration heat decrement by using more pozzolan. Masazza [27] also shows that the more portland cement replacement with pozzolan will causes more decrement of released hydration heat.

2.10.4 Porosity and Permeability

Mather [28] and Davis [29] proved that using pozzolans in concrete mixtures with low cement amount is very effective on decrement of permeability and this decrement is related to ability of pozzolan to react. Increasing pozzolan value, the reaction of lime and pozzolan will continue and pore's volume decreases. On the other, hand bigger pores (with the size of more than 500 Angstrom) effect strength, permeability, and as a result durability of the concrete. Mehta [30] shows a direct relation between concrete permeability and the volume of pores with the size of more than 500 Angstrom for the mixtures of cement and Santorin soil. Davis [25] says thatusing suitable pozzolan in dam concretes with low cement amount can achieve such low permeability ratio which is not accessible in any other way.

2.10.5 Elasticity

In general condition, concrete properties such as modulus of elasticity and creep is affect by concrete strength, aggregates' modulus and their volume in unit volume of concrete, environment's relative humidity, temperature, cement type, and stress value. Obviously, concrete containing natural pozzolanic portland cement with low strength in early age have less modulus of elasticity and more creep than non-pozzolanic concrete.

Abdun and Nur [31] realized that concrete modulus of elasticity, made up of fly ash, in early age will be low and during passing time will be increased. Naturally, concretes which contain fly ash have more modulus of elasticity than the one which do not have fly ash. Ghosh and Timusk [32] observed concrete containing fly ash with the age of 28 days. They have concluded that for all strength values, modulus of elasticity of concrete with and without pozzolan are approximately equal. Lane and Best [33] have seen in their experiments that concretes made up of pozzolanic cement in early age have less modulus of elasticity than concrete with non-pozzolanic cement and in the age of 90 days this relation will be changed somehow that the modulus of elasticity of concrete with pozzolanic cement will be more than that of concrete with non-pozzolanic cement.

2.10.6 Concrete Workability

Workability is one of the significant properties of concrete paste that is basically related to adhesive. Davis et al [29] show that pozzolanic portland cement need more water to gain same workability than normal portland cement. Though, it is obvious that increasing cement replacement with pozzolan and also increasing pozzolan fineness will increase water need, but Tuthill and Cordon [34] show that these bad effects can be removed by using plasticizers and super plasticizers which decrease water amount used in concrete mix. Wallace and Ore [35] presented some results of using additives such as water reducer and retarder in pozzolanic portland concretes. They observed water reducer effect and show that strength and durability are improved. Also conclude that changes due to expansion in water environment, shrinkage due to drying, and permeability is not affect intensively by using retarders and water reducer.

2.10.7 Primary and Final Setting of Pozzolanic Portland Cement

Primary and final setting of pozzolanic portland cement is affect by the value of replaced normal portland cement, fineness and ability of pozzolan to react.Davis et al [29] show that replacing 20% of cement with pozzolan, setting time is approximately is the same of normal Portland Cement.

Process of strengthening for concretes containing micro silica is more than common concretes and concretes containing mineral pozzolans. On the other hand, pozzolanic activity of nano silica is very faster than that of other available pozzolans [36]. Rate of strengthening for concretes containing rice husk in early age is less than that of older ages of concrete and by increasing concrete’s age rate of strengthening for concretes containing rice husk increases. Therefore pozzolanic reaction of rice husk soot increases during the time and causes the increment of concrete strength [37].

2.10.8 Durability

Durability and stability of concrete against environmental aggressive factors around concrete is very important. Generally, such factors including solution of sulfates especially sodium sulfate, potassium sulfate, calcium sulfate, magnesium sulfate, chlorides, and alkaline are often present in soil and water naturally. Concrete permeability has a basic importance for permeating bad chemical materials such as acids and sulfates. Since the pozzolanic reaction of mineral additives have the ability to proof the porosity and decreases concrete permeability, will make valuable improvement in chemical durability of concretes containing such materials. Additives are approximately able to use calcium hydroxide in hydrated cement paste and thus it is excellent to improve concrete strength against sulfate attack [38].

2.10.8.1 Sulfate attack and the advantage of using pozzolan

Concrete damage due to sulfate attack can be affected by cement amount, cement type, and mineral additives. It is known that solid salts don't attack concrete, but when they are in solution form, can react with strengthened cement paste. All components of strengthened cement paste will be attacked with sulfate solutions.During this attack, sulfates react with calcium hydroxide and hydrated calcium aluminate. Generally, reactions between strengthened cement paste and sulfate ions can be classified to three groups due to their significance:

- Production of sulfur-aluminates including mono sulfate and ettringite
- Production gypsum
- Other reactions which will accelerate with sulfated concrete

The volume of these reactions is valuably more than replaced complex volumes somehow that reaction with sulfates causes the concrete to expansion and rupture of concrete [39].

Sodium sulfate can react with calcium hydroxide as bellow:

$$Ca(OH)_2 + Na_2SO_4.10\,H_2O \rightarrow CaSO_4.2\,H_2O + 2\,NaOH + 8\,H_2O$$

Replacement of portland cement with pozzolan causes better condition in the case of sulfate attack. First step of sulfate attack is expansive reaction between sulfate ions and calcium hydroxide. Pozzolan reacts with calcium hydroxide and as a result reduces the expansion amount. Like alkali reaction of silica due to sulfate attack, enough pozzolan should be added to control the expansion. Conclusions of trass experiments by Lea [40] shows that 20% replacement of portland cement with pozzolan has a negligible improvement in the required time to gain 0.1% expansion but 40% replacement of portland cement with pozzolan causes a valuable improvement. Mehta [23] by usig Santorin soil shows that replacement of 10% does not cause effective control in concrete expansion although replacement of 20% and 30% is very effective.

The second effect of pozzolan is reduction of C3A in cement. Thus, the more replacement causes the presence of less amount of C3A in mixture. The main reason of expansion in portland cement due to sulfate attack is a reaction which makes the transformation of aluminum mono-sulfate to ettringite possible. Turriziani and Rio [41] believe that profusion of hydrated calcium silicate and also less amount of the ratio of CaO in respect to SiO2 in comparison with the same ratio in portland cement paste causes the ability of hydrated calcium silicate in saving lime and decreases the problem of its flow out.

The third beneficial effect of pozzolan is decrement of concrete permeability. Pozzolan decreases the rate at which sulfate solution penetrates inside the concrete. Putting concrete in the environment of sulfate solution causes strength decrement and this reduction is due to sulfate ion density and also due to concrete properties.

According to Massaza and Costa [42], calcium hydroxide in hydrated pozzolanic cements not only presents lowly, but also is confined with C-S-H gel. This condition is not suitable for producing ettringite which is generally the reason of expansion and crack. On the other hand, permeability of cement paste increases the saving factor of hydrated lime which hardened the permeation of ions inside concrete.

In another research by Mehta [43], effect of replacement with the value of 10%, 20%, and 30% with Santorin soil on the sulfate resistance of portland cement of type I with two different research methods is observed. He realized that sulfate attack is remarkably low in the mortars with 20% and 30% pozzolanic cements.

2.10.8.2 Silica and Cement Alkali Reaction and Advantage of Pozzolan Reaction

Some of aggregates have a special kind of silica which reacts with the alkalis present in the cement paste. The product of this reaction is expansive and causes deep cracks in concrete. The shape of passive silica can be blurred or not. This reaction starts with attack of alkalis inside the cement to the aggregates silica. These alkalis which participate in the reaction are hydroxides produced from Na_2O and K_2O.The signs of injury of concrete due to reaction of concrete's alkali with non-blurred silica of aggregate are expansion, crack, exit of Sodium silicate and potassium silicate from pores and crakes, production of hard particles at the concrete surface, and protrusions. The size of cracks increases during the time and finally causes the failure of concrete member. The mechanism of this attack is similar to sulfate attack, because just some of concrete components participate in this reaction. There is a difference between this attack and sulfate attack which is the place of it. Sulfate attack occurs in cement but this attack is in aggregates. Generally, type of active materials, value of active materials, value of alkali in cement, water value in the mixture, and permeability of hardened cement paste affect the reaction of alkalis with aggregates. To reduce the reaction of alkali silica with cement, either the value of alkali in cement should be limited or special type of cement which stops harmful reaction between aggregates and alkalis should be used.

ASTM C441 [24] specifies controlling alkali reactions of aggregates using mineral additives. Mehta [39] showed that for increasing the replacement of cement in the mortar with Santorin soil, the expansion decreases.

Davis [25] says that effect of a specific pozzolan on expansion control of alkali silica is depend on react ability of that pozzolan and this factor can specify the value of cement replacement, i.e. silica soot is more reactive than rhyolite, though to control the alkali silica expansion, it is less used.

2.10.8.3 Shrinkage Based on Dehydration

Saturated cement paste, during being in a common environment will not have constant size due to dehydration of C-S-H gel partially in unsaturated environment. Indeed the strain due to shrinkage is imputed to the outflow of absorbed water and water flow from hydrated cement paste. The subsidiary reason of shrinkage based on dehydration is flow and outflow of the water in capillary spaces (with the size of more little than 50nm) in hydrated cement paste due to hydrostatic tension.

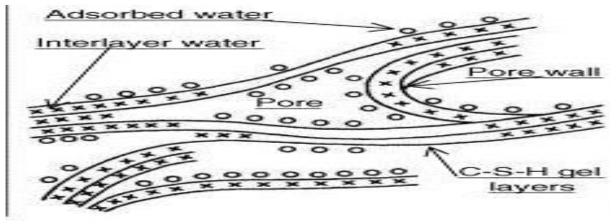


Figure 2- 1 different water in C-S-H

Practically, replacement of humidity in hydrated cement paste, which is basically controlling shrinkage strain of concrete, is effected by multiple factors simultaneously. The relation among these factors is very complicated and is not so easy to be studied. Some of these factors are mentioned and discussed in beneath.

2.10.8.3.1 Materials and Their Amount in Mixture

The main resource of transformation based on concrete moisture is hydrated cement paste. Therefore, many efforts in the case of finding relation between shrinkage based on dehydration and the volume of hydrated cement paste are done. This volume is measured from amount of used cement and hydration degree. Although shrinkage based on dehydration is a function of cement paste amount, there is no straight relation available. This is due to restrict of transformation. Factors such as grading of aggregates, the maximum size of aggregates, shape and texture of aggregates are also effective on the shrinkage amount. Most of researchers believe that aggregate’s modulus of elasticity is the most important factor in this case and the others affect the shrinkage indirectly, i.e. either with effect on compressibility of the concrete mix or with effect on the amount of aggregates. The effect of aggregate’s properties and specially, modulus of elasticity during 23 years of concrete age is proved in a research by according to many study. He shows in this research that concrete shrinkage is increased up to 2.5 times more by replacing aggregates with the ones that have less modulus of elasticity.

2.10.8.3.2 Time and Humidity

Drainage of absorbed water and confined water in the little pores (smaller than 50 nanometer) by capillary of hydrated cement paste to the bigger pore or to the outside of the sample is a time dependent process which will occur during a long time.

2.10.8.3.3 Shape of Concrete Member

Because of resistance against water extension from concrete environment, its rate is depend on the length which should be passed with the water from inside to surface and this is the water that exits during shrinkage. In a constant related humidity, the shape and size of the concrete sample will affect the amount of shrinkage. Often the size and shape of sample are shown with a number known as effective thickness or theoretical thickness. This parameter is equal to the ratio of area over the half-perimeter of the surface that is in contact with atmosphere.

2.10.8.3.4 Pozzolans

Pozzolans cause the little pores' in cement hydration products to be grown. Since shrinkage in concrete is based on confined water in pores with the size of 3nm to 20nm, concretes with additive, which make more little pores, show usually more shrinkage. Additives will cause better distribution of non-hydrated cement particles in concrete, such as plasticizers, improve the situation of pores in hydration productions.

2.11. Concrete Expansion

2.11.1Expansive Reactions

The chemical reactions which produce expansive productions can be somehow harmful for the system. Expansion may be non-destructive primarily, but increment of internal stresses finally shows itself by closing the expansion joints, displacement of structure's different points, cracking, and flaking the concrete surface. These four events are related to chemical expansive reactions: sulfate attack, alkaline aggregates' attack, postponed hydration of free CaO and MgO, and steel corrosion in concrete.

2.11.2 Sulfate Attack Base Expansion

Decrement of concrete quality by chemical reacting of hydrated Portland cement and sulfate ions from an external resource is known which can be occurred in two completely different types. The items that can cause the system to follow which type of corrosion processes are the density and the resource of present sulfate ion in the water either in touch with the concrete or is used in the concrete mix. The sulfate attack can be detected as concrete expansion. When concrete cracks, its permeability is increased and the water is penetrated in concrete more easily, therefore corrosion process will accelerated. Sometime this expansion will cause significant structural problems such as building's wall displacements by slab expansion. Sulfate attack also can cause continues decrement of strength.

2.12 Pumice

Pumice is a volcanic rock which is made of highly vesicular rough textured volcanic glass. Despite similarities in chemical composition, it should be noted that pumice is different from scoria which is another vesicular volcanic rock as it has larger and thicker vesicles. In addition, colour of scoria is darker in comparison with colour of pumice which is normally light coloured. These vesicles are pore spaces created as a result of evacuation and exit of dissolved gas of magma after reaching the earth surface [48]. Rush of gas from the vent shreds the magma and blows it out as a molten froth. Therefore, the froth rapidly solidifies as it flies through the air and falls back to earth as pieces of pumice [48]. There are two kinds of pumice: acidic pumice (white or oyster white colour) and basic pumice (brown or black). However, acidic pumice is the most common pumice type in the world [49]. According to US Geological Survey Report, global production of pumice and pumicite was approximately 18 and 17 million tonnes in 2011 and 2012.

2.12.1 Characterization of pumice

Chemical composition of pumice reported by different researchers from different countries in the world is shown in table below. As can be seen, main chemical ingredient of pumice is SiO_2 which is approximately 61% to 76% of the total composition. Second chemical compound is Al_2O_3 which is around 10% to 17% of pumice chemical composition. Furthermore, Loss on Ignition (LOI) of pumice is between 2.56% and 4.27%.

Table 2- 3 Chemical composition of pumice

Chemical composition	**Typical range* (%)**
SiO_2	60.82 - 75.51
Al_2O_3	9.94 - 17.24
CaO	0.25 - 4.44
Fe_2O_3	1.05 - 3.39

K_2O	2.5 - 5.12
MgO	0.34 - 0.99
Na_2O	2.04 - 5.20
SO_3	0.08 - 0.33
LOI (%)	2.56-4.27

2.12.2 Pumice in concrete

Pumice rocks are porous and amorphous materials which consist mainly of SiO_2 andAl_2O_3 [50]. Traditionally, pumice as aggregate has been used for producing light weight building blocks, concrete and assorted building products in construction industry [51].

For example, several investigations have been carried out to study performance of prefabricated concrete panels and frames with pumice. For example, investigated performance of prefabricated light weight pumice concrete infill panels under quasi-static loading [48].

Furthermore, [51] made three different kinds of reinforced wall panels using lightweight pumice stone concrete, light weight expanded clay concrete and normal concrete to compare their structural responses under horizontal cyclic and constant vertical loading.

They recommended that pumice light weight concrete is a good alternative for use in construction, particularly in areas where pumice is locally available and for types of structural systems which consist of bearing elements that do not require high resistance against horizontal loads and ductility/energy dissipation.

In recent years, some researchers have evaluated the possibility of using pumice in geopolymer concrete. The industrial manufacturing process of cements based on the alkaline activation of blast furnace slag (AAS). This type of binder can save large amounts of energy and fuel asits production does not require traditional procedure of Portland cement production based on decarbonation of limestone. [48] Used pumice aggregate in geopolymer concrete but its strength was decreased. [52] Studied strength and durability of alkali activated blast furnace slag concretes with very finely ground pumice at 5% and 10% replacement of slag. They reported that samples with and without pumice powder had close values of compressive, flexural and drying shrinkage while durability of samples with pumice powder were better than those without it.

However, pumice is still mainly used in construction industry and recently, many researchers have worked on using pumice in concrete as cement replacement and aggregate for developing a green sustainable construction material.Pumice was used as a construction material in ancient Rome over 2000 years ago and several important buildings such as Pantheon building constructed in 126 AD are still standing [49].

2.12.3 Pumice as cement replacement in concrete

Although using of pumice as aggregate seems an environment-friendly and cost effective method for developing green concrete, technical performance of such concretes conveys important concerns because of high water absorption of pumice aggregate. Another option for utilizing pumice in concrete industry is developing usage of finely-ground pumice powder as a cement additive. Many researchers have studied effects of pumice as a pozzolanic material on properties of concrete which is reviewed in this section.

Pumice has pozzolanic characteristics and can react with calcium hydroxid as one of hydration products of Portland cement to form more hydrate-silicate-calcium so that long term strength and durability can be improved [48].

Research works for evaluating effects of pumice powder as a cement additive on concrete properties, some researchers have attempted to develop new concrete elements including pumice powder.

2.13 Location of natural pumice in Ethiopia

The East African rift valley originated during Late Tertiary with expansive out pouring of lava and pyroclastic flow forming pumicite and pumicious ash in the Main Ethiopian Rift Valley (MERV).

Although, there are a lot of occurrences of pumicein the MERV, the best known deposits are Gari Baldi Pass, Koka, Dere, Bishoftu, Modjo, Alemtena and Meki. Fentale, Lake Verdi and Kinbibit are not studied well [44]. Occurrences are also found in Adami-Tulu and Langano (Figure 1).

2.13.1 Kimbibit

The Kinbibit pumice is located at 08°32’00"-8° 32’25N and 39°13’22’’-39°3’45"E, and lies five kilometers west of Nazareth along the Nazareth- Addis Ababa road, near the Ethiopia leather factory, According to the local farmers, deposit has been quarried for long time. It is approximately 500 meters long 5 meters wide and 3 meters deep; 7,500 cubic meters.

Photo: Out crop of pumice (Langano). & pumice outcrop, Bishoftu

Photograph: by sentayehu zewdie

2.13.2 Bishofetu

The Bishofetu pumice is located in the south of Dbrezeyit Town about 15km to the south.The main geological units exposed are pyroclastic falls comprising of dominantly pumice and subordinate pumiceous ashes inter layers. The pumice deposit covers extensive area of variable thickens of overburden which is commonly soil cover fluvial, colluvial and debris (Figure 2). No detail work undertaken to get the reserve.

2.13.3. Koka, Alemtena and Meki

Alemtena, Koka and Meki Pumice are located around Koka, Meki and Alemtena towns in south

Shoa zone. Oromiya Regional State. The pumice is a high volcanic glass and usually rhyoitic, dacitic or trachytic in composition. It is light colored composed of fine ash. The grain size of the particle throw out of the volcano diminish with distance from the eruption center as the particle thrown out of volcano one go away from the source .these deposit composed of ash and fine grained pumice beds which indicate that the source of the ash is far compared to the coarser variety [44]. Extents and reserves of the deposit is not known. Although pumice is widespread in Ethiopia, it is utilized only in limited areas for the purpose of cement and block production.

Photo: Thick Pumice outcrop (Meki and Alemtena).

Photo: Light grey, fine grained pumice (Meki).

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1. Study area

The study area of this research is meki town. It is a town in east center Ethiopia. Located in misraq shewa zone of the oromia region it has latitude and longitude of 8^0 9' N 38^0 49' E with elevation of 1636 meter above sea level. meki is the administrative center of dugda wereda.

Figure 3- 1 Satellite Map of Meki

3.2. Study Design

Since determination of mechanical property of fresh and hardend concrete was the main aim of this research, this research follow experimental study to obtain data. Which begins by collecting samples. The sages involved in the study include:

- ✓ Collecting samples
- ✓ Preparation of samples for each laboratory test
- ✓ Laboratory test on chemical and physical test on pumice sample
- ✓ Laboratory test on cement, fine and coarse aggregate for development of mix design
- ✓ Casting of concrete molds
- ✓ Curing of concrete samples
- ✓ Laboratory test on concrete samples

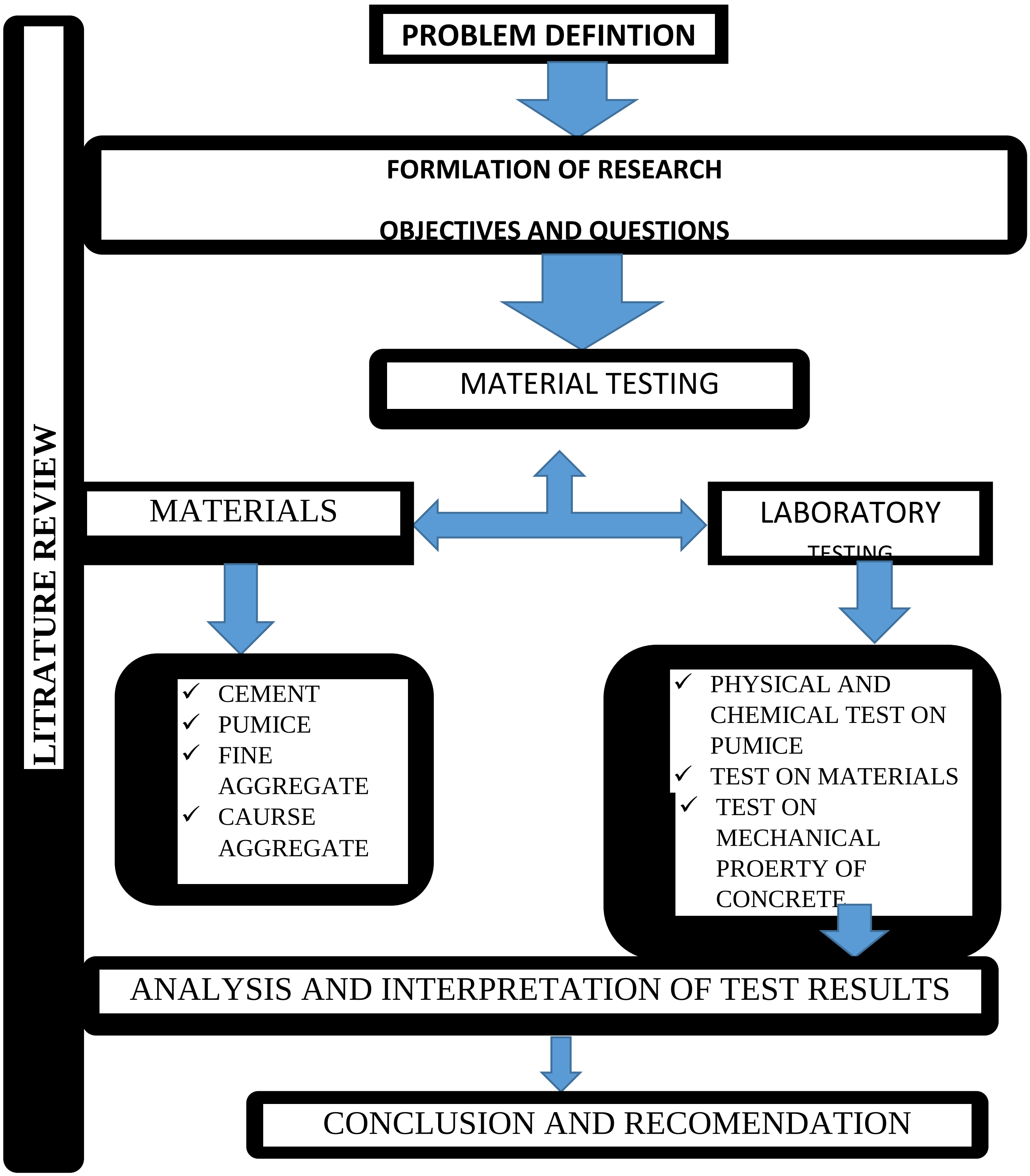


Figure 3- 2: Study design process

3. 1 Population of the Research

The sample frame or target population of this research were include ingredients of pozzolonic concrete like cement, pumice, sand, coarse aggregate, and water.

3.4. Study variables

Independent Variable:

- ➢ properties of fresh concrete
  - ✓ Workability(slump test)
- ➢ Mechanical properties of concrete
  - ✓ Compressive strength
  - ✓ Flexural strength

Dependent Variable:

- ✓ Usability of pumice natural pozzolona

3.5. Sources of Data

Both primary data sources and secondary data sources were used. Secondary data needed for this research was collected from different journals, book, website etc. during the literature review and primary sources of data for this study were a laboratory experimental output.

3.6. Sampling Techniques

The sampling technique was used for this research was a purposive Sampling technique which is the non-probability method. This sampling technique was proposed based on the information that to determine the strength of the concrete. Most of the tests on the hardened concrete are about measuring the strength. These tests are destructive test. Destructive tests are such as compression test and flexural strength test. Generally tests which have done in this research are as bellow:

- ✓ Chemical and physical properties of pumice.
- ✓ Material test on the ingredients of concrete (cement. Fine aggregate and coarse aggregate)

- ✓ Compressive strength of concrete cube samples with four different percentage of pumice (0% as control mix, 30%, 40%, 50%) as cement replacement in various ages of 7, and 28 days.
- ✓ Flexural strength of concrete beam samples with four different percentage of pumice (0% as control mix, 30%, 40%, 50%) as cement replacement in various ages of 7, and 28 days.

- **For concrete sampling there should be some facilities available:**
  - ✓ Molds and needed tools for their installing and uninstalling should be all from the material that don't react with concrete and also don't absorb its water. Molds should remain in the same shape and size during their service and also have to not to leak the concrete's wetness.

Figure 3- 3 concrete molds

The procedure of making concrete is as bellow:

- ✓ Before starting the concrete to be made, all aggregates, cement, pumice, and water should be measured and be prepared according to calculated mix design. If we don't prepare all these materials before starting to mix them together, it may take time during mix procedure and causes cement to start its primary setting and causes the samples to not to show proper results.
- ✓ One of the other works that before preparing the fresh concrete is to lubricate all molds which are going to be used. Because if we do not lubricate them the samples cannot be de molded properly and be used for the research. This lubrication should be somehow that let the sample be de molded easily and also should not be so much to let the lubricating oil to affect the concrete and react with it. The molds, which

should be made ready in this research, were in two different sizes of cube 150*150*150 millimeter, and prismatic mold of the size 500*100*100 millimeter.

Figure 3- 4 lubricating of molds

- ✓ The mixing of the concrete batch should be well mixed.
- ✓ In this research uses hand mixing for production of concrete.

3.6.1 .Materials for Laboratory Experimental Works

I. **Cement: -** Type of Cement was used in the concrete mix was Muger-Ordinary Portland cement (OPC) whose Cement Grade 42.5R which is commercially available cement.

II. **Coarse aggregate: -** "Agaro" crushed stone 25mm maximum Nominal size that was commonly used in Jimma Town.

III. **Sand: -** The sand were used from Gambella Regional State available in Jimma zone.

IV. **Water: -** Drinkable (potable) water was used from Jimma University, Jimma institute of technology laboratory.

V. **Pumice: -** the pumice were used from Meki quarry site collected from Dangote cement factory.

3.6.2. Laboratory experimental works procedure

Stage-1: Sampling preparation stage

- **Pumice**

Sample was taken by sampling tube from bulk storage during discharge. If the load is sampled at the point of discharge into the rail car or tanker, the top surface shall be removed to a depth of at least 200 mm (8 in.) according to ASTM 311 before sampling.

The used pumice was obtained from Dangote cement factory (as Dangote cement factory uses pumice from meki quari site for production of Portland pozzolona cement) and dried on oven dry the sample, after that grinding in the laboratory Dangote cement factory by the author of this thesis and sieved according to ASTM-C 618 which allows up to 34% to be remained on the 45 micron sieve.


Figure 3- 5 Taking sampling method for pumice and grinding Machine

- **Coarse Aggregate**

Coarse aggregate sample was sun dried to minimize effects on concrete. For all the concrete mixes, the same coarse aggregate “Agaro crushed stone “was used. This aggregate is commonly used in the Jimma Town area and as such, is readily available and best simulates normal construction practice in the region. Using a single type of coarse aggregate ensured that any variations in concrete properties were not due to this material. After the coarse aggregate sample was saturated surface dried then the sample was prepared to the laboratory experimental test of the coarse aggregate sample by using rifling method.

- **Fine Aggregate (Sand)**

The sand sample was sun dried in order to minimize the effect of impurity on concrete and Check the saturated surface dry of the sample by using small cone and tamper.

Stage -2: Laboratory tests on ingredient of concrete

- Tests on coarse aggregate according to ASTM Standard Procedures. (I.e. sieve analysis or gradation, water absorption, unit weight, specific gravity, moisture content)
- Tests on fine aggregate according to ASTM Standard Procedures. (I.e. sieve analysis or gradation, water absorption, unit weight, specific gravity, moisture content and Silt/Clay Test of Sand sample).
- Tests on cement (i.e. Consistency test, initial and final setting time test and fineness of cement test).

- **Test on pumice**

In this thesis the researcher did both the chemical and physical properties tests of natural pozzolona (pumice).

Chemical composition test

Chemical analysis of the specimens was conducted to determine the effectiveness of the natural pozzolan in contributing to sulfate resistance. The results of the chemical analysis are given in Tables 4.5.

Chemical composition analysis: The chemical analysis of the pozzolana samples was determined using the X-ray fluorescence equipment (Spectro X-lab) in Dangote chemical lab. 10g pumice sample was taken and then milled in a milling machine for 6 minutes to produce a homogeneous mixture. The mixture was poured into a disc and placed under a press pellet machine. The pellet machine produced a tab which was placed in a container. The container and its content were fixed in the Spectro X-lab. Finally to determine the chemical composition of the samples.

Figure 3- 6 Mailing and X-Rey Machine

Loss in mass on ignition test

Determine loss on ignition in accordance with the procedures outlined in Test Methods C 114, except that the material remaining from the determination of moisture content shall be ignited to constant mass in an uncovered porcelain, not platinum, crucible at 750 ± 50 °C (1382 6 190 °F).

Calculate the percentage of loss on ignition to the nearest 0.1, as follows:

$$\text{Loss on ignition (\%)} \Longrightarrow (A/B) \times 100$$

Where:

A = loss in mass between 105 and 750 °C (221 and 1382°F)

B = mass of moisture-free sample used.

The following physical tests were conducted on the pozzolan specimens:

- Fineness per sieve analysis (ASTM C311-00)
- Blaine fineness (ASTM C204-00)

Blaine fineness test

The Blaine test was performed to measure the fineness of all cement and Natural pozzolona. The measurements were done according to ASTM C 204, *Standard Test*

Method for Fineness of Hydraulic Cement by Air-Permeability Apparatus. This method is based on the relationship between the surface area of the cement particles in a porous bed and the rate of fluid through the bed. This apparatus is consisted of permeability cell, disk, plunger, U-tube manometer, and manometer liquid including a scale as shown Figure bellow.

Mass of sample was calculated using Equation below (A) and was weighted using scale. The sample is then placed into permeability cell. The permeability cell is inserted to the top of the manometer tube. Air is slowly evacuated in the one arm of the manometer U-tube until the liquid reaches the top mark, after which the valve is closed tightly to prevent the liquid from falling. With a timer ready, the valve is opened and the time the liquid reaches calibrated marks (middle and bottom) on the manometer are recorded. Specific surface values were calculated using Equation (B).

Figure 3- 7 Blaine air-permeability apparatus

$W = \rho V (1 - \epsilon) \ldots\ldots (A)$ $S = (Ss\sqrt{t})/\sqrt{ts} \ldots\ldots$ (B)

Where, W: grams of sample required

S = specific surface of the test sample

Ss = specific surface of the standard Sample used in calibration of apparatus, (m2/kg)

T = measured time interval, s, of manometer drop for test sample

TS: measured time interval

ρ = density of test sample

V = bulk volume of bed of Material (cm3) ϵ = desired porosity of bed of material

Stage 3: concrete Mix design

In this research work, the ACI Method of concrete mix design was used to design C-25 concrete grade having a 33.5 MPa target mean strength with 0.51 of water to cement ratio. In addition to this, the slump was 25 to 100mm. On this base; 4 different types of mix-design was prepared based on percentage of pumice replacement (0% as control mix, 30%, 40%, 50%). For all the concrete mixes, the same w/c ratio was used.

The quantity of concrete materials was calculated by using the physical properties of the materials and Table 3.1 show the quantity of materials for one cubic meter for C-25 concrete grade. The Standard cast iron molds of size 15cmx15cmx15cm are used in the preparation of concrete cubes for compressive strength tests and 50cm×10cm×10cm for flexural strength.

Table 3- 1**:** Concrete Mix -Design for 1 m3 of concrete

Percentage of pumice	Parameter	Mass(kg)
0% pumice(control)	Water	185
	Cement	365
	Pumice	0
	Fine Aggregate	774
	Coarse aggregate	1075
30%pumice	Water	185
	Cement	255.5
	Pumice	109.5
	Fine Aggregate	774
	Coarse Aggregate	1075
40%pumice	Water	185
	Cement	219
	Pumice	146
	Fine aggregate	774
	Coarse aggregate	1075
	Water	185
	Cement	182.5

50%pumice	Pumice	182.5
	Fine aggregate	774
	Coarse aggregate	1075

- **Concrete mixing and Production Process**

The ingredients, such as; cement, pumice, fine aggregate (sand), coarse aggregate and water were measured to an accuracy of 0.1g balance. After that the weighted coarse aggregate was first added on the large flat plat and the fine aggregate was added after the coarse aggregate and then the cement and pumice is added next to fine aggregate and dry mixed for a minute. Then, water was added to the dry mixed concrete ingredients mixture and thoroughly mixed for two more minute. Mixing of concrete by varying percentage of pumice content (0%, 30%, 40% and 50%) and the mix coarse aggregate, fine aggregate and water are constant for all C-25 concrete mix.

N.B No chemical admixtures were used on production process of the concrete.

- **Concrete cube casting and slump Testing**

The mixed concrete was checked for workability by filling the standard slump cone with three layers by rodding each layer with 25 times according to ASTM C143. Between each mix, the tools was cleaned using tap water to ensure that there was no contamination between the mixes. After checked the slump the mixed concrete was placed in the mold and was well compacted in three layers with the help of a tape rode by rodding each layer with 25 times and as well as Side compaction of the molds was carried out by using tire hammer . For each mix, prepare 3 cubes molds having (15cmx15cmx15cm) and (10cm×10cm×50cm) size and totally 36 cubes and 36 beam test samples were caste for compressive and flexural.

Figure 3- 8 slump tests

- **De-molding Specimen and coding (identification) of the sample concrete cubes**

The concrete mix was casted in the molds for the first 24 hours. After that, the concrete was removed from the molds but removing the cubic mold with a great care to prevent any damage, external and internal, to the specimen. After that Coding the concrete cube samples based on percentage of pumice added and day of curing.

- **Curing of the Concrete cube samples**

The concrete cubes were cured by immersion in water in the curing tank for 7, 28 days at a temperature of 23 ± 1^{o}C for curing to take place until the testing age was reached.

Stage-4: Mechanical properties of concrete testing of molds

After 7 and 28 days of curing period the concrete mold specimens was removed from the water bath then placed in dry surface until the specimens was surface dried while weighted concrete cubes specimens in order to determine the unit weight of the concrete cube Finally, the specimens was tested by using "Wizaro Basic" a Digital readout Universal Testing Machine for compressive strength. Loading Rate for 150 mm cube was 140 kg/cm2 per minute till the Specimens fails. The method of applying two point loads on a beam with simply supports is used to measure flexural strength of concrete. Loading should be without any inclination and the extension loads should intersect to the axes of the beam. The distance between point load and support should not be less than depth of the beam. The length of sample should be at least three times more than its depth.

Figure 3- 9 Compression test apparatus and 2 point load flexural test apparatus

- The calculation of compressive stress bat failure is as follows:
  - **Compressive stress (σ) = Force/Area**
- The calculation of the flexural stress at failure is as follows:

$C = D/2$ cm; $M = PL/3$ N.m ; $I = bd^3/12$ m^4 ;

Flexural stress (σ) =Mc/I M……………. [47].

Where:

P = Failure Load σ = Bending Strength

M = Maximum Moment L = Span of Specimen

I = Moment of Inertia D = Depth of specimen

C = Centroidal depth

3.7: Analysis and discussion

- Compare and contrast the quality of concrete due to different percentage of pumice as replacement of cement. Discussed on the concrete produced by pumice on the workability and mechanical properties of the concrete (compressive and flexural strength).
- Analysis and discuss the result by using Tables, Bars, Charts and Graphs. Generally for this research, four mixes of concrete produced due to different percentage of pumice as

replacement of cement. Their properties evaluated in terms of their properties of fresh concrete and mechanical properties of the concrete.

CHAPTER FOUR

RESULT AND DISCUSSIONS

4.1 Material property

4.1.1 Cement property

Ordinary Portland Cement (OPC) Muger 42.5R Cement Grade was used throughout the experiment which is commercially available in Jimma Town. The chemical composition obtained from cement factory is shown below in table 4.1 and physical property of cement is tested as shown below table 4.2.

Table 4- 1**: Summary of the chemical composition of Muger cement**

No	Chemical composition	Requirement ES 1176-2:2005	Obtained Data
1	Silka SiO_2 %	18-24	20.77
2	Alumina, $Al2O3$ %	2.8-6	5.23
3	Iron oxide,$Fe2O3$%	1.5-7	3.53
4	CaO%	61-69	63.31
5	MgO%	0-4.5	1.41
6	So_3%	0.2-4	2.44
7	Loss of ignition	Not exceed 5	4.17
	Typical composition of portland cement		
	Chemical Name	Chemical formula	Weight in percent
8	Tricalcium silicate (alite)	$3CaO\ SiO_2$ (C3S)	52.40
9	Dicalcium silicate (belite)	$2CaO\ SiO_2$ (C_2S)	20.02
10	Tricalcium aluminate	$3CaO\ Al_2O_3$ (C_3A)	8.000
11	Tetracalcium aluminoferrite	$4CaOAl_2O_3Fe_2O_3$(C_4AF)	10.74
12	Gypsum	$CaSO_4\ 2H_2O$	5

Chemical formulas of cement are commonly expressed as a function of sums of oxides. Most widely used abbreviations are listed in Table 4.1. The chemical composition of OPC can be determined by many methods, with X-ray Florescence (XRF) Spectroscopy and chemical methods most commonly used. The results are reported as its oxide and can be converted to the chemical composition by the Bogue calculation. ASTM C 150, Standard Specification for Portland cement, a simple Bogue calculation can be produced by Equations below.

When $A/F \geq 0.64$

$$C_3S = 4.071\,C - 7.600\,S - 6.781\,A - 1.430\,F - 2.852S$$

$$C_2S = 2.867\,S - 0.7544\,C_3S$$

$$C_3A = 2.650\,A - 1.692\,F$$

$$C_4AF = 3.043\,F$$

When $A/F < 0.64$

$$C_3S = 4.071\,C - 7.600\,S - 4.479\,A - 2.859\,F - 2.852\,S$$

$$C_2S = 2.867\,S - 0.7544\,C_3S$$

$$C_3A = 0$$

$$C_4AF + C_2F = 2.100\,A + 1.702\,F$$

Table 4- 2**: Summary of the Physical Properties of Muger cement**

Material	Types of cement	Types of cement test	Test results	
CEMENT	**ORDENARY PORTLAND CEMENT (OPC)**	Fineness of cement	95% pass	
		Consistency of cement w/c ratio water penetration	32% 160 9.3	
		Setting time	Initial	1hr.32min
			Final	4hr.20min
		Specific gravity	3.15	
		Blain value(cm^2 /gm)	3650	

4.1.2. Coarse Aggregate Property

The coarse aggregate used for this research was basaltic crushed rock from "Agaro" Oromia region state of Ethiopia which is located 46.1km from Jimma town. The size of coarse aggregate used for experimental investigation was a maximum size of 37 mm diameter aggregate was used in all the concrete mix design because using a single type of coarse aggregate ensured that any variations in concrete properties were not due to this material. This aggregate is commonly used in the Jimma Town and its surround and as such, is readily available and best simulates normal construction practice in the region. Typical coarse aggregate sieve analysis are shown in Tables A1.2. In this study the physical properties of coarse aggregate test results and gradation chart are shown below in the Table 4.2 and Figure. As the Figure 4-1 results, describes the sieve size, cumulative percentage pass of course aggregate with grade limit for the coarse aggregate based on ASTM limit standard. Which explain, the aggregate does not lie between the standard limit in some extent, Coarse aggregate is not well graded one because sieve size in 4.75 mm cumulative percentage pass is the outside of grading system. This leads to the bondage between aggregates is minimum. The maximum size of aggregate is 37.5mm because all particles of aggregates passes sieve number 37.5mm size.

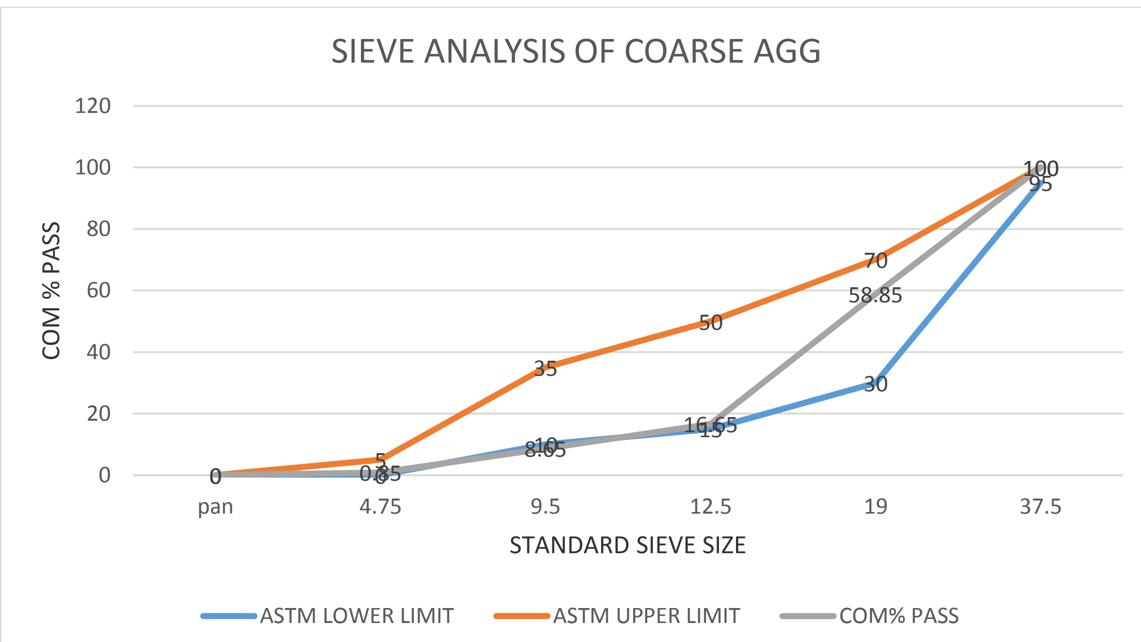


Figure 4- 1 Gradation chart of coarse aggregate

Table 4- 3: **Summarized test results for "Agaro" Crashed Stone/Coarse Aggregate**

Source of sample	Material type	Types of test		Test result
AGARO	CRUSHED AGREGATE	Unit weight	compacted	1589.4kg
		Bulk specific gravity	Oven dray	2.485
			SSD	2.512
			Apparent	2.562
		Water Absorption capacity		1.2275%
		Moisture content		0.894%
		Fineness		7.674
		Size of aggregate	Max.size	37mm
			Nominal Max.size	25mm

4.1.3. Fine Aggregates Property

The fine aggregate used in the concrete productions was natural river sands and they were dried to saturated and surface dry (SSD) state before any test was carried out. In addition to this, all fine aggregate which retain on 9.5mm sieve size were no longer relevant, and all the passing fine aggregate were used for experimentation.

As the Figure 4-2**,** describes the sieve size, cumulative percentage pass of Gambella sand with grade limit for the fine aggregate based on ASTM limit standard. Which explain that, sand lies between the standard limit. But there was small amount of fine sand less than 0.015mm compared to the standards.

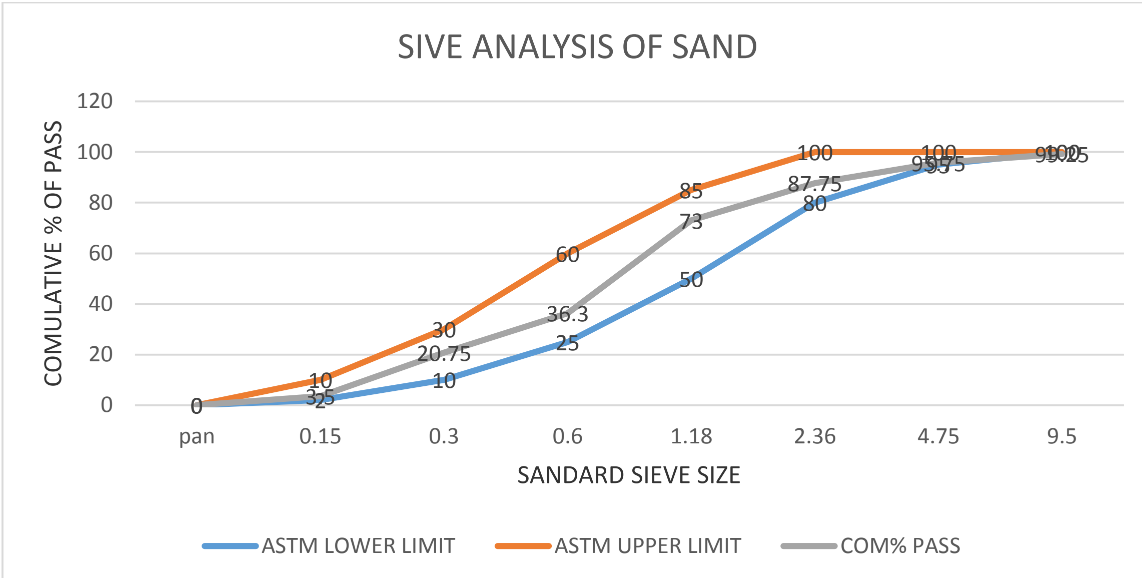


Figure 4- 2 Gradation chart of fine aggregate

Table 4- 4**: Summarized test results of sand.**

Source of sample	**Material type**	**Types of test**		**Test result**
Gambela	**FINE AGGREGATE AGREGATE/SAND**	Unit weight	compacted	1741.85kg
		Bulk specific gravity	Oven dray	2.570
			SSD	2.594
			Apparent	2.632
		Water absorption capacity		0.914%
		Moisture content		0.096%
		Silt/clay content		2.545
		fineness		2.835%

4.1.4 Pumice property

Investigations were made on pumice procured from Dangote cement factory as Dangote uses pumice from Meki query site. It was tested for chemical and physical properties per ASTM C 618%.The chemical and physical properties of the pumice used in this investigation are listed in Table 4.5 and Table 4.6 respectively. Pumice should be dry and grinding through grinding machine until its fineness 34% pass through 45μmm sieve size.

4.2 laboratory test results

4.2.1 Chemical composition and physical property of pumice test results

The rate of the pozzolanic reaction is dependent on the basic characteristics of the pozzolan such as the specific surface area and the chemical composition. The rate of the pozzolanic reaction can also be controlled by external factors such as the

- ✓ The mix proportions
- ✓ The amount of water
- ✓ The temperature of reaction.
- ✓ Replacement ratio
- ✓ Water to binder ratio
- ✓ Curing condition

According to the table 4-7, all chemical properties of used pumice in this research are compared with the acceptable ranges of ASTM C618 and they are all in range. The test result of the chemical Analysis is shown in table 4-7 below shown the result of the chemical analysis of pumice and this shows that the total content of Silicon Dioxide (SiO2), Aluminum Oxide (Al2O3) and Iron Oxide (Fe2O3) was 83.84% which is above the minimum of 70% specified in ASTM C 618, which is acceptable as a good pozzolan. Pumice has cementitious compounds like calcium oxide, alumina and iron oxide a total of about 16.84%. And the amount of carbon (Loss on ignition) in the pumice is 4.12% so the test not exceed 10%, which is acceptable to use as mineral admixture in Portland cement.

As shown in table 4-8 the physical property of pumice was conducted on the test fineness specific surface in (m^2/kg) and residue on 45 micron (wet sieving in %) is 377 m^2/kg and 30.05%. from the result the test results fulfill the requirements according to ASTM C-618.Therefor it is acceptable to use as mineral admixture in Portland cement.

Table 4- 5 Chemical composition test results of pumice

S.No	Chemical composition	Requirement ASTM C 618(%)	Test results %	Compare result
1	$(SiO_2+Al_2O_3+Fe_2O_3)$, %	70 minimum	83.84	In range
2	SiO_2, %	35 minimum	68.28	In range
3	Al_2O_3	-	8.71	
4	Fe_2O_3	-	6.93	
5	Cao	-	1.20	
6	MgO	5 maximum	0.08	In range
7	Moisture content	3 maximum	2.4	In range
8	Loss on ignition	Not Exceed 10%	4.12	In range

Table 4- 6 physical property of test results of pumice.

S.No	Characteristics	Requirement ASTM C 618	Test results	Compare result
1	Fineness Specific Surface (m^2/kg)	3200 min	377	In range
2	Residue on 45 micron (wet Sieving in %)	34 max	30.05	In range
3	Silka reactivity (%)	25min	-	-

4.2.2 FRESH PROPERTIES

4.2.2.1 Slump test results

Early age properties measure the workability and setting behavior of fresh concrete. These generally include slump, unit weight, setting time, and heat of hydration. The properties of fresh concrete are important because they affect the choice of equipment needed for handling and consolidation and because they may affect the properties of hardened concrete.

A concrete mix must be made of the right amount of cement, aggregates and water to make the concrete workable enough for easy compaction and placing and strong enough for good performance in resisting stresses after hardening. If the mix is too dry, then its compaction will be too difficult and if it is too wet, then the concrete is likely to be weak.

During mixing, the mix might vary without the change very noticeable at first. For instance, a load of aggregate may be wetter or drier than what is expected or there may be variations in the amount of water added to the mix. These all necessitate a check on the workability and strength of concrete after producing. Slump test is the simplest test for workability and are most widely used on construction sites. In the slump test, the distance that a cone full of concrete slumps down is measured when the cone is lifted from around the concrete. The slump can vary from nil on dry mixes to complete collapse on very wet ones. One drawback with the test is that it is not helpful for very dry mixes.

The mold for the slump test is in the form of a frustum of a cone, which is placed on top of a metal plate. The mold is filled in three equal layers and each layer is tamped 25 times with tamping rod. Surplus concrete above the top edge of the mold is struck off with the tamping rod. The cone is immediately lifted vertically and the amount by which the concrete sample slumps is measured. The value of the slump is obtained from the distance between the underside of the round tamping bar and the highest point on the surface of the slumped concrete sample. The types of slump i.e. zero, true, shear or collapsed are then recorded. Table 5.1 shows the results of the slump test for all mixes.

The result of the workability of the concrete mix on the samples at 0%, 30%, 40% and 50% percent of replaced cement with pumice are shown.

Table 4- 7 Results of workability tests

Workability	Cement replacement			
	0%	30%	40%	50%
Slump (mm)	65	65	60	60

From the results it can be seen in table 4-9 as the percentage replacement of OPC with pumice increases, the workability of concrete decrease. Replacing cement by an equal mass of pumice causes an increase in volume since the density of cement is higher than that of pumice. This therefore increases the water demand and as the pumice content increases the workability reduces since the quantity of water remains the same for all mixes. According to the mix design the slump of the concrete mix is 25-100mm so the result of the slump of all the four mixes as shown in figure 4.1 below are acceptable. as shown in figure 4.1 the replacement of cement with pumice at 30% is the same slump test result as comparing to control mix at 0% of replacement of cement with pumice and at 40% of replacement of cement with pumice the result of slump is 60 mm it show 7.7% of reduction in workability of the concrete mix and the same at 50% of replacement of cement with pumice. Therefore the overall results of the concrete mix when the percentage of pumice increase shows reduction in workability of the concrete. This is due to the specific surface of the pumice which is greater than cement.

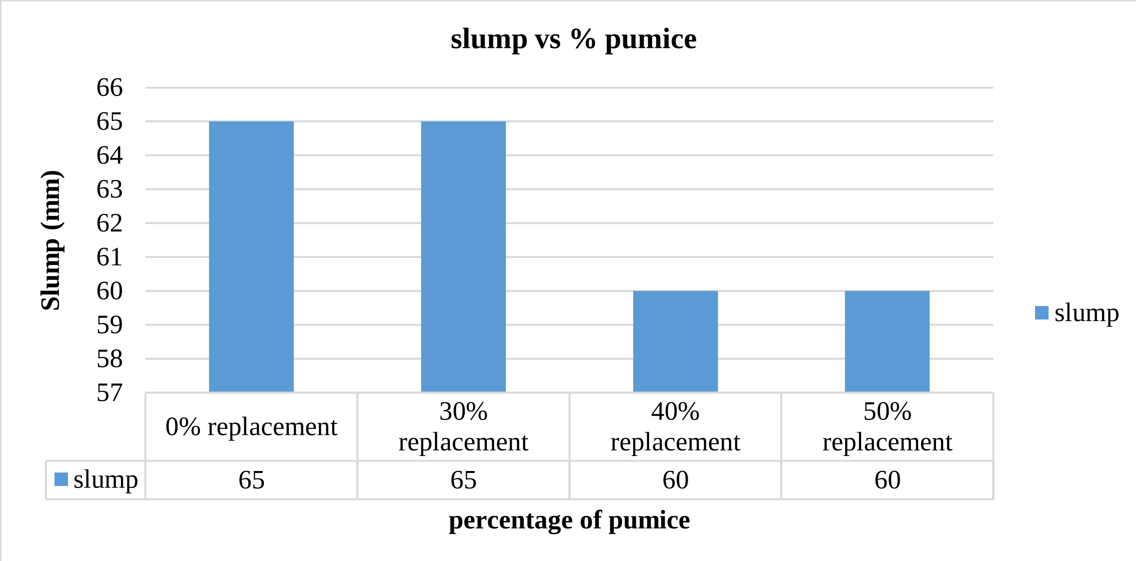


Figure 4- 3 slump test results

4.2.3 Hardened concrete

4.2.3.1 Compressive strength test results

In this part, the results of compressive strength experiments on the concrete C-25 different percentage of replaced cement with pumice are shown in table 4-10 and 4-11 below. Compressive strength was measured at different ages of 7 and 28 days. For each age of each concrete mixture, three concrete specimens were tested.

The average compressive strength of samples, tested in the ages of 7 and 28 days of curing with different values of (0%, 30%, 40% and 50%) replaced cement with pumice for concrete C-25 are presented shown in figure 4-5 below.

4.2.3.1.1 Effect of pumice on compressive strength

To quantify influences of pumice as a pozzolanic material on compressive strength of concretes, "Strength Coefficient Index" is defined in this study as below:

Strength Coefficient Index: SCI (%) = (A/B) × 100

Where:

A = average compressive strength of test concrete mixtures containing pumice MPa

B = average compressive strength of control mixtures without pumice, MPa

Table 4- 8 compressive strength at 7 day and % strength loss

Percent of pumice	No of samples	Failure Load (KN)	Compressive Strength (Mpa)	Unit weight (kg)	Percent of strength loss
0%	1	488.250	21.70	2.55	**Control Mix**
	2	457.875	20.35	2.47	,,
	3	499.275	22.19	2.45	,,
	Mean	**481.725**	**21.41**	**2.49**	,,
30%	1	414.500	18.42	2.43	13.96 **Compare**
	2	415.700	18.48	2.41	13.69 **Mean**
	3	414.600	18.43	2.42	13.92
	Mean	**414.930**	**18.44**	**2.42**	**13.87**
40%	1	274.700	12.21	2.33	42.97
	2	294.400	13.08	2.40	38.91 ,,,,,,
	3	287.500	12.78	2.39	40.31
	Mean	**285.530**	**12.69**	**2.37**	**40.73**
50%	1	216.400	9.612	2.35	55.11 **Compare**
	2	221.700	9.852	2.37	53.98 **Mean**
	3	220.500	9.800	2.36	54.23
	Mean		**9.76**	**2.36**	**54.42**

Table 4- 9 compressive strength at 28 day

Percent of pumice	No of saple	Failure load	Compressive Strength (Mpa)	Unit weight (Kg)	Percent of strength loss
0	1	776.250	34.50	2.55	**Control Mix**
	2	724.500	32.20	2.47	,,
	3	780.750	34.70	2.45	,,
	Mean	**760.500**	**33.80**	**2.49**	,,
30	1	717.750	31.90	2.47	5.62 **compare**
	2	693.000	30.80	2.53	8.88 **Mean**
	3	731.250	32.50	2.51	3.85
	Mean	**713.925**	**31.73**	**2.50**	**6.12**
40	1	667.350	29.66	2.43	12.25 **compare**
	2	642.375	28.55	2.41	15.53 **Mean**
	3	671.625	29.85	2.44	11.69
	Mean	**660.450**	**29.35**	**2.43**	**13.17**
50	1	596.250	26.50	2.36	21.59 **compare**
	2	580.500	25.80	2.39	23.67 **Mean**
	3	603.000	26.80	2.41	20.71
	Mean	**594.000**	**26.40**	**2.38**	**21.89**

From the figure 4-4 the average compressive strength of at 7 day with replacement of 30%, 40%, and 50% is 86.13%, 59.27 and 45.58% respectively of the compressive strength of the control mix. The compressive strength of at 28 day with replacement of 30%, 40%, and 50% is 93.88%, 86.83% and 78.11% respectively of the compressive strength of the control mix. Table below shows the strength coefficient index comparing to control mix.

Table 4- 10 strength coefficient index

SCI (%)	30% replacement	40% replacement	50% replacement
7-day	86.13	59.27	45.58
28 day	93.88	86.83	78.11

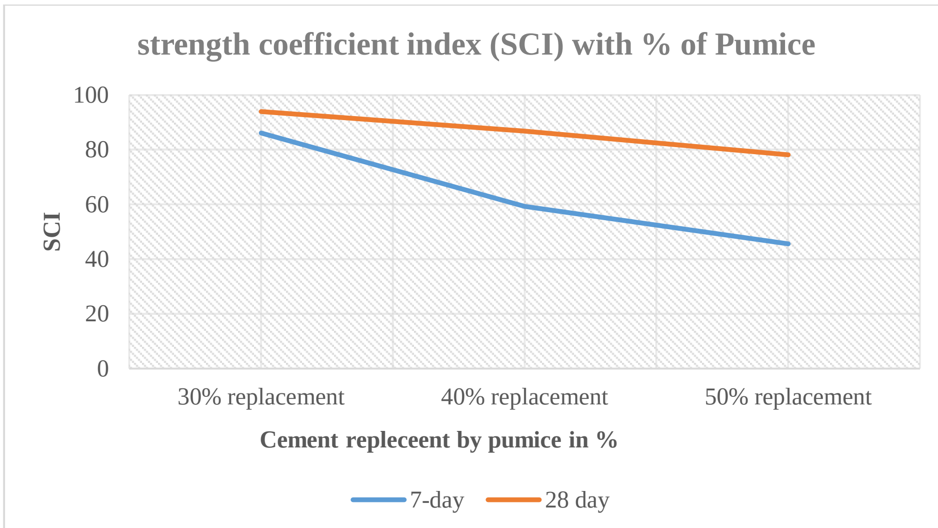


Figure 4- 4 Strength coefficient index (SCI) with % of Pumice for compressive strength

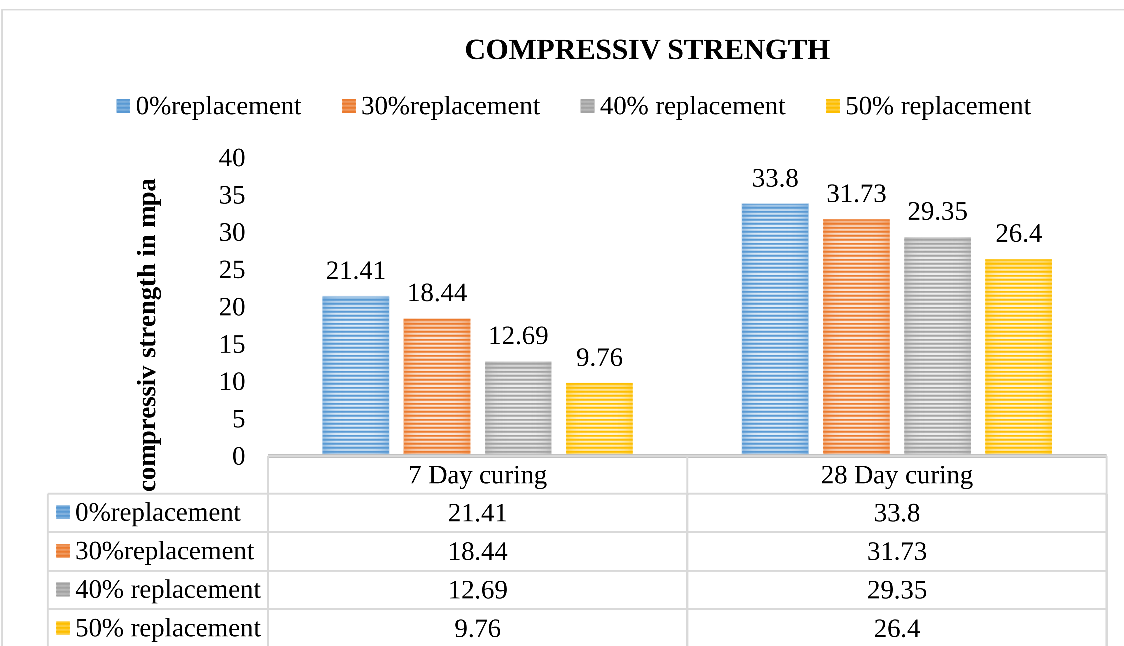


Figure 4- 5 Average Compressive strength test result

According to different studies natural pozzolona promote to the strength gain of concrete. However, the strength of concrete containing these materials can be higher or lower than the strength of concrete using Portland cement as the only cementing material. But from the figure shown in figure 4-5 and 4.7 that the compressive strength decrease as the replacement percentage of pumice increase. The result from the figure 4-7 shows that increase the replacement of pumice resulted reduction in compressive strength compared to control concrete mix. This reduction increase with increase of percentage of pumice. Loss in compressive strength at 7 day of curing at 30 percent replacement is 13.87%, at 40% replacement is 40.73 and at 50% replacement is 54.42% see in figure 4-6.

With regard to the dominant C-S-H forming reaction, it is appropriate to compare hydration reactions of Portland cement and pozzolanic material and Portland cement. The main reactions in these two situations are as below:

Portland cement:

$$\mathbf{C_3S + H \xrightarrow{\text{Fast}} C\text{-}S\text{-}H + CH}$$

Portland-pozzolanic cement:

$$\text{Pozzolona} + CH + H \xrightarrow{\text{Slow}} C\text{-}S\text{-}H$$

In general, the reaction between a pozzolan and calcium hydroxide is known as the pozzolanic reaction. There are three main technical benefits of using pozzolanic materials which are explained below.

- The reaction is slow; therefore, the rates of heat liberation and strength development will be accordingly slow.
- Second, the reaction is lime-consuming instead of lime producing, which has an important bearing on the durability of the hydrated paste in acidic environments.
- Third, pore size distribution studies of hydrated

Loss of compressive strength at 28 day of curing at 30% replacement of pumice is 6.12%, at 40% replacement of pumice is 13.17% and at 50% replacement of pumice is 21.89%.

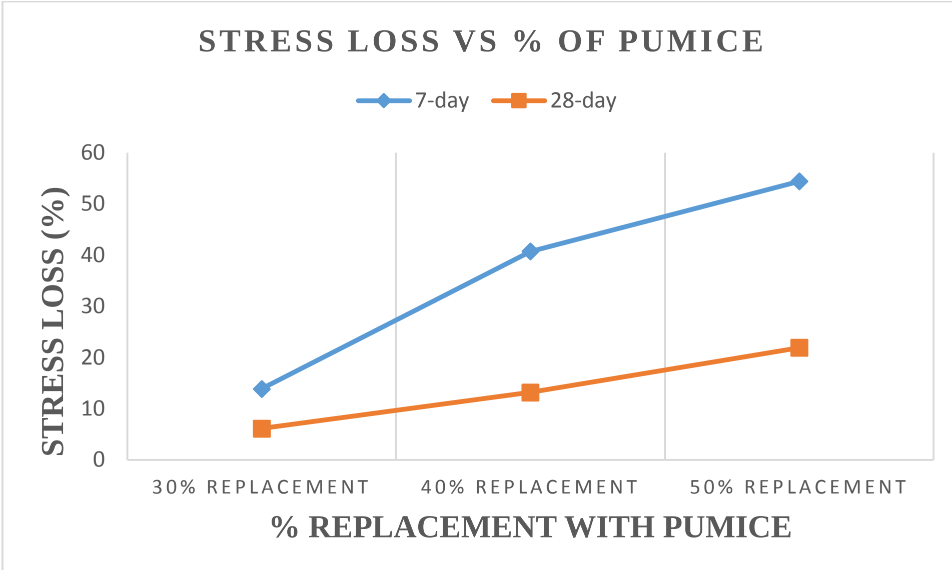
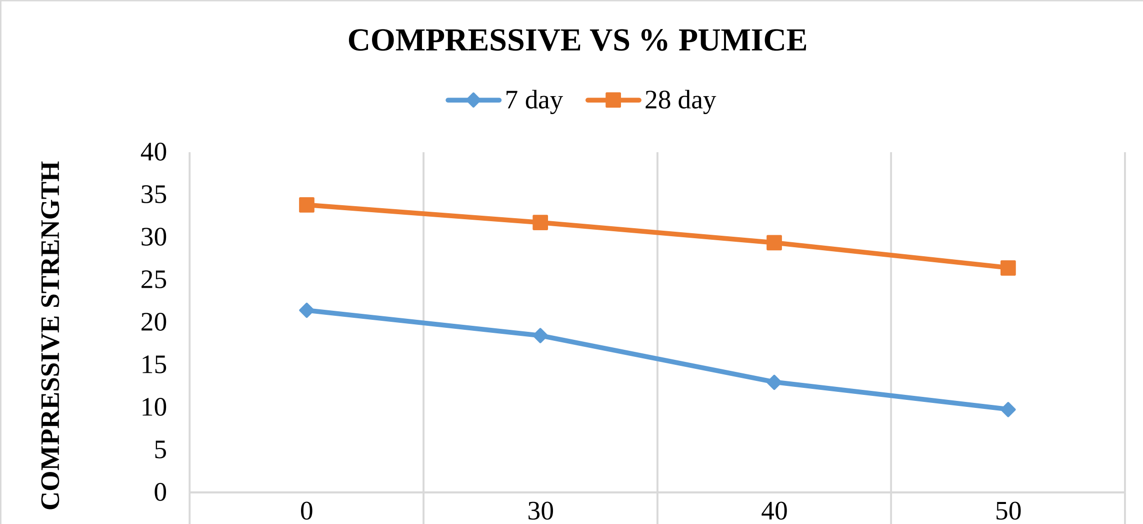


Figure 4- 6 compressive stress loss vs percent of pumice

Concrete grows its strength from the pozzolanic reaction between silica in pozzolana and the calcium hydroxide liberated during the hydration of OPC. At low percentages of replacement, the quantity of silica is low, therefore, only a limited quantity of C-S-H can be formed, though a large quantity of calcium hydroxide is liberated due to the relatively large quantity of Portland cement. However, at high percentage replacement, the quantity of pozzolana in the mix increases, C-S-H reduces due to liberation of a small quantity of calcium hydroxide from the hydration of the relatively small quantity of Portland cement available. The strength of concrete at 0% and 30% is high comparing to 40% and 50% replacement of cement with pumice. It can also be concluded that the strength of concrete depends on the relative proportions of silica in pumice (Pozzolona) and calcium hydroxide on ordinary Portland cement.

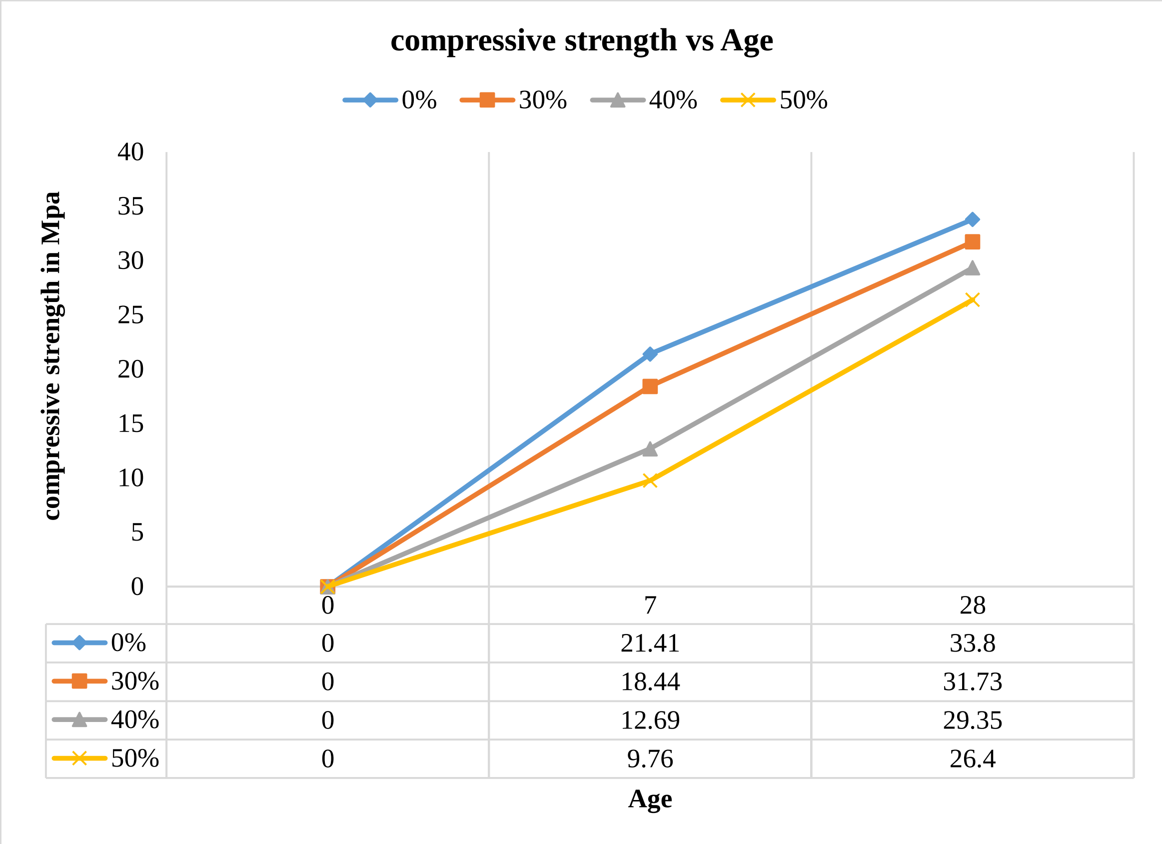


	0	30	40	50
7 day	21.41	18.44	12.96	9.76
28 day	33.8	31.73	29.35	26.4

Figure 4- 7 compressive strength vs % pumice

In previous works done in the case of mechanical properties of concretes with cement replaced with pozzolans, it is mentioned that the effect of using pozzolan is growing the compressive strength of concrete in long life. Here we can see that this result is show in figure 4-8 increase in compressive strength as the age of the concrete increase. Pozzolanic reaction begins immediately after hydration of cement and continues for a long time thereby increasing strength. Concrete approximately the same compressive strength result pumice replacement of 30%**;** corresponding to an increase of 5.22% in the 28-day strength compared to the control concrete mix. Similarly at replacement of 40% is 20.1% and at replacement of 50% is 26.34% in the 28-day strength compared to the control concrete mix.

The concept of later-age strength requirement is relevant and applicable. Based on this concept, it is possible to make sustainable concrete with 50% replacement of Portland cement with pumice.



	0	7	28
0%	0	21.41	33.8
30%	0	18.44	31.73
40%	0	12.69	29.35
50%	0	9.76	26.4

Figure 4- 8 Compressive strength Vs Age of concrete

- **Comparison of compressive strength with characteristics of compressive strength**

It is known the compressive strength at 7th day the concrete should attained 65% of the characteristics of the compressive strength. In this research the characteristics compressive strength is C-25 so the results of the average compressive strength shown in figure 4-5 at 7th day at 0% and 30% of replacement of cement with pumice attained 85.64% and 73.76% respectively. Similarly the compressive strength at 40% and 50% replacement of cement with pumice attained 50.76% and 39.04% respectively. And also the compressive strength at 28 day the concrete should attained 99% of the characteristics compressive strength or specified strength so the result of the average compressive strength at 28 day of curing at 0%, 30%, 40% and 50% replacement of cement with pumice attained beyond the specified compressive strength shown in figure 4-5. Strength rising in pozzolanic Portland cement at the beginning for a specific pozzolan is related to the amount of replaced cement with pozzolan. In many countries, it is allowed to replace up to 40% of hydraulic cement with pozzolan with the condition of feat the needed compressive strength. In this research it is allowed to replace up to 50% of hydraulic cement with pumice.

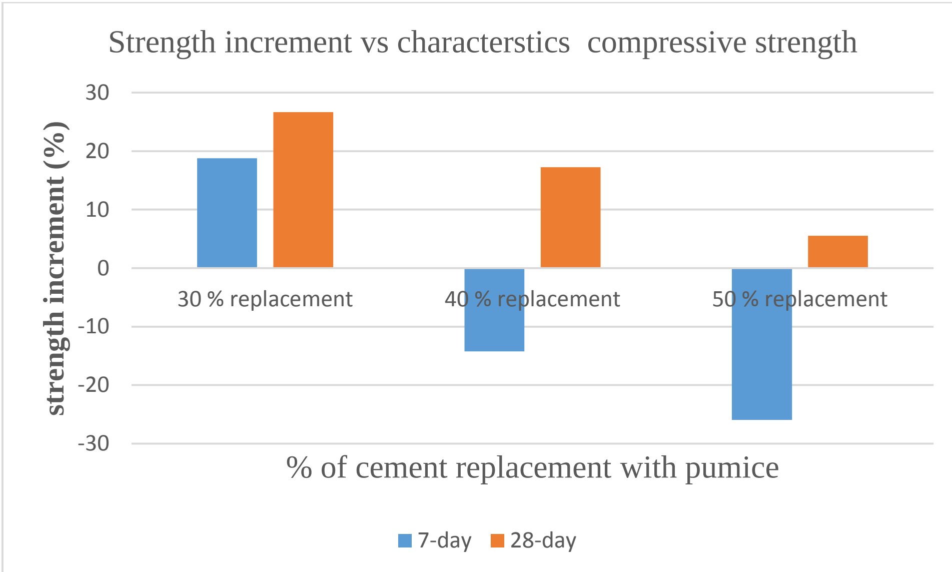


Figure 4- 9 strength increment vs specified compressive strength

- **Comparison of compressive strength with mean target compressive strength**

In this research the mean compressive strength is 33.5Mpa at 28 day so the result shown in figure 4-5 the average compressive strength at 30%, 40% and 50% is below the mean compressive strength except the control mix is slightly above the Mean compressive strength.

4.2.3.2 Flexural strength

4.2.3.2.1 Effect of pumice on flexural strength

In this part, the results of flexural experiments on the concrete C-25 different percentage of replaced cement with pumice are shown.

The flexural strength of samples, tested in the ages of 7 and 28 days of curing with different values of (0%, 30%, 40% and 50%) replaced cement with pumice for concrete C-25 are presented in figure 4-11. Table below shows the strength coefficient index comparing to control mix.

Strength Coefficient Index: SCI (%) = (A/B) × 100

Where:

A = average flexural strength of test concrete mixtures containing pumice MPa

B = average flexural strength of control mixtures without pumice, MPa

Table 4- 11 strength coefficient index

SCI (%)	30% replacement	40% replacement	50% replacement
7-day	93.41	85.42	76.82
28-day	92.27	90.93	74.76

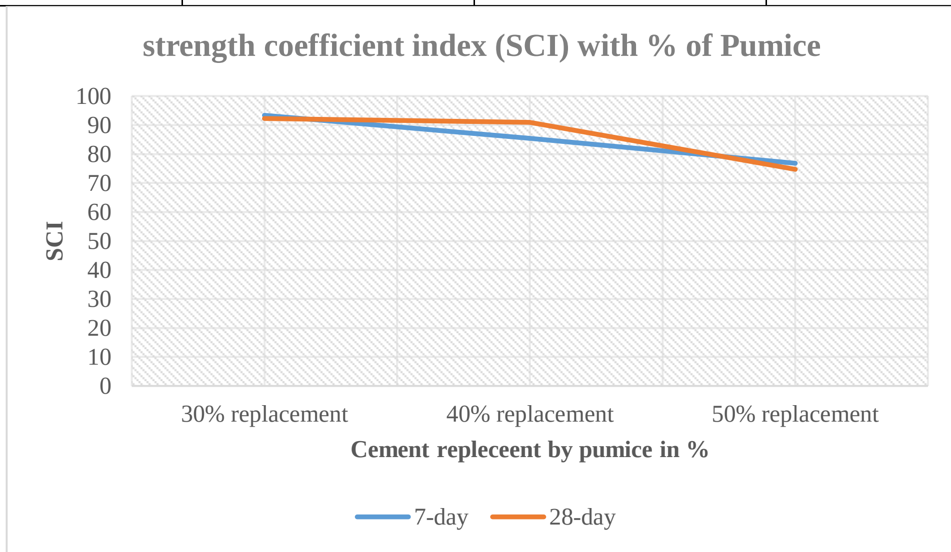


Figure 4- 9 Strength coefficient index (SCI) with % of Pumice for flexural strength

From the figure 4-9 above the result of flexural strength at 7 day curing day with 30% replacement of cement with pumice is 93.49% of the flexural strength of the control mix, with 40% replacement of cement with pumice is 85.42% of the flexural strength of the control mix and with 50% replacement of cement with pumice is 76.82% of the flexural strength of the control mix. The flexural strength at 28 day curing day with 30% replacement, 40% replacement, and 50% replacement of cement with pumice is 92.7%, 90.93%, & 74.06 % respectively the flexural strength of the control mix.

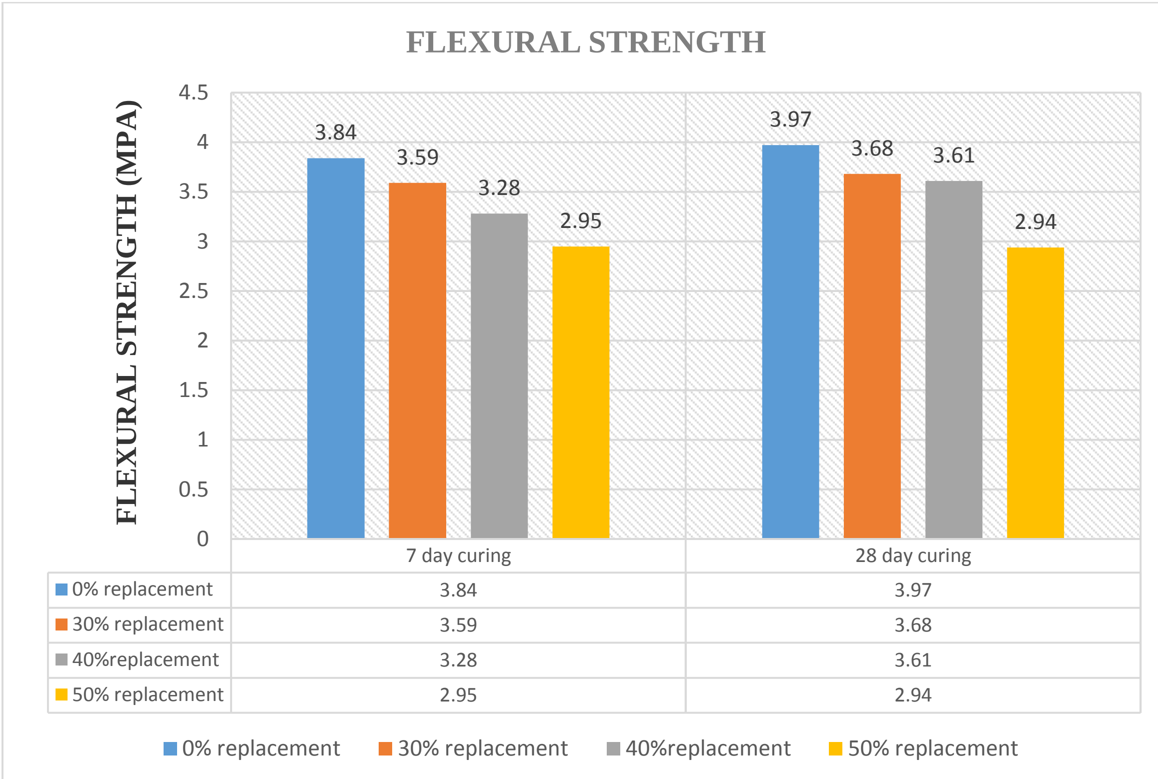


Figure 4- 10 Average flexural strength test result

Table 4- 12 flexural strength at 7 day and stress loss

%pumice	Sample no	P[kN]	M[N.m]	I[m^4]	C[cm]	Stress [Mpa]	% flexural stregth Loss
0%	1	3.855	642.50	8.3333E-06	5.00	3.86	**Control mix**
	2	3.667	611.17	8.3333E-06	5.00	3.67	,,
	3	3.995	665.83	8.3333E-06	5.00	3.99	,,
	Mean	**3.839**	**639.83**			**3.84**	**,,**
30%	1	3.779	629.83	8.3333E-06	5.00	3.78	1.56 **Compare**
	2	2.995	499.17	8.3333E-06	5.00	2.99	22.14 **Mean**
	3	3.985	664.17	8.3333E-06	5.00	3.99	-
	Mean	**3.586**	**597.67**			**3.59**	**6.51**
40%	1	3.731	621.83	8.3333E-06	5.00	3.73	2.86 **Compare**
	2	3.045	507.50	8.3333E-06	5.00	3.05	20.57 **Mean**
	3	3.055	509.17	8.3333E-06	5.00	3.06	20.31

	Mean	**3.277**	**546.17**			**3.28**	**14.58**
50%	1	3.155	525.83	8.3333E-06	5.00	3.15	17.97
	2	2.655	442.50	8.3333E-06	5.00	2.66	30.73 **Compare**
	3	3.050	508.33	8.3333E-06	5.00	3.05	20.57 **Mean**
	Mean	**2.953**	**492.17**			**2.95**	**23.18**

Table 4- 13 flexural strength at 28 day and stress loss

%pumice	Sample no	P[kN]	M[N.m]	I[m^4]	C[cm]	**Stress [Mpa]**	**Percent stress loss**
0%	1	3.875	645.83	8.3333E-06	5.00	3.88	**Control mix**
	2	3.865	644.17	8.3333E-06	5.00	3.87	,,
	3	4.155	629.50	8.3333E-06	5.00	4.16	,,
	Mean	**3.965**	**660.83**			**3.97**	**,,**
30%	1	3.885	647.50	8.3333E-06	5.00	3.89	2.01 **compare**
	2	3.165	527.50	8.3333E-06	5.00	3.17	20.15 **Mean**
	3	3.995	665.83	8.3333E-06	5.00	4.00	10.31
	Mean	**3.682**	**613.67**			**3.68**	**7.3**
40%	1	3.751	625.17	8.3333E-06	5.00	3.75	5.54 **Compare**
	2	3.735	622.50	8.3333E-06	5.00	3.74	5.79 **Mean**
	3	3.335	555.83	8.3333E-06	5.00	3.34	15.87
	Mean	**3.707**	**617.83**			**3.61**	**9.07**
50%	1	3.150	525.00	8.3333E-06	500	3.15	20.65 **Compare**
	2	2.675	445.83	8.3333E-06	5.00	2.68	32.49 **Mean**
	3	3.000	500.00	8.3333E-06	5.00	3.00	24.43
	Mean	**2.942**	**490.00**		5.00	**2.94**	**25.94**

The loss of flexural strength at 7 day curing is 6.51% in 30% replacement, 14.58% in 40 % replacement and 23.18% in 50% replacement of cement with pumice. The loss of stress at 28 day of curing at replacement of 30%, 40%, and 50% is 7.3%, 9.07% and 25.94% respectively. From figure 4-12 below shows the reduction of flexural stress due to the percentage increment of pumice. This is due to reduction of C-S-H in the concrete mix.

Generally from the figure 4-13 show that the flexural strength dramatically increase through age of curing except at 50% replacement of cement with pumice. The results of experiments show a slightly reduction in the flexural strength of concrete by increasing the value of used pumice in mix design. Most of the researchers mentioned in their works that if pozzolan participate in the chemical reactions of concrete, can change flexural strength of concrete positively and improve it. Since in this research, shows that flexural strength of concrete shows slightly reduction with replacement of cement with pumice as shown in figure 4-12.

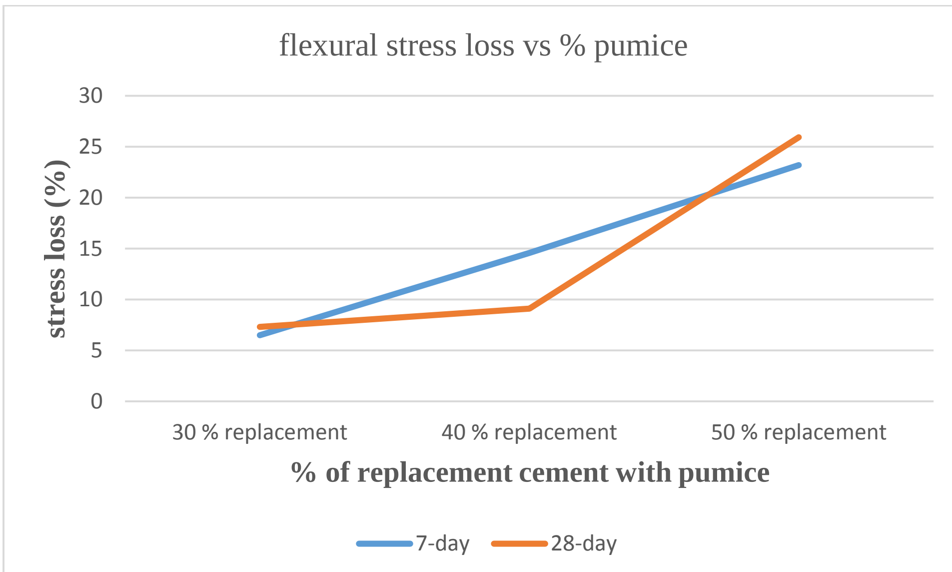


Figure 4- 11 Flexural stress loss VS % of pumice

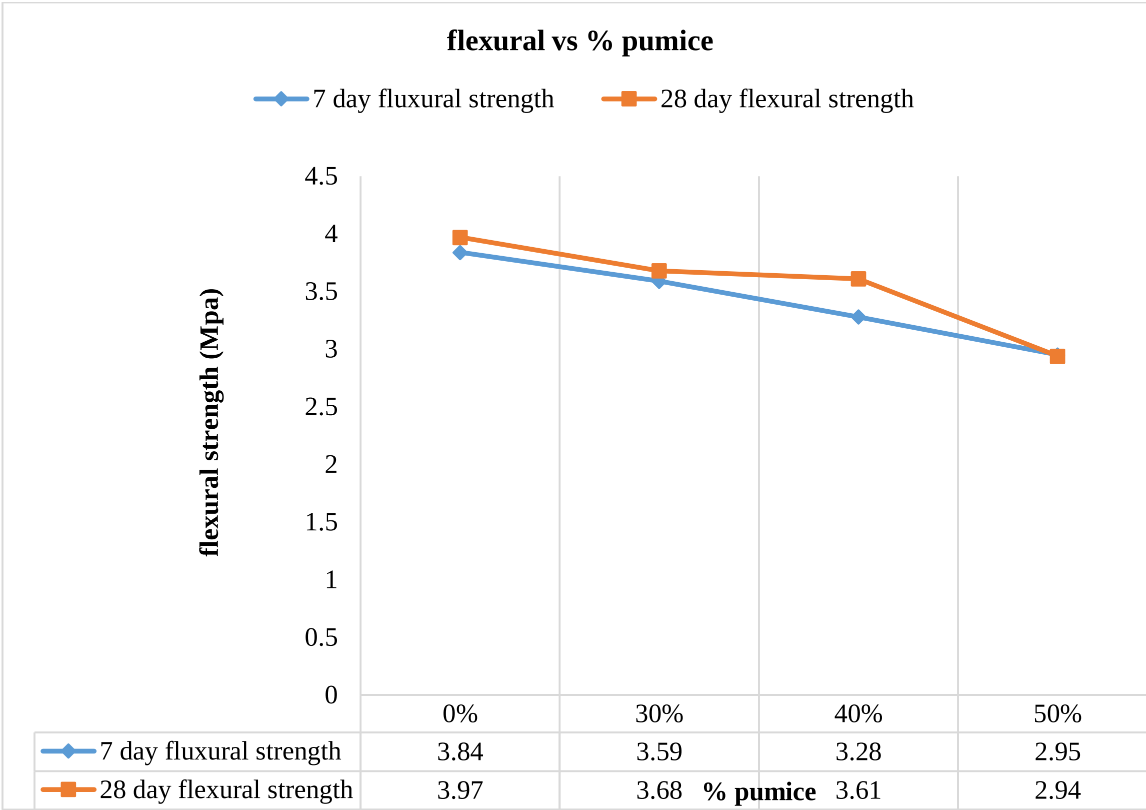


Figure 4- 12 flexural vs % pumice

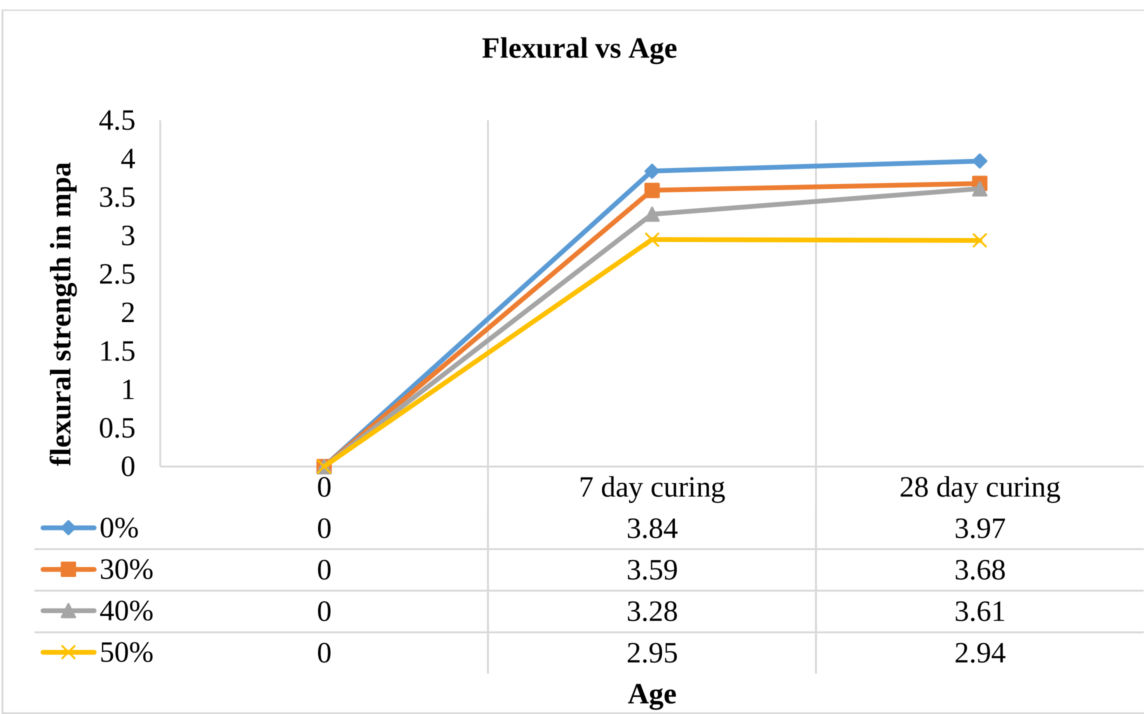


Figure 4- 13 Flexural VS Age

CEMENT REPLACEMENT WITH HIGH CONTENT OF PUMICE ON MECHANICAL PROPERTY OF CONCRETE

Generally pumice is a pozzolanic material which has more than 70% of SiO2. However, it has been well-known that pozzolanic reactions are slower than hydration reaction of Portland cement and when substantial part of Portland cement is replaced with supplementary cementitious materials, there is always a possibility of seeing a lower rate of strength gain while final strength is same due to chemical and physical effects of supplementary cementitious materials. Strength gaining is observed in all percentage of replacement except in 50% replacement which shows reduction in flexural strength.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

In the present research, for C-25 grade of concrete is studied. Four different percentage of replacing cement with pumice 0% (without any pumice as a control sample), 30%, and 40%, and 50% selected to be tested. For all above mix designs, samples tested on the curing age of 7 days and 28 days. The effect of using local pumice in the mix design of concrete on compression and flexural strength was observed and bellow results achieved:

1. From the laboratory test results of the physical properties and chemical composition of the natural pumice material satisfy the requirements of ACTM-618 so we can use it as natural pozzolona for the replacement of cement for the production of concrete.
2. The slump value at 0%, 30%, 40% and 50% replacement of cement with pumice were 65mm, 65mm, 60mm, and 60mm respectively. Therefore the workability of concrete with replacement of cement with pumice slightly show reduction in workability of the concrete. With percentage increment of pumice the mix needs water demand. To control the stiffness of the concrete it is necessarily to add water during mixing by controlling the slump of the mix design. Therefore this study conclude that workability of the concrete depend on density and specific surface of the material.
3. The average compressive strength results at 0%, 30%, 40%, and 50% replacement of cement with pumice were 21.41Mpa, 18.44Mpa, 12.69Mpa, and 9.76Mpa respectively at the age of 7 day of curing and 33.8Mpa, 31.73Mpa, 29.35Mpa, and 26.4Mpa respectively at the age of 28 day of curing. The compressive strength of the concrete mix shows reduction due to increment of pumice content comparing to the control mix. But all percentage of the replacement of cement with pumice satisfies the specified compressive strength or characteristics strength of the concrete. This study conclude that the compressive strength of the pozzolonic concrete depends on the amount of silicon oxide on the pozzolona and calcium hydro oxide on ordinary Portland cement.

4. The flexural strength results at 0%, 30%, 40%, and 50% replacement of cement with pumice were 3.84Mpa, 3.59Mpa, 3.28Mpa, and 2.95Mpa respectively at the age of 7 day of curing and 3.97Mpa, 3.68Mpa, 3.61Mpa, and 2.94Mpa respectively at the age of 28 day of curing. The flexural strength of the concrete mix shows reduction due to increment of pumice content comparing to the control mix. But flexural strength in all percentage replacement of cement with pumice were satisfies the requirement, as flexural strength is 10% of the compressive strength of the concrete. This study conclude that the flexural strength of the pozzolonic concrete depends on the amount of silicon oxide on the pozzolona and calcium hydro oxide on ordinary portland cement.

5.2. Recommendation

1. Portland pozzolona cement is one of the alternative cementing materials well suited to our construction industry with technical, economic and environmental benefits. Therefore concerned bodies should be made aware and promote production and use of these cement type with high content to replace Portland cement.
2. Since there is enough quantity of pumice in Ethiopia with required chemical composition, it is possible to replace 50% of pumice as replacement of cement for the production of Portland pozzollona cement (PPC).
3. In Ethiopian cement industry, it is known they add a maximum of 25% of natural pozzolona for the production of PPC. Therefore, cement production companies as well as governmental decision makers together with professional’s particularly material engineers should take an active part to manipulate the existing resource for using it economically.
4. The following suggestions for further studies is forwarded:
   - ✓ This research is done only with the same water cement ratio, it is recommended for further study another research with the same cement replacement percentages and also different water cement ratios to see the effect of water cement ratio also.

- ✓ In this research the age of the concrete were 28 day of curing therefore it is recommended to observe the results of experiments for the curing age of older than 28 days.
- ✓ In this research for handling of concrete mix was through hand mixing so there is an effect on the result, therefore it is recommended for further study , the mix through mechanical mixer for effective result.
- ✓ In this research, the concrete grade was C-25 grade of concrete so try with same replacement of cement percentage to high grade of concrete strength.

REFERACES

[1] British Standard Institution, *Specifications for Portland cement*. BSI, London, BS 12:1996.

[2] Chengzhi Z., Aiqin W., Mingshu T. and Xiaoyu L, *Cement and Concrete Research*, 26(6), 943-947 1996.

[3] Crow, J. M., the Concrete Conundrum. Available at http://www.chemistryworld.com (Accessed July 28, 2012)

[4] Hewlett P; Lea's Chemistry of Cement and Concrete. 4th ed., Elsevier. London, 2004.

[5] Jackson, M., Sagnotti, L., Rochette, P. and Sølheid, P., the IRM Quarterly, 13(3), 112. Fall 2003.

[6] Mindess S., Young J.F.and Darwin, D, Concrete. 2nd ed.: Prentice Hall. London, 2003.

[7] Murdock., T.G. Pumice Deposit in Lake Verdi, 1994.

[8] Carr, D., Industrial Minerals and Rocks. 6th Edition. Society for Mining, Metallurgy and Exploration, Inc. Littieton, Colorado, 1994.

[9] Canadian Standards Association, CAN/CSA A3000-98, 'Cementations Materials Compendium‖, 193 pgs, 2000

[10] Day, Robert L.,Pozzolans, for use in low-cost housing, A state of the art report prepared for the international development research center, Ottawa, Canada, 1990

[11] Malquori, G. Portland pozzolan cement, Chemistry of Cement, proc. Of 4th Intnl. Symp, Washington, VII, pp 983 – 1005 (with discussion), 1960.

[12] Hammond A.A., Pozzolana cements for low cost housing. Proceedings of a symposium on appropriate building materials for low cost housing, p: 73-83. Nairobi, 1983.

[13] Malhotra V. M., Metha P. K., High performance, high volume flyash concrete. , Supplementary cementing materials for sustainable development 2nd ed. Ottawa, ONT, 2005.

[14] Sersale, R., "Structure and characterization of pozzolans and fly ashes" On the Chemistry of Cements, Pans, Sub Theme IV-1, pp. 1-18, Proc 7th Int. Cong., 1980.

[15] Takemoto, K., and Uchikawa, H., "Hydration of pozzolanic cement", Proc. &th Int. Cong. On the Chemistry of cements, Paris, Sub Theme IV-2, pp.1-28, 1980.

[16]Tasouji, M.E., Design and control of Concrete mix design”, Tehran, Mighat Publications, First Edition, 1986.

[17] Costa, U., and Massaza, F., “Factors affecting the reaction with lime ofItalian pozzolans”, 11 Cemento 71, pp.131-139, 1974.

[18] Chatterjee, M. K., and Lahiri, D., “pozzolanci activity in relation to specific surface of some artificial pozzolanas”, Trans. Indian Ceramic Soc.26, pp.6-74, 1967.

[19] Smith, M.A., and Halliwell, F., “The application of the BS 4550 test for pozzolanic cements to cements pulverized-fuel ashes”, Magazine Conc. Res.31, pp.159-170, 1979.

[20] Price, W.H., “pozzolans- a review”. J. Amer. Conce. Inst., pp.225-232, 1975.

[21] Ahmadi Moghadam, H., “A research and comparison between mechanical properties of concrete with and without pozzolan”, Master Thesis, Bahonar University of Kerman, (2006).

[22] Wild, S., Sabir, B., and Khatib. J. M., “factor influencing strength development of concrete containing silica fume”, Cement and Concrete Research, Vol. 25, No. 1 (1995).

[23] Metha, P.K., “Pozzolanic and cementitous by products as mineral admixtures for concrete-a critical review”, Proceeding of the International conferenceon the use of fly ash, Silica Fume, Slag, other mineral Byproducts in concrete, ACI, SP-79, Vo1, Edit V.M.Malhotra, (1983).

[24] Loland, E.K. and Hustad, T., “Silica in concrete-mechanical properties”, cementand concrete instituts of the newegian, Institute of Technology, Report No. STP 65A 811031, (1981).

[25] Davis, R.E. “A review of pozzolanic materials and their use on concrete”, Symp. On Pozzolanic Materials in Mortars and Concretes, STP-99, ASTM, pp.3-15, (1950).

[26] Mather, B., “Use of concrete of low Portland cement in combination with pozzolans and other admixtures in construction of concrete Dams”, J.Amer. Conc. Inst., pp.589-599, (1974).

[27] Masazza, F., "Chemistry of pozzolanic additions and mixed cements", Principal paper, Proc.6th Int.comg. On the chemistry of cements, Moscow, (1974).

[28] Mather, B., "Use of concrete of low Portland cement content in combination with pozzolans and other admixtures in construction of concrete dams", J. Amer .Conc.Inst.,P.71, 589-599, (1974).

[29] Davis, R.E., Kelly, J.W. and Troxell, G.F., and Davis, H.E., "Properties of mortar sand concretes containing Portland-pozzolan cements", Proc. J. Amer.Conc. Inst. 32, pp.80-114, (1935).

[30] Mehta, P.K., "Studies on blended Portland cements containing Santorin earth", Cem. Con. Res., pp.11, 507-518, (1981).

[31] Abdun & Nur, E.A., "Fly ash in concrete, an evaluation", Highways Research Bulletin 284, (1961).

[32] Ghosh, R.S., and Timask, J., "Creep of fly ash concrete", ACI journal vol. 78, No. %, P351, 1981.

[33] Lane, R.D., and Best, J.F., "Properties and use of fly ash in Portland cement concrete", Concrete Institute, Vol.4, No.7, (1981).

[34] Tuthill, L.H., and Cordon, W.A., "Properties and uses of initially retarded concrete", Proc.J.Amer. Conc.Inst.52, PP.273-286, (1955).

[35] Wallace. G.B., and Ore, E.L., "Structural and lean mass concrete as affected by water reducing, set-retarding agants", Symp, on Effect of Water- Reducing Adminxtures and Set Retarding Admixtures on Properties of concrete, STP 266, ASTM, pp.38-94, (1960).

[36]Maghsoudi, A.A., Ahmadi Moghadam, H.,"Using Nano-particles and their effect on mechanical properties of common concretes in dams", Karaj, First National Symposium of Dams and Hydraulic Structures, (2006).

[37] Mehta, P.K., "Rice husk ash – unique supplementary cementing material", In:V.M. Malnotra (Ed), Proceedings of the International Symposium on advances In Concrete technology. Cammet/Act. Sthens, Greece, pp. 407-430, (1992).

[38]Chemical materials of construction, "The Use of Micro Silica Gel in Concrete", (2006).

[39] Neville, A.M., “Concrete Technology”, Pearson Education, (2008).

[40] Lea, F.M., “The chemistry of cement and concrete”, Edward Amold, London, (1970).

[41] Turriziani, R., and Rio, A., “High chemical resistance pozzolanic cements”, Proc. 4th Int. Symp., On the chemistry of Cements, Washington, PP.1067-1073, (1960).

[42] Massazza, F., and Costa, U., “Aspects of the pozzolanic activity and properties of pozzolanic cements”. The cement 76, pp.3-18, 1979.

[43] Metha, P.K., “Studies on blended protland cements containing Santorin earth”, Cement and Concrete Research, pp.507-518, (1981).

[44] Murdock, T.G., Pumice Deposit in Lake Verdi 1994.

[45] ASTM C618-78, “Specification for fly ash and raw or calcined natural pozzolan for use as a mineral admixture in Portland cement concrete”.

[46] ASTM C441-89, “Effectiveness of Mineral Admixtures of Ground Blast-Fumace Slag in Preventing Execessive Expansion of Concrete Due to the Alkali-Silica Reaction”.

[47] Abebe Dinku, Construction Materials Laboratory Manual, Addis Ababa University Printing Press, Addis Ababa, 2002.

[48] HOSSAIN, K. M. A. & LACHEMI, M., Performance of volcanic ash and pumice based blended cement concrete in mixed sulfate environment. *Cement and Concrete Research*, 36**,** 1123-1133, 2006.

[49] GUNDUZ, L.,The effects of pumice aggregate/cement ratios on the low-strength concrete properties. *Construction and Building Materials,* 22**,** 721-728, 2008.

[50] Karimaian. K. A., Amrane, A., Kazemian, H., Panahi, r. & Zarrabi, M.,Retention of phosphorous ions on natural and engineered waste pumice: Characterization, equilibrium, competing ions, regeneration, kinetic, equilibrium and thermodynamic study. *Applied Surface Science,* 284**,** 419-431, 2013.

[51] CAVALERI, L., MIRAGLIA, N. & PAPIA, M., Pumice concrete for structural wall panels. *Engineering Structures,* 25**,** 115-125, 2003.

[52] OZODABAS, A. & YILMAZ, K., Improvement of the performance of alkali activated blast furnace slag mortars with very finely ground pumice. *Construction and Building Materials*, 48**,** 26-34, 2013.

[53] Anon., .Ethiopia's Climate -Resilient Green Economy: Green economy strategy, 2011.

APPENDIX 1

MATERIALS TEST RESULTS

1.1. Properties of Cement

1.1.1. Fineness of Hydraulic Cement

Calculation

Calculate the fineness of the samples as: $F = 100 - \left[\frac{R_s * 100}{W}\right]$

Where:

F= fineness of cement expressed as the percentage passing the sieve,

Rs = residue from sample retained on the sieve,

W = weight of sample, gm,

Laboratory results

W=100gm Rs=5gm

$F = 100 - \left[\frac{R_s * 100}{W}\right] = 100 - \left[\frac{5*100}{100}\right]$ =**95% passing**

OR 100%-95%=**5% retaining**

Note: - According to Ethiopian Standard the weight of residue left on the sieve should be less or equal to 10% of the total cement in treatment for ordinary Portland cement.

Therefore the cement type is **OPC.**

1.1.1. Normal Consistency of Hydraulic Cement

According to Ethiopian Standard the usual range of water-cement ratio for normal consistency is between 26% and 33% and the paste is said to be of normal consistency when the rod settles 10±1 mm below the original surface within thirty seconds.

Calculation $\% \text{water} = \frac{\text{weight of water in g}}{\text{weight of cement in g}} * 100$

Table A1- 1**:** Consistency of Hydraulic Cement.

Wt. of Cement (gm)	500	500	500	500	500	500	**500**
% of water	26	27	28	29	30	31	**32**
Wt. of water (gm)	130	135	140	145	150	155	**160**
Penetration depth(mm)	5	6	6.5	7	8	8.7	**9.3**

1.2. Properties of Coarse Aggregate

1.2.1. Sieve Analysis

Table A1- 2**:** Sieve analysis for coarse aggregate.

SIEVE SIZE	**Wt.retained** (gm)	**Wt.retained** (%)	**Com (%) retained**	**Com (%) pass**	**ASTM LIMIT**	
					LOWER	**UPPER**
37.5	0	0	0	100	100	100
19	4115	41.15	41.15	58.1	30	70
12.5	4220	42.20	83.35	16.65		
9.5	800	8	91.35	8.65	10	35
4.75	780	7.8	99.15	0.85	0	5
Pan	85	0.85	100	0		
TOTTAL	10000	100				

1.2.2. Unit weight

1.2.2.1. Compacted Unit weight and Loose Unit Weight

- For Maximum Size of coarse aggregate 37.5mm
- Cylinder have –height (h) =30cm and Diameter (D) =25cm

$$A = \frac{\pi D^2}{4} \qquad V=A*h$$

Table A1- 3**:** Compacted weight of coarse aggregate Initial sample mass=3219.3 g

Sample	Wt. Of cylinder metal (Kg)	Wt. Of cylinder + Wt. Of sample (Kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt. Of Sample (Kg)	Vol. Of cylinder (m^3)	Unit Weight (Kg/m^3)
Sample-1	9.99878	32.648	0.3	0.25	23.37888	0.0147	1590.4
Sample-2	9.99878	32.05	0.3	0.25	23.34948	0.0147	1588.4
Average(Mean)							**1589.4**

1.2.3 Specific gravity

Weight of oven dry sample in air (mass A) = 3176.5 gm

Weight of saturated surface dry sample in air (mass B) = 3213.3 gm

Weight of saturated sample in water (mass C) = 1943.5 gm

- **Bulk specific gravity:**

$$Bulk\ Spe.gra = \left[\frac{A}{(B - C)} \right]$$

.

$$Bulk\ Spe.gra = \left[\frac{3176.5}{(3213.3 - 1943.5)} \right] = 2.485$$

- **Bulk specific gravity (saturated surface dry basis):**

$$Bulk\ Spe.gra = \left[\frac{B}{(B - C)} \right]$$

$$Bulk\ Spe.\ gra = \left[\frac{3213.3}{(3213.3 - 1943.5)} \right] = 2.52$$

➢ **Apparent specific gravity**

$$Apparent\ Specific\ gravity = \left[\frac{A}{(A - C)} \right] \quad ......Equ.5A$$

$$Apparent\ Specific\ gravity = \left[\frac{3176.5}{(3176.5 - 1943.5)} \right] = 2.562$$

➢ **Absorption capacity:**

$$Absorption\ Capacity = \left[\left[\frac{(B - A)}{A} \right] *100 \right]$$

$$Absorption\ Capacity = \left[\left[\frac{(3213.3 - 3176.5)}{3176.5} \right] * 100 \right] = 1.227\%$$

1.2.4. Moisture content

A = weight of original sample = 2000 gm

B= weight of oven dry sample = 1975 gm

MC= moisture content (%)

$$MC = \left[\frac{(A - B)}{B} \right] * 100$$

MC= [(2000-1975)/1975] = 1.27%

1.3. Properties of Fine Aggregate

1.3.1. Silt/clay content

A= percentage of material that is finer than 75µm (#200) sieve size (percentage of silt/clay content)

B= Original dry mass before wash

C= Dry mass of sample after washed

$$A = \left[\frac{(B - C)}{B} \right] * 100$$

Total Silt/Clay % = A+ % silt/clay amount on pan after sieving Dry washed sample (D)

For instance, silt/clay content of the sand

B=1224.9gm C= 1197.5gm D=0.308 %

$$A = \left[\frac{(1224.9 - 1197.5)}{1224.9} \right] * 100 = 2.237\%$$

Total silt/clay %=2.237%+0.308%=**2.545%**

1.3.2. Sieve Analysis

Table A1- 4 sieve analysis for sand

SIEVE SIZE	Wt.retained (gm)	Wt.retained (%)	Com (%) retained	Com (%) Pass	ASTM LIMIT	
					LOWER	UPPER
9.5	15	0.75	0.75	99.25	100	100
4.75	70	3.5	4.25	95.75	95	100
2.36	160	8	12.25	87.75	80	100

1.18	295	14.75	27	73	50	85
0.6	730	36.5	63.5	36.3	25	60
0.3	315	15.74	79.25	20.75	10	30
0.15	345	17.25	96.5	3.5	2	10
PAN	60	3.5	100	0		
TOTTAL	**1990**	**283.5**				

Fineness Modulus (FM) for the sand sample

$$Finnes\ modulus = \frac{\sum (com\%\ rtained)}{100} \ldots\ldots\ldots.. \frac{283.5}{100} = 2.835$$

1.3.4. Unit weight

1.3.4.1. Compacted Unit weight of Sand

Cylinder (Mold) Mass=4063.2 gm   Internal Diameter =15.5cm

Internal Height = 15.5cm   Volume of the Mold= 0.002925m^3

Table A1- 5**:** Compact unite weight of sand

Compacted Unit Weight of sand							
Sample	Wt. Of cylinder metal (Kg)	Wt. Of cylinder + Wt. Of sample(Kg)	Height of cylinder (m)	Dia. of cylinder (m)	Wt. Of sample (Kg)	Vol. Of cylinder (m3)	Unit Weight (Kg/m3)
Sample-1	4.0632	9.1441	0.155	0.155	5.0809	0.002925	1737.06
Sample-2	4.0632	9.1721	0.155	0.155	5.1089	0.002925	1746.632
Average(Mean)							**1741.846**

1.3.5. Specific gravity (Relative density) and water absorption

Formula used for the calculation of Bulk Specific gravity and water absorption of Fine aggregates.

$$Bulk\ Spe.gra.(Oven\ Dry) = \left[\frac{D}{(A-(B-C)}\right]$$

$$\text{Spe.gra. (SSD)} = \left[\frac{A}{(A-(B-C)}\right]$$

$$Apparent\ Spe.gra. = \left[\frac{D}{(D-(B-C)}\right]$$

$$Water\ Absorption\ Capacity = \left[\left[\frac{(A-D)}{D}\right]*100\right]$$

For instance, the bulk specific gravity and water absorption for GSU was calculated as showed below and also for all the sand samples calculated in this way.

Relative density(Bulk Specific gravity) and Water Absorption Capacity					
Specimen reference	Symbol	Unit	Trail		Average
			1	2	
Mass of saturated-dry fine aggregate in Air	A	g	502.7	501.6	
Mass of vessel +sample filled with water	B	g	1035.9	1037.5	
Mass of vessel filled with water only	C	g	727.8	728.5	
Mass of oven dry fine aggregate in air	D	g	497.8	497.4	
Relative density on an oven -dry basis	γd_{ry}	g/m3	2.558	2.583	**2.570**

Relative density on a SSD basis	γ_{SSD}	g/m3	2.583	2.604	**2.594**
Apparent relative density (Bulk spe. Gravity)	$\gamma_{App.}$	g/m3	2.624	2.640	**2.632**
Water Absorption Capacity	$W_{abso.}$	%	0.984	0.844	**0.914**

Table A1- 6**:** Bulk specific gravity and water absorption for Sand

1.3.6. Moisture content of the fine aggregate

The moisture content of the fine aggregates was performed by using Equ.6A; For instance, the moisture content of the sand for sample-1 and for all sand samples followed the same procedure.

A = weight of original sample = 914.48gm

B= weight of oven dry sample = 913.6 gm

MC= moisture content (%)

$$MC = \left[\frac{(914.48 - 913.6)}{913.6} \right] * 100 = 0.096$$

Sand sample	Weight of sample before dray(gm)	Weight of sample after oven dray(gm)	Moisture content (MC) (%)	
1	914.48	913.6	0.096	**0.096**
2	952.40	951.5	0.095	

Table A1- 7**:** Moisture content for fine (sand) sample

1.3.7. Bulking of the fine aggregate (Sand)

Bulking of sand samples was determined as showed below:-

$$BS(\%) = \left[\frac{(A - B)}{B} \right] * 100$$

.

For instance, the Bulking of the sand for sample-1 and for all sand samples followed the same procedure.

A = weight of original sample = 400 ml

B= weight of oven dry sample = 360 ml

$$BS\ (\%) = \left[\frac{(400 - 360)}{360} \right] * 100 = 11.11\%$$

Table A1- 8 bulk of fine aggregate

Sample of sands		Original volume (V1) ml	Volume after bulking of sand (V2) ml	% of Bulking (BS)	Average Bulking (%)
Sand	sample-1	400	360	11.11	**10.619**
	sample-2	400	363.2	10.13	

APENDEX 2

MECHANICAL PROPERTIES TEST RESULTS

2.1 compressive strength test result

Table A2- 1: Compressive strength at 7 days test results

(%) of pumice	No of Samples	Dimensions of cubical mold (cm)			Sample Weight (kg)	Volume of cub (cm3)	Failure Load (KN)	Compressive Strength (MPa)	Unit Weight (gm/cm3)
		L	W	H					
0%	1	15	15	15	8.600	3375	488.250	21.70	2.55
	2	15	15	15	8.350	3375	457.875	20.35	2.47
	3	15	15	15	8.255	3375	499.275	22.19	2.45
	Mean						**481.725**	**21.41**	**2.49**
30%	1	15	15	15	8.185	3375	414.500	18.42	2.43
	2	15	15	15	8.145	3375	415.700	18.48	2.41
	3	15	15	15	8.155	3375	414.600	18.43	2.42
	Mean						**414.930**	**18.44**	**2.42**
40%	1	15	15	15	7.850	3375	274.700	12.21	2.33
	2	15	15	15	8.100	3375	294.400	13.08	2.40
	3				8.050	3375	287.500	12.78	2.39
	Mean						**285.530**	**12.69**	**2.37**
50%	1	15	15	15	7.945	3375	216.400	9.612	2.35
	2	15	15	15	7.990	3375	221.700	9.852	2.37
	3	15	15	15	7.960	3375	220.500	9.800	2.36
	Mean						**219.53**	**9.760**	**2.36**

Table A2- 2: Compressive strength at 28 days test results

(%) of pumice	No of Samples	Dimensions of cubical mold (cm)			Sample Weight (kg)	Volume of cub (cm^3)	Failure Load (KN)	Compressive Strength(MPa)	Unit Weight (gm/cm3)
		L	W	H					
0%	1	15	15	15	8.605	3375	776.250	34.50	2.55
	2	15	15	15	8.350	3375	724.500	32.20	2.47
	3	15	15	15	8.250	3375	780.750	34.70	2.45
	Mean						**760.500**	**33.80**	**2.49**
30%	1	15	15	15	8.350	3375	717.750	31.90	2.47
	2	15	15	15	8.550	3375	693.000	30.80	2.53
	3	15	15	15	8.455	3375	731.250	32.50	2.51
	Mean						**713.925**	**31.73**	**2.50**
40%	1	15	15	15	8.200	3375	667.350	29.66	2.43
	2	15	15	15	8.150	3375	642.375	28.55	2.41
	3	15	15	15	8.250	3375	671.625	29.85	2.44
	Mean						**660.450**	**29.35**	**2.43**
50%	1	15	15	15	7.950	3375	596.250	26.50	2.36
	2	15	15	15	8.050	3375	580.500	25.80	2.39
	3	15	15	15	8.125	3375	603.000	26.80	2.41
	Mean						**594.000**	**26.40**	**2.38**

Table A2- 3 Flexural strength at 7th day of curing test results

%pumice	Sample no	Dimension[cm]			P[kN]	M[N.m]	I[m^4]	C[cm]	Stress [Mpa]
		L	B	D					
0%	1	50	10	10	3.855	642.50	8.3333E-06	5.00	3.86
	2	50	10	10	3.667	611.17	8.3333E-06	5.00	3.67
	3	50	10	10	3.995	665.83	8.3333E-06	5.00	3.99
	Mean				**3.839**	**639.83**			**3.84**
30%	1	50	10	10	3.779	629.83	8.3333E-06	5.00	3.78
	2	50	10	10	2.995	499.17	8.3333E-06	5.00	2.99
	3	50	10	10	3.985	664.17	8.3333E-06	5.00	3.99
	Mean				**3.586**	**597.67**			**3.59**
40%	1	50	10	10	3.731	621.83	8.3333E-06	5.00	3.73
	2	50	10	10	3.045	507.50	8.3333E-06	5.00	3.05
	3	50	10	10	3.055	509.17	8.3333E-06	5.00	3.06
	Mean				**3.277**	**546.17**			**3.28**
50%	1	50	10	10	3.155	525.83	8.3333E-06	5.00	3.15
	2	50	10	10	2.655	442.50	8.3333E-06	5.00	2.66
	3	50	10	10	3.050	508.33	8.3333E-06	5.00	3.05
	Mean				**2.953**	**492.17**			**2.95**

Table A2- 4 Flexural strength at 28th day of curing test results

%pumice	Sample no	Dimension[cm]			P[kN]	M[N.m]	I[m^4]	C[cm]	**Stress [Mpa]**
		L	B	D					
0%		50	10	10	3.875	645.83	8.3333E-06	5.00	3.88
		50	10	10	3.865	644.17	8.3333E-06	5.00	3.87
		50	10	10	4.155	629.50	8.3333E-06	5.00	4.16
	Mean				**3.965**	**660.83**			**3.97**
30%		50	10	10	3.885	647.50	8.3333E-06	5.00	3.89
		50	10	10	3.165	527.50	8.3333E-06	5.00	3.17
		50	10	10	3.995	665.83	8.3333E-06	5.00	4.00
	Mean				**3.682**	**613.67**			**3.68**
40%		50	10	10	3.751	625.17	8.3333E-06	5.00	3.75
		50	10	10	3.735	622.50	8.3333E-06	5.00	3.74
		50	10	10	3.335	555.83	8.3333E-06	5.00	3.34
	Mean				**3.707**	**617.83**			**3.61**
50%		50	10	10	3.150	525.00	8.3333E-06	500	3.15
		50	10	10	2.675	445.83	8.3333E-06	5.00	2.68
		50	10	10	3.000	500.00	8.3333E-06	5.00	3.00
	Mean				**2.942**	**490.00**		5.00	**2.94**

APPENDIX 3

MIX DESIGN CALCULATION

Properties of materials

Absolute Volume Method (Metric)

Conditions and Specifications:

Concrete is required for **concrete structural work** (i.e. Reinforced foundation walls, Plain footing, caissons, Substructure walls footing, Beams and reinforced , Building columns, Pavement and slabs etc. that will not be exposed to moisture in a severe freeze-thaw environment. A specified compressive strength, of 25 MPa is required at 28 days. Slump should be between 25 mm and 75 mm. A nominal maximum size aggregate of 25 mm is required. The materials available are as follows:

For C-25 concrete

- **Cement**

Ordinary Portland cement –Muger 42.5R Cement Grade

Specific gravity =3.15 (ASTM C 1157-standard performance specification for hydraulic cement)

- **Coarse aggregate**

Crashed Aggregate was used

Specific gravity and water absorption capacity

- Maximum Aggregate size =37.5mm
- Nominal Maximum Aggregate size=25mm (ASTM C33-standard specification for Concrete aggregate or AASHTO M 80-coarse aggregate for Portland cement concrete)

- Average Result
  - ✓ Ave. Bulk spe. Gravity (ODM)=2.485
  - ✓ Ave. Bulk spe. Gravity (SSDM)=2.515
  - ✓ Ave. Apparent spe. Gravity=2.562
  - ✓ Ave. Absorption Capacity=1.84 %
  - ✓ Compacted Unit Weight=**1589.4** Kg/m3

- ✓ Moisture content**=0.894%**
- ✓ **Ave. F.M=7.674**

Sand/Fine aggregate

- Gambella Sand was used
- ✓ Moisture content = **Ave. MC (%) = 0.503%**
- ✓ Bulking of Sand (%) =Ave.BS=10.619% and Bulking Factor = Ave.BF=1.106
- ✓ Compacted Unit Weight**=**1743.54 Kg/m3
- ✓ **Ave. FM=2.84**
- ✓ Silt /clay content=**6.28% in field test**
- ✓ **Specific gravity of Sand-**
- ✓ Relative density on an oven -dry basis=**2.570**
- ✓ Relative density on a saturated & surface dry basis=**2.594**
- ✓ Apparent relative density=**2.632**
- ✓ Water Absorption Capacity =**0.914%**
- **Mix Calculation: –**

Strength: Concrete is required for Mass concrete that will not be exposed to moisture in a severe freeze-thaw environment, for the specified compressive strength 21-35 Mpa the target compressive strength(fcr') from Table 9-11 is equal to fc'+ 8.5. Therefore, fcr'= 25 + 8.5 = **33.5 MPa.**

Water to Cement Ratio: The recommended water to cementitious material ratio for a ft' of 33.5 Mpa is 0.491 from interpolated from Table 9-3 [{(35 –33.5) (0.54 – 0.47) / (35 – 30)} + 0.47 = **0.491**].

Air Content: From Table 9-5 recommends a target air content of 1.5 % for a 25-mm nominal maximum size aggregate.

Slump: The slump is specified at 25 mm to 100 mm. Use 50 mm ±25 mm for proportioning Purposes.

Water Content: Table 9-5 recommend that a 25-50 mm slump, for non-air-entrained concrete made with 25-mm nominal maximum-size aggregate should have a water content of about **179 kg/m3**.

Cement Content: The cement content is based on the recommended water-cement ratio and the water content. Therefore, 179 kg/m3 of water divided by a water-cement ratio of 0.491 requires a cement content of **364.562 kg/m3≈365 kg/m3**

Coarse-Aggregate Content: The quantity of 25-mm nominal maximum-size coarse aggregate can be estimated from Table 9-4. The bulk volume of coarse aggregate recommended when using sand with a fineness modulus of 2.84 is 0.67. Since it has a bulk density of 1589.4 Kg/m3, the oven dry mass of coarse aggregate for a cubic meter of concrete is 1589.4 X 0.67 = **1064.898 Kg≈ 1065 kg**

Fine-Aggregate Content: At this point, the amounts of all ingredients except the fine aggregate are known. In the absolute volume method, the volume of fine aggregate is determined by subtracting the absolute volumes of the known ingredients from 1 cubic meter. The absolute volume of the water, cement and coarse aggregate is calculated by dividing the known mass of each by the product of their relative density and the density of water. Volume computations are as follows:

Water $\frac{179}{1\times1000}$ = $0.179m^3$

Cement $\frac{365}{3.15\times1000}$ = $0.116m^3$

Air $\frac{1.5}{100}$ = $0.015m^3$

Coarse aggregate $\frac{1065}{2.485\times1000}$ = $\underline{0.429m^3}$

Total volume of ingredients **$0.739m^3$**

The calculated absolute volume of fine aggregate is then 1 – 0.739 = 0.261 m3

The mass of dry fine aggregate is 0.261 x 2.570 x 1000 = 670.77kg **≈ 671 kg**

The mixture then has the following proportions before trial mixing for one cubic meter of concrete:

Table A2- 5proportion of ingredients in Kg.

Materials	Proportion mass in (kg)
Water	179
Cement/pumice	365
Fine aggregate	671
Coarse aggregate	1065
Total mass	2280

- ✓ Slump 50 mm (±25 mm for trial batch)
- ✓ Ave. Absorption Capacity=1.84 %.....for Coarse Aggregate
- ✓ Water Absorption Capacity =0.914%......For Fine Aggregate
- ✓ Estimated concrete density (using SSD aggregate) = 179 + 365 + (1065 x 1.012*) + (671 x 1.009*) = **2299 kg/m3**

Moisture: Corrections are needed to compensate for moisture in and on the aggregates. In practice, aggregates will contain some measurable amount of moisture. The dry-batch weights of aggregates, therefore, have to be increased to compensate for the moisture that is absorbed in and contained on the surface of each particle and between particles. The mixing water added to the batch must be reduced by the amount of free moisture contributed by the aggregates. Tests indicate that for the coarse-aggregate moisture content is 0.894% and fine-aggregate moisture content is 0.098%.

With the aggregate moisture contents (MC) indicated, the trial batch aggregate proportions become:

Coarse aggregate (0.894% MC) = 1065 x 1.009 = **1075 kg**

Fine aggregate (0.503% MC) = 671 x 1.005 = **774 kg**

Water absorbed by the aggregates does not become part of the mixing water and must be excluded from the water adjustment. Surface moisture contributed by the coarse aggregate amounts to 0.894% – 1.227% = -0.333%; that contributed by the fine aggregate is, 0.503%- 0.914%

= - 0.411%. The estimated requirement for added water becomes

179 – (1065 x (-0.003)) – (671 x (-0.00411)) = 185 kg

The estimated batch weights for one cubic meter of concrete are revised to include aggregate

Moisture as follows:

Table A2- 6 revised proportion of ingredients of concrete

Materials	Proportion mass in kg
Water	185
Cement/pumice	365
Fine aggregate	774
Coarse aggregate	1075
Total mass	2399

Trial Batch: At this stage, the estimated batch weights should be checked by means of trial batches or by full-size field batches. Enough concrete must be mixed for appropriate air and slump tests and for casting the three Cubic's required for 28-day compressive-strength tests. For a laboratory trial batch it is convenient, in this case, to scale down the weights to produce 0.02 m3 of concreteas follows:

Table A2- 7 trail batch table

materials	Proportion in mass (Kg)	
water	185× 0.02	3.70
Cement/pumice	365× 0.02	7.30
Fine aggregate	774× 0.02	15.48
Coarse aggregate	1075 × 0.02	21.5
Total		47.98

Table A2- 8 Mix Ratio

Material	Cement/pumice	Fine aggregate	Coarse aggregate	Water
Mass	7.3Kg	15.48Kg	21.5Kg	3.70Kg
Ratio	1	2.121	2.95	0.51

APPENDEX 4

SAMPLE PHOTO GALLERY TAKEN DURING THE RESEARCH


Photo: During taking of Pumice Sample



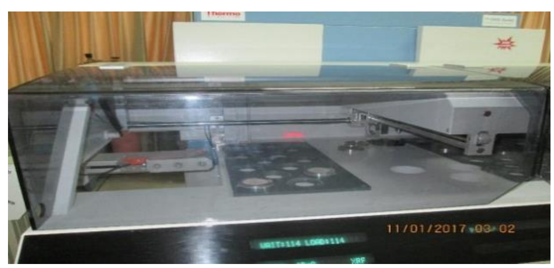



Photo: Taking During chemical and physical property test


Photo: Taking of aggregate samples from site






Photo: taken during material test


Photo: during lubricating of molds


Photo: during weighing of materials for mixing of concrete


Photo: during mixing and slump test of concrete

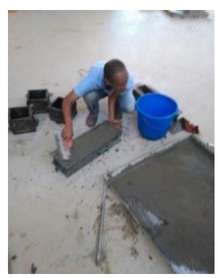




Photo: during casting of concrete and curing of concrete

Photo: During before and after testing of compressive strength

Photo: During before and after testing of flexural strength

Photo: Failure of concrete cube and beam