Jimma University

School of Graduate Studies

Jimma Institute of Technology

Civil Engineering Department

Construction Engineering and Management Stream

INVESTIGATION ON SELF-CURING CAPACITY OF LIGHT WEIGHT CONCRETE USING RED ASH AS AN AGGREGATE

A Thesis submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Master of Science in Civil Engineering

BY

Yeshi Getachew

September, 2016

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BY: Yeshi Getachew

Main Advisor: Prof. Emer T. Quezon

Co-Advisor: Eng. Getachew Kebede (MSc)

September, 2016

JIMMA, ETHIOPIA

DECLARATION

I, the undersigned, declare that this thesis entitled "**Investigation on self-curing capacity of light weight concrete using red ash as an aggregate** "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 dually acknowledged.

Candidate:

Ms. Yeshi Getachew

Signature________________________________

As Master research Advisors, we hereby certify that we have read and evaluate this MSc research prepared under our guidance, by Ms. Yeshi Getachew entitled: **Investigation on self-curing capacity of light weight concrete using red ash as an aggregate.**

We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

Prof. Emer T.Quezon ______________________ __________

Advisor Signature Date

Engr. Getachew Kebede ____________________ __________

Co-Advisor Signature Date

ABSTRACT

Concrete is most widely used construction material due to its good compressive strength and durability. According to (Nilson, 2004) depending upon the nature of the work cement, fine aggregate, coarse aggregate and water are mixed in specific proportions to produce plain concrete. Plain concrete needs amiable atmosphere by providing moisture for a minimum period of 28 days for good hydration and to attain desired strength. The properties of hardened concrete, especially the durability, are greatly influenced by curing since it has an effect on the hydration of the cement.

Any carelessness activity in curing will badly affect the strength and durability of concrete. Self-curing concrete is one of the special concretes in mitigating insufficient curing due to human negligence, scarcity of water in arid areas, inaccessibility of structures in difficult terrains. This study was focused on the self- curing capacity of light weight concrete using red ash as an aggregate. The main objective of this study is to evaluate self- curing capacity of light weight concrete using red ash as an aggregate.

This thesis deals with an experimental investigation on the self-curing capacity of light weight concrete replacing coarse and fine aggregate with light weight aggregate (LWA) specifically the red ash and natural sand. Two different concrete mixes having both natural sand and red ash sand with red ash coarse aggregate as a common for the two types of mixes and control mix by natural gravel and natural sand (i.e.RRCO 2, RNCO2 and GNCO2) were prepared for normal strength (C-25) using a water cement ratio and cement content of 0.48, 360kg/m3 respectively. Concrete was cured outside the water at ambient temperature for 7, 14 and 28 days.

The results of the hardened properties of the mixes have shown that concrete mix with pre-wetted red ash coarse aggregate and natural sand achieve a higher self-curing capacity and compressive strength with the value 34.28 Mpa at the 28thday curing period than the normal concrete by self-method of curing. The self-curing capacity and the compressive strength of concrete mix with natural gravel and natural sand is less than the curing capacity mix by red ash aggregates. This study also reveal that potential of this technology in saving the waste time to showering or other conventional curing method, reduce waste of fresh water in the curing time of concrete as well as the costs saved to the manpower for the follow up curing activity and reduce costs for material. It is recommended that to use red ash, the quality test for each source of red ash must be taste and the government create an awareness for contractors, client and suppliers to use red ash coarse aggregate instead of natural coarse aggregate using the internal method of curing.

Keywords: *Self –curing, Capacity, Light weight aggregate, Light weight concrete*

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ABBREVIATIONS

μm	micrometer
ACI	American Concrete Institute
ASTM	American society for testing and materials
BUDSWS	Building & Urban Design & Supervision Works Sectors
GNC2	Gravel coarse and Natural sand aggregates concrete
Kg/m^2	kilo gram per meter square
Kg/m3	kilogram per meter cube
KN/m2	kilo newton per meter square
LWAC	Lightweight Aggregate Concrete
LWC	Lightweight Concrete
M^3	meter cube
Mm	millimeter
Mpa	mega Pascal
OPC	Ordinary Portland cement
RNC	Red ash coarse and natural sand fine aggregate concrete
RRC	Red ash coarse and fine aggregate concrete
UK	United Kingdom

CHAPTER ONE

INTRODUCTION

1.1. Background

Ethiopia is one of the countries which exist in the fast growing in Africa. One of growing manifestation of the country is the available of modern construction industry. Always if there are the issues of construction we mean the components of the construction material in addition to other supplementary components. Currently the construction industry are being in continues growth not only in the expansion aspect but also in the modernity sense. The technological growth up of material assess in the direction of the availability of the material, increase of quality with the optimum cost and safe for the work. In Ethiopia the construction industry, construction with the concrete work is almost the same in the production method and in the type of ingredients of concrete.

The construction in Ethiopia nowadays is becoming wide and need attention to follow up the quality, the cost of material, method of construction technology, finishing time of the construction, percentage of problem alleviate beside of construction directly or indirectly and others must be seen.

Recently, the construction of building sector, construction of road and high way sector and other structures like bridge, slab culvert, culvert etc. are found in ongoing status. This is the indication of how much Ethiopia need construction materials.

Ethiopia is located in the Horn of Africa between 2000 and 3000 meters above sea level. Great Rift Valley passes through Ethiopia and there is occurrence of volcanic eruption. Due to this, there are materials ruptured from volcanic action. Scoria (red ash) is abundantly distributed in Ethiopia, especially in the Great Rift Valley (Negussie.T. and shiferaw.T., 1984). “Scoria is a volcanic cinder which generally has a porous nature and rough surface and whose colour ranges from red to black. Scoria is formed as a result of cooled and solidified lava in which large volume of gasses has been formed”.

The major problems on each sector of the construction work in Ethiopia are the material cost as well as the labor cost become high. In order to tackle these problems, it is necessary change the methodology of the work as well as search materials that can replace the previous materials without reduce the quality.

Light weight concrete has been used in construction since before the days of the Roman Empire. The earliest types of light weight concrete were made by using Grecian and Italian pumice as the light weight aggregate. In concrete construction, structural lightweight concrete is an important and give solves weight and durability problems in building (Shirtey, 1975). In many items around the characteristic of lightweight aggregate for housing and the effect of material regarding the durability, the compressive strength, water absorption and workability are significant for the structural lightweight aggregate concrete (Clarke, 1993).

“Lightweight aggregate concrete is usually defined as a concrete having an air-dry density of below 1850 kg/m3”. The lightweight concrete has its obvious advantages of high strength/weight ratio, good tensile strength, low coefficient of thermal expansion, and superior heat and sound insulation characteristic due to air voids in lightweight aggregates (Mouli et al., 2008).

The scarcity of the construction material, increase in the cost of material, using the low quality to compensate material and also additional cost of material transportation including manpower cost starting from transportation to the curing treat until the final stage of curing. So it need for producing the low cost material with the good quality.

After placing and finishing of concrete, maintaining adequate moisture and temperature is of paramount importance; this happens through a process referred to as Curing. Curing is essential if concrete is to perform the intended function over the design life of the structure. Curing is defined as the process by which hydraulic-cement concrete matures and develops hardened properties as a result of continued hydration of the cement in the presence of adequate water and heat (ACI 308R-01, 2008).

There are various methods of curing. Internal (self) curing is one of curing method of concrete to perform the future designed purpose. Internal curing is a process by which the hydration of cement continues because of the availability of internal water that is not part of the mixing water (ACI 213-03R, 2012). Self-curing solves the problem when the degree of hydration is lowered due to self-curing agent like poly-acrylic acid which has strong capability of absorbing moisture from the atmosphere and providing water required for curing .Strength of self-curing concrete is better than with conventional concrete and also can answer to many problems faced due to lack of proper curing (Dayalan J.and Buellah M., 2014).

This research was assessing self- curing capacity of light weight concrete using red ash as an aggregate. Hence the major output of the study is, reduce the cost and time for curing by manpower and the cost of water to be wasted for the curing as the same time the cost of red ash is lower than the cost of normal gravel.

1.2. Statement of the problem

Construction is a basic human need. Unfortunately delivery of any construction at affordable rates to low income earners have not been successful due to the high cost of construction materials (Ndububa, 2004).

Generally concrete production in Ethiopia is usually the same. Means using the same ingredients with the same method of production and method of curing but in the modern construction industry logic is, trying different method of production with different ingredients may increase the quality of concrete and also may reduce some unnecessary costs. Now a day in Ethiopia the expansion of construction increases in every sector of construction. But the costs of construction material and labor or manpower increase. One of the problems alleviate regarding to material cost is finding other materials which can replace the previous one without reducing the quality by taking under consideration of the abundant available of material. In the other way, by finding the method of curing which can reduce the time, manpower as well as unnecessary waste of water in the curing of concrete by relating suitable material property for the desired method of curing.

Thus, this research attempts to forward alternative use of ingredients of construction material with better curing method of concrete that can be used as a construction material and method of curing.

1.3. Research Questions

1. What are the ingredients properties of light weight concrete using red ash as an aggregate?
2. To what extent the red ash can affect the curing process of concrete?
3. Can the self- curing concrete using red ash as an aggregate attain the compressive strength as per ASTM standard?

1.4. Objectives of the research

1.4.1. General objective

The general objective of this research is to investigate the self- curing capacity of light weight concrete using red ash as an aggregate.

1.4.2. Specific objectives

- To determine the property of ingredients of light weight concrete using red ash as an aggregate.
- To evaluate the effect of red ash on the curing process of concrete.
- To check compressive strength attainment of self- curing concrete using red ash as an aggregate per ASTM standard.

1.5. Scope of the study

The study was focused on the self- curing capacity of light weight concrete using red ash as an aggregate and compares the results with respect to the values of compressive strength of light weight concrete which is put by ASTM standard. Natural sand also used as a fine aggregate with red ash as a coarse aggregate. The study has the mix type using the normal gravel and natural sand concrete as a control mix by the self or internal curing method

1.6. Significance of the research

Using available construction materials as a replacement of the usual construction material by the available construction material which has optimum cost and quality and also using better curing method of concrete by relating concurrent property of material has an advantage.

The main aspects have the major contribution behind this study are: (1) makes the concrete to have better self or internal curing capacity than the conventional curing method by applying the self-cuing method of concrete, (2) reduce the cost with regard to the cost of man power and waste of water at the time of curing and also the cost of the material is cheapest than the usual ingredients of the concrete, (3) reduce transportation cost for places in which this materials are available and also reduce the waste of time by keeping until the material is reach from other places. In addition of the above mentioned significance from this study, it will be used as a technical data reference for those who are used this material and also will show direction for future similar studies.

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CHAPTER TWO

LITERATURE REVIEW

2.1. General Overview

Even if the levels of problems are unequal, in most of construction work different problems are happen. The issues of the problem which are raised could be due to natural or human himself. There is a perception that majority of problem issue on the construction perspective is human factors. Many literatures imply that most of the construction industry did not finished by its project budget. The factors that affect for the cost overrun of the project is the increasing of material cost time in time. The way of discouraging this problem is the creation of deferent methods to reduce the availability and cost of material with the good quality by optimum cost.

Structural lightweight aggregate concrete is an important and versatile material in modern construction. It has many and varied applications including multistory building frames and floors, bridges, offshore oil platforms, and pre-stressed or pre-cast elements of all types. Many architects, engineers, and contractors recognize the inherent economies and advantages offered by this material, as evidenced by the many impressive lightweight concrete structures found today throughout the world (Defroit and Michigan, 1987). According to (expanded clay, shale and slate institute) Lightweight concrete precast elements offer reduced transportation and placement costs. Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities such as lessened the dead weight (Mat, 1978).

2.2. Concrete

Concrete by definition is the composite material that is composed of typically made by combining cement, aggregates, water and often, mineral admixtures in appropriate proportions (Edward & Nawy, 2008). To demonstrate compliance with specific project needs special mixing, placing and curing practices may be needed to produce and handle various concretes. Concrete is stone like material that is obtained by carefully proportioned mixture of cement, sand, gravel and water to give shape and dimension of the structure. Using special cements, special aggregates (various light weight and heavy weight), admixtures and special curing methods permit wider variety of concrete properties (Nilson Darwin, 2004).

Concrete has the basic building material appreciably show the level of a modern civilization. The concrete has unlimited advantages with a low cost raw material, has an environmental acceptance, has a possible achievements in various performance condition, available for the maintenance technology, attractive material and leading positions on foreseeable prospect (L.Dvorkin and O.Dvorkin, 2006). According to (L.Dvorkin and O.Dvorkin,2006) classification of concrete is based on:

1. Types of binder - cement, gypsum, lime, slag-alkaline, polymer, polymer-cement.
2. Density - normal-weight, high-weight and light-weight.
3. Types of aggregates - normal-weight, heavy-weight, light-weight, inorganic and organic.
4. Size of aggregates – coarse and fine
5. Workability of concrete mixtures - stiff and plastic consistency
6. Porosity of concrete - high-density, low density and Cellular
7. Typical properties –high strength, resistance to action of acids or alkalis, sulfate resistance, rapid hardening and decorativeness.
8. Exploitation purpose - structural concrete, concrete for road and hydro technical construction, Concrete for thermal isolation, radiation protective concrete, white and coloured concrete.

In addition to the continuous improvement in concrete production method, the selection of materials and their productions take a big place. Now a day the importance of quality control in compaction and curing of concrete to implement in the actual structure make difference in the result (Shri Ghansham, 2007).

Good concrete, whether plain, reinforced or pre stressed, should be strong enough to carry superimposed loads during its anticipated life. Other essential properties include impermeability, durability, minimum amount of shrinkage, and cracking (Taylor, 1977). If a concrete is to be suitable for a particular purpose, it is necessary to select the constituent materials and combine them in such a manner as to develop the special qualities required as economical as possible. The selection of materials and choice of method of construction is not easy, since many variables affect the quality of the concrete produced, and both quality and economy must be considered. The characteristics of concrete should be evaluated in relation to the required quality for any given construction purpose. The closest practicable approach to perfection in every property of the concrete would result in poor economy under many conditions, and the most desirable structure is that in which the concrete has been designed with the correct emphasis on each of the various properties of the concrete, and not solely with a view to obtaining of maximum possible strength (Wilby, 1991).Due to limited means within developing countries, it is necessary to seek ways to reduce construction costs, especially for low-income housing, as well as adopting easy and effective solutions for their repair and maintenance. Such objectives can be achieved partially through the production and use of cheap yet durable locally available building materials (Adam, 2001).

2.3. Light weight concrete

2.3.1. Definition

Lightweight concrete can be defined as a type of concrete which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities such as fallibility and lessened the dead weight (Mat, 1978). It is lighter than the conventional concrete with a dry density of 300 kg/m3 up to 1840 kg/m3; 87 to 23% lighter. Light weight concrete has a unit weight that ranges from 1121kg/m3 to 1922kg/m3 compared from normal concrete unit weight ranges from 2243kg/m3 to 2483kg/m3 (ACI 213R -03).

It was first introduced by the Romans in the second century where 'The Pantheon' has been constructed using pumice, the most common type of aggregate used in that particular year (Mohd, 1997). From there on, the use of lightweight concrete has been widely spread across other countries such as USA, United Kingdom and Sweden. Light weight concrete has a minimum 28-day compressive strength of 17.3 Mpa but can achieve strengths more than 55.2Mpa in some cases (Kosmatka et al. 2002). Structural light weight concrete is made of aggregates that are all light weight aggregates, or a combination of light weight aggregates with the normal weight aggregates.

Due to the light weight aggregate has voids, the light weight concrete has an advantages of high strength/weight ratio, good tensile strength, low coefficient of thermal expansion, and superior heat and sound insulation characteristics [Mouli,et al., 2008]. The reduction in dead weight of the construction results in a decrease in cross-section of the structural members and steel reinforcement (Hossain, 2006).

According to L.Dvorkin and O.Dvorkin, Light weight concrete is concrete having density up to 2000 kg/m^3. And also light weight concrete is divided in to 3 by their purpose.

1. Heat insulating – For heat insulation with density 300-500kg/m3
2. Structural-heat insulating - For enclosing structures with density500-1400 kg/m3
3. Structural - For load-carrying structures with density 1400-1800 kg/m3

2.4. Ingredients of concrete

2.4.1. Cement

Cement is the most important binding ingredient of concrete. “The mix design of concrete indirectly means optimizing the use of cement for obtaining the desired properties of concrete in green as well as hardened state”. The modern cement is also called ordinary Portland cement because it resembles in colour and quality with the Portland stone, quarried in Dorset – UK after setting.

The process of manufacturing of cement essentially involves,

- Proportioning of raw material
- Grinding, intimate mixing
- Burning in a large rotary kiln

The raw material is always available in the form of oxides in nature with different percent amount (ShriGhansham, 2007).

Table 2.1.Oxides of raw material percentage ranges (Shri Ghansham, 2007).

Oxides of raw material	Percent amount
Calcium oxide (CaO)	59-64%
Silica oxide (Si_2O)	12-24%
Aluminum oxide (Al_3O_2)	3-6%
Ferric oxide (Fe_3O_2)	1-4%
Magnesia (MgO)	0.5-4%

After heated oxides of raw material of cement in the kiln, these oxides get converted in to silicates and aluminates in addition to some compounds. These compounds are usually regarded as the major constituents of cement and tabulated with their abbreviated symbols with percentage amount, in Table

Table 2.2.Typical composition (Shri Ghansham, 2007).

Name of compound	Oxide composition	Abbreviation	percentage
Tricalcium Silicate	$3CaO.SiO_2$	C3S	39 – 50 %
Dicalcium Silicate	$2CaO.SiO_2$	C2S	20 – 45 %
Tricalcium aluminate	$3CaO.Al_2 O_3$	C3A	8 – 12 %
Tetracalciumaluminoferrite	$4CaO.Al_2O_3.Fe_2O_3$	C4AF	6 – 10 %

From those compounds of cement is contributed mainly by silicates. “Silicate react with water and produce a gel called calcium silicate hydrate (C-S-H) gel”. Initially this gel is weak and porous but through time, it becomes stronger and less porous. It is exothermic reaction with a lot of heat is generated. The chemical reaction processes are:

$2C_3S + 6H$ [redacted] $C_3S_2H_3$ (61 %) + 3CH (39 %) +114 KJ/mole

$2C_2S + 4H \rightarrow C_3S_2H_3$ (82 %) + CH (18 %) +43 KJ/mole

Where, C = CaO

S= SiO_2

H= H_2O

From the cement compound, strength of cement is mainly contributed by silicates which are C_3S and C_2S whereas C_3A is responsible for setting (ShriGhansham, 2007).

2.4.1.1. Types of cement

2.4.1.1.1. Ordinary Portland cement (OPC)

"Ordinary Portland cement is the most commonly produced and used cement". The name derived from lime stone called Portland stone quarried in Dorset – UK; it is due to resemblance to Portland stone at the hardened time (Shri Ghansham, 2007).

Ordinary Portland (Type-I) cement is suitable for general concrete construction when there is no sulphate in the soil and made from 95% to 100% of the standard Portland cement clinker and from 0% to 5% of non-cementations material (Neville, 1986).

2.4.1.1.2. Portland pozzolana cement (PPC)

"Pozzolana essentially means a silicious material having no cementing properties in itself but finely divided form it reacts with Ca $(OH)_2$ in the presence of water at ordinary temperature and forms compounds possessing cementing properties". The chemical reaction processes are:

$2C_3S + 6H = C_3S_2H_3 + 3CH$

$Ca(OH)_2 + SiO_2 + Al_2O_3 = C_3S_2H_2$ + other compound

Fly ash, shale, volcanic ash, opaline, diatomaceous are used as pozzolanas. It is easier to grid together OPC clinkers with pozolana than mixing the pozolana after wards at time of mixing because mixing pozolana being finer than cement. Fineness of pozolana is 300 m^2/kg as compared to OPC which is 225 m^2/kg.

The obvious advantage of using PPC is impermeable and denser concrete is produced by blending OPC with fly ash. The early strength of PPC is contributed by OPC fraction and pozzolana starts contributing after some. The early strength (7 days) strength is not less than 22 Mpa and 28 Mpa is not less than 31 Mpa, other properties like soundness, setting time etc. are the same with OPC (ShriGhansham, 2007).

2.4.2. Aggregate

2.4.2.1. General

Aggregate is one component of concrete. Aggregate could be fine aggregate or coarse according to its size. But based on the source, aggregate classified as natural or artificial. Natural aggregates are obtained from the quarries by crushing in to smaller parts and from the river bed. And also artificial aggregates obtained from the industrial by products (Abebe, 2005). According to him, the most relevant and easy for the production of aggregate for Ethiopia construction sector is the aggregates which are found naturally.

"Aggregate gives body to the concrete". It is cheaper than cement, it is economical to put much aggregates as practically possible, not only the use of more volume of aggregate in concrete is economical, it also provides higher volume stability to the concrete. Aggregate should be strong to make strong concrete because weak aggregates cannot make strong concrete and may limit the strength of concrete (Shri Ghansham, 2007). Therefore, the selection of aggregate is very vital. Based on size aggregate can be:

1. Fine (aggregate passing 4.75 mm sieve) and
2. Coarse aggregate (aggregate retained over 4.75 mm sieve).

2.4.2.2. Light weight aggregate

Structural light weight aggregate is an important in modern construction and has varied application. Many architects, engineers, and contractors recognized the inherent economies and advantages offered by the many impressive light weight concrete structures found today throughout the world (ACI 213R-87).

Lightweight aggregates are light due to the inclusion of air voids and it follows that they are absorbent, expect for the very few with sealed cells. This absorbency plays an important part in the way the concrete performs in its wet state. Most lightweight aggregates are manufactured and hence are, by careful production control, uniform and consistent, which is important to mixing, placing and compaction (Clarke, 1993). Aggregates having high porosity make low-weight concretes of excellent thermal insulating value but little resistance to stress. The less porous lightweight aggregates can produce concretes which are strong enough to resist structural stresses, but which are denser and less efficient thermal insulators than those made with the high-porosity aggregates (Shirley, 1975). Light weight aggregate can be classified in to two:

1. Natural light weight aggregate – are produced by processing naturally occurring materials such as pumice, scoria or tuff (Andrews, 2009).
2. Manufactured aggregates should meet the requirements of ASTM C330 and include rotary kiln expanded clays, shales, slates, sintering grate expanded shales and slates, pelletized or extruded fly ash and expanded slags (Kosmatka et al. 2002).

According to ASTM standard, 2007 light weight aggregate is an aggregate with bulk density less than 1120 kg/m^3 , such as: pumice, scoria, volcanic cinders, tuff, and diatomite, expanded or sintered clay, shale, slate, diatomaceous shale, perlite, vermiculite, or slag, and end products of coal or coke combustion.

According to ACI code (the American Concrete Institute), structural lightweight aggregate concrete has a 28-day compressive strength of 17.2 Mpa or more and a weight not exceeding 1840kg per cubic meter. Lightweight concrete may also contain normal or lightweight, fine and/or coarse aggregates.

2.4.2.2.1. Red ash (Scoria)

Scoria (red ash) is found in many places of Ethiopia especially around rift valley. According to (Melese Y., 2015) both the coarse aggregate and fine aggregate of varies grading could be produced from the sources which is found Dire near Debrezeit for the manufacture of scoria-scoria concrete.

Scoria is irregular in shape and very vesicular and has the basic composition of basalt. Scoria is usually heavier, darker and more crystalline than pumice (Khandaker M. and Anwar H., 2006). Scoria is abundant in various parts of the world (Moufti et al. 2000). ASTM limits the unit weight of coarse aggregate up to 880kg/m3 and also for the sand it is about 1120kg/m3. Generally the larger the size, the smaller the unit weight of the aggregate and sand size will generally range from 50 to 800 kg/m3 to 1088 kg/m3 213R-87, A.C.I. 1987).

The suitability of scoria for a particular end use is dependent on their physical properties such as density, grain size, grain shape and toughness. Scoria has SiO_2 content. It will increase hardness and increase resistance to chemical attack (Robbins, 1984).

Scoria is a natural material of volcanic origin used in cement industry as natural pozzolan. Pozzolans are defined as amorphous silicate or aluminosilicate material that reacts with calcium hydroxide formed during the hydration of cement in concrete to create additional cementations material in the form of calcium silicate and calcium silicoaluminate hydrates in the presence of moisture (Lewis et al., 2003).

Scoria is found abundantly in Ethiopia. The use of scoria so far has been limited to highway construction as a base course, as mortal aggregate in masonry construction and for the production of hollow concrete block. However, scoria, which can replace sand and crushed stone aggregate, has not been used in reinforced concrete contraction. This may be attributed to lack of sufficient technical data necessary for structural design (Negussie T. and Shiferaw T., 1984).

2.5. Properties of scoria light weight concrete

Lightweight concrete (LWC) is favorable over normal weight concrete (NWC) for earthquake prone areas as LWC reduces the dead load of a structure, thus, to reduce the risk of earthquake damages, because the earthquake forces are proportional to the mass of those structures (Yasar et al., 2003). Also, the reduction in self-weight will reduce reinforcements, transportation and handling cost (Topcu, 1997).

The lightness of scoria is due to porousness of the material that is highly sensitive to water content and high water absorption compared to granite crush rock aggregate (Bogam and Gomes, 2013). The porous nature of the aggregate enhances interlocking sites for the cement paste to infiltrate and to form dense uniform interfacial zones between aggregate (Lo 2004). "This strong interfacial bond compensates for the strength loss in lightweight aggregate due to its porosity relative to normal gravel aggregate".

2.6. Curing

Curing is essential if concrete is to perform the intended function over the design life of the structure while excessive curing time may lead to the escalation of the construction cost of the project and unnecessary delays. Curing is the maintenance of satisfactory moisture content and a temperature in concrete for a period of time immediately following placing and finishing also developing the desired properties of concrete (Kosmatka et al., 2003).

Concrete is cured to obtain desirable properties by maintain a favorable moisture and temperature conditions in a freshly mixed concrete. Curing is currently thought to be a one major concern regarding concrete studies. (Islam et al., 2011).

Curing has a great impact on a hardened concrete's properties. With a proper curing, durability, strength, water tightness, abrasion resistance, volume stability and resistance to freezing and thawing will increase (Kosmatka et al., 2003).

The chemical reaction that is the hydration is takes place between the cement and water. Hydration has a great effect on the strength and durability of the concrete When concrete's curing is interrupted the strength development of concrete can continue for little time and then stops when the internal relative humidity is around 80%. If curing is then started again, the strength development can continue again but the potential of the concrete with constant curing may not be achieved (Kosmatka et al., 2003).

2.6.1. Internal curing

After casting the fresh concrete, curing is attained by applying external agent on the concrete in the conventional method of curing but for the cause of internal (self-curing), not applying external agent for the achievement of curing.

The ACI-308 code states that "Internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water." Internal curing also referred as self- curing. Self-Curing Concrete can be achieved by adding self-curing agents. According to (Dayalan J.and Buellah M., 2014) "the concept of self-curing agents is to reduce the water evaporation from concrete and hence increase the water retention capacity of the concrete.” From the foundation, water soluble polymers can be used as self-curing agents in concrete.

One way to know how internal curing works is considers chemical shrinkage. it is a process in which the products of a reaction occupy a smaller volume than the reactants (L’Hermite, 1960).pre- wetted lightweight aggregate used as an internal curing agent is not new (Lura.p and O.Jensen).

Self-curing concrete is provided to absorb water from moisture from air to achieve better hydration of cement in concrete (Dayalan J.and Buellah M., 2014). And also it states that, self-curing solves the problem when the degree of hydration is lowered due to self-curing agent like poly-acrylic acid which has strong capability of absorbing moisture from the atmosphere and providing water required for curing. (Dayalan J.and Buellah M., 2014) concluded that “Strength of self-curing concrete is better than with conventional concrete. Self-curing concrete is the answer to many problems faced due to lack of proper curing.”

2.6.1.1. Types of self (internal) curing

There are two major methods available for internal curing of concrete (Ankith MK, 2014). The first method uses saturated porous lightweight aggregate (LWA) in order to supply an internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration. The second method uses poly-ethylene glycol (PEG) which reduces the evaporation of water from the surface of concrete and to water retention.

2.6.1.2. Uses of self-curing (Internal curing)

One benefit of internal (self-curing) is the reduction in autogenous shrinkage (Lura, 2003). Properly proportioned volume of lightweight aggregate could be used to reduce shrinkage of mortars with a varying percentage of the sand replaced with pre-wetted lightweight aggregate (Henkensiefken et al.).And also states that the mixes with pre-wetted lightweight aggregate have reduced absorption of water in hardened concrete. According to (Akeem Aynde Raheem, 2013) water retention for the concrete mixes incorporating self-curing agent is higher when compare to conventional concrete mixes and also it concluded that self-curing concrete resulted in better hydration with time compared to conventional concrete.

2.6.2. Impacts of curing

Curing is the name given to the procedures used for promoting the hydration of the cement with a control of temperature and moisture movement from and into the concrete. Curing allows continuous hydration of cement and continuous gain in the strength.

Moisture condition is one major factor for the curing of concrete. Moisture conditions are critical, because the hydration of cement stops when the relative humidity within the capillaries drops below 80% (Neville, 1996). Due to insufficient water, the hydration will not process and the concrete will not reach the desired strength and impermeability. This is the cause for durability problems (Fauzi, 1995). Temperature is the other factor affect the strength of concrete. Concrete cured at high temperature develops higher early strength, but generally lowered strength at 28 days and more (ACI committee 305R-99 and ACI manual, 2009). Strength also governed by moist-curing period, the longer the moist-curing period higher the strength of concrete (ACI committee 301).

Curing has a strong influence on the properties of hardened concrete. "Proper curing will increase durability, strength, volume stability, abrasion resistance, impermeability and resistance to freezing and thawing" (http://www.ce.memphis.edu/1101/Notes/.

2.7. Mix design method

Mostly composite of concrete considered as composed of four basic separate ingredients: cement, coarse aggregates, fine aggregates, and water. For this concrete design method is based on the absolute volume method from the America Concrete Institute's committee 211.2-98, standard practice for selecting proportions for light weight aggregate concrete and American Concrete Institute's committee 211, standard practice for selecting proportions for normal weight concrete.

2.7.1. Mix design procedure

2.7.1.1. Volume basis

Step-1: Choice of slump

The slump test is the most widely used method to measure workability (213R-03, A.C.I.1999). Slump is an important factor in achieving a good floor surface with lightweight concrete and generally should be limited to a maximum of 125 mm .A lower slump of about 75 mm imparts sufficient workability and also maintains cohesiveness, thereby preventing the lower-density coarse particles from working to the surface (213R-03, A.C.I.1999). Pre-wetting minimizes the mixing water being absorbed by the aggregate, therefore minimizing the slump loss during pumping.

Table 2.3. Recommended slumps for various types of construction (ACI committee 211.2-98).

Types of construction	Slump, inch (mm)	
	maximum	minimum
Beams and reinforced walls	4 (100)	1 (25)
Building columns	4 (100)	1 (25)
Floor slabs	3 (75)	1(25)

Step 2: Choice of maximum size of lightweight aggregate

- Large size of aggregate is preferred in concrete because of the following reasons:
- It reduces the cement requirement
- It reduces the water requirement
- It reduces shrinkage of concrete

But there are factors which limit the use of higher size aggregates in the concrete like: thickness of section, spacing of reinforcement and clear cover (ShriGhansham, 2007). According to (ACI 213R-03, 1999) committee for light weight concrete, When high-strength concrete is desired, better results may be obtained with reduced nominal maximum sizes of aggregate because these can produce higher strengths at a given w/c or w/cm.

Table 2.4. Grading requirements for light weight aggregate for structural concrete from designation: ASTM C 136

	Percentages (mass) passing sieves having square openings									
Nominal size designation	25mm	19mm	12.5mm	9.5mm	4.75mm	2.36mm	1.18mm	300µm	150µm	75µm
Fine aggregate:										
4.75 mm to 0				100	85-100	-	40-80	10-35	5-25	-
Coarse aggregate:										
25 mm to 4.75 mm	95-100	-	25-60	-	0-10					0-10
19 mm to 4.75 mm	100	90-100	-	10-50	0-15					0-10
12.5 mm to 4.75 mm		100	90-100	40-80	0-20	0-10				0-10
9.5 mm to 2.36 mm			100	80-100	5-40	0-20	0-10			0-10
Combined fine and coarse aggregate:										
12.5 mm to 0		100	95-100	-	50-80	-	-	5-20	2-15	0-10
9.5 mm to 0			100	90-100	95-90	35-65	-	10-25	5-15	0-10

Step- 3: Required average compressive strength when data are not available to establish a sample standard deviation

When the prior experience trial data are not available the data which are in table below are required for the purpose to continue the work (ACI 318M-08).

Table2.5.The required average compressive strength (ACI 318M-08)

Specified compressive strength, Mpa	**Required average compressive strength, Mpa**
$f_c'<21$	**$f'_{cr} = f_c' +7.0$**
$21< f_c' \leq 35$	**$f'_{cr} = f_c' +8.3$**
$f_c' > 35$	**$f'_{cr} = 1.10\ f_c' +5.0$**

Where, f_c' = the specified compressive strength

f'_{cr}= the required average compressive strength

Step- 4: Estimation of mixing water and air content

Mixing water is an active component providing hardening of cement paste and necessary workability of concrete mix. Water with pH in the range of 4 to 12.5 is recommended for making concrete (L.Dvorkin and O.Dvorkin, 2006).

According to ACI stander method, quantity of water per unit volume of concrete required to produce a given slump is dependent on:

The nominal maximum size,

Particle shape, and

Grading of the aggregates;

The concrete temperature;

The amount of entrained air; and

Use of chemical admixtures.

Table, provides estimates of required mixing water for concrete made with various maximum sizes of aggregate, with and without air entrainment.

Table 2.6. Approximate mixing water and air content requirements for different slumps and nominal maximum sizes of aggregates (ACI 211,2-98 committee,2004).

Aggregate size	9.5 mm	12.5 mm	19 mm
Air-entrained concrete			
	Water, lb/yd3 (kg/m3) of concrete		
Slump, 1 to 2 in. (25 to 50 mm)	305 (181)	295 (175)	280 (166)
Slump, 3 to 4 in. (75 to 100 mm)	340 (202)	325 (193)	305 (181)
Slump, 5 to 6 in. (125 to 150 mm)	355 (211)	335 (199)	315 (187)
	Recommended average total air content, %, for level of exposure		
Mild exposure	4.5	4.0	4.0
Moderate exposure	6.0	5.5	5.0
Extreme exposure	7.5	7.0	6.0
Non air-entrained concrete			
Slump, 1 to 2 in. (25 to 50 mm)	350 (208)	335 (199)	315 (187)
Slump, 3 to 4 in. (75 to 100 mm)	385 (228)	365 (217)	340 (202)
Slump, 5 to 6 in. (125 to 150 mm)	400 (237)	375 (222)	350 (208)

Approximate amount of entrapped air in non-air-entrained concrete, %	3	2.5	2

Step- 5: Selection of water-cement ratio

Water cement ratio is the guideline to calculate the mix proportion of cement. But the light weight aggregate due to uncertainty of calculating that portion of the total water in the mix which is applicable is not used directly to the mix. The water absorbed in the aggregate prior to mixing is not part of the cement paste, and complication is introduced by absorption of some indeterminate part of the water added at the mixer. It is quite probable that this absorbed water is available for continued hydration of the cement after normal curing has ceased. The general practice with lightweight aggregates is to proportion the mix, and to assess probable physical characteristics of the concrete, on the basis of given cement content at a given slump for particular aggregates (A.C.I 213R-87, 1987).

Table 2.7. Relationships between w/c and compressive strength of concrete(ACI committee 211.2-98).

	Approximate water-cement ratio, by weight	
Compressive strength at 28 days, psi (MPa)	Non air-entrained concrete	Air-entrained concrete
6000 (41.4)	0.41	-
5000 (34.5)	0.48	0.40
4000 (27.6)	0.57	0.48
3000 (20.7)	0.68	0.59
2000 (13.8)	0.82	0.74

Step- 6: Calculation of cement content

The amount of cement per unit volume of concrete is fixed by the determinations made in Steps 3 and 4 above. Based on ACI, however, the specification includes a separate minimum limit on cement in addition to requirements for strength and durability; the mixture must be based on whichever criterion leads to the larger amount of cement.

The cement and water contents required for a particular strength and slump have significant effects on the hardened concrete properties. With lightweight concrete, mix proportions are generally expressed in terms of cement content at a particular slump rather than by the water-cement ratio (Fahrizal Z. and Mahyuddin R., 2008). Increasing the mixing water without increasing the cement content will increase slump and also increase the effective water-cement ratio. The usual range of compressive strengths may be obtained with reasonable cement contents with the lightweight aggregates being used for structural applications today.

Step- 7: Estimation of light weight coarse aggregate content

The volume of coarse aggregate in a unit volume of concrete depends only on its nominal maximum size and fineness modulus of the normal weight fine aggregate. The volume of aggregate, in (m^3), on an oven-dry loose basis, for a unit volume of concrete is equal to the value from table in by $1m^3$. This volume is converted to dry weight of coarse aggregate required in a unit volume of concrete by multiplying it by the oven-dry loose weight per m3 of the lightweight coarse aggregate (ACI committee 211.2-98).

Table 2.8.Volume of coarse aggregate per unit volume of concrete (ACI committee 211.2-98).

Maximum size of aggregate, in. (mm)	Volume of oven-dry loose coarse aggregates per unit volume of concrete for different fineness modules of sand			
	2.40	2.60	2.80	3.00
3/8 (9.5)	0.58	0.56	0.54	0.52
1/2 (12.7)	0.67	0.65	0.63	0.61
3/4 (19.0)	0.74	0.72	0.70	0.68

Step- 8: Estimation of fine aggregate content

At completion of Step 6, all ingredients of the concrete have been estimated except the fine aggregate. Its quantity is determined by difference. Either of two procedures may be employed (ACI committee 211.2-98).

The weight method -If the weight of the concrete per unit volume is assumed or can be estimated from experience, the required weight of fine aggregate is simply the difference between the weight of fresh concrete from table and the total weight of the other ingredients.

Table 2.9. First estimate of weight of fresh lightweight concrete comprised of lightweight coarse aggregate and normal weight fine aggregate (ACI committee 211.2-98).

Specific gravity factor	First estimate of lightweight concrete weight, lb/yd3(kg/m3)		
	Air-entrained concrete		
	4%	6%	8%

1.00	2690 (1596)	2630 (1561)	2560 (1519)
1.20	2830 (1680)	2770 (1644)	2710 (1608)
1.40	2980 (1769)	2910 (1727)	2850 (1691)
1.60	3120 (1852)	3050 (1810)	2990 (1775)
1.80	3260 (1935)	3200 (1899)	3130 (1858)
2.00	3410 (2024)	3340 (1982)	3270 (1941)

The absolute volume method - This procedure is applicable to all lightweight or to sand lightweight concrete comprised of various combinations of lightweight aggregate and normal weight aggregate. The required volume is the difference of $1m^3$ from the obtained material after changing in to volume.

Step- 9: Adjustment for moisture aggregate

The aggregates will be moist and their dry weights should be increased by the percentage of water they contain, both absorbed and surface. The mixing water added to the batch must be reduced by an amount equal to the free moisture contributed by the aggregate that is, total moisture minus absorption.

2.8. Compressive strength

Strength is one of the important properties of concrete as it influences many other desirable properties of hardened concrete. It usually gives an overall picture of the quality of concrete because it directly related to the structure of the hydrated cement paste.

(Dayalan J.and Buellah M.,2014) concluded that Compressive strength results tells that strength of internal cured specimens at 21 days and 28 days are greater but at the age of 7 days the strength is lower than conventionally cured specimens. As a general it states that the compressive strength for the internally cured concrete resulted in values 20% higher when compared to the plain concrete and The use of lightweight aggregate for internal curing of concrete is particularly beneficial as it reduces various shrinkage cracks due to the pore structure of the concrete which reduces internal drying and extends hydration process which thereby increases strength and durability of the concrete.

The compressive strength of light weight aggregate reaches up to 35 Mpa, but "there is no reliable correlation between aggregate strength and concrete strength". By varies the resources and the type of aggregate has different strength and quality is the only way of it (ACI committee, 213R).

According to (Melese Y., 2015) " structural scoria a lightweight concrete can produce up to strength of 30Mpa by using the locally available cement (Derba PPC cement) with the cement content of 360kg/m3" with using conventional type of curing method of concrete.

CHAPTER THREE

RESEARCH METHOD AND MATERIALS

3.1. Study area

The study was conducted in Addis Ababa which is 345 Km far from Jimma with latitude 8^0 50 ′N- 9°05′E and longitude 38°41′ N -38° 54 ′ E. specifically Akaki-Kality sub-city in Tullu Dimitu quarry site.

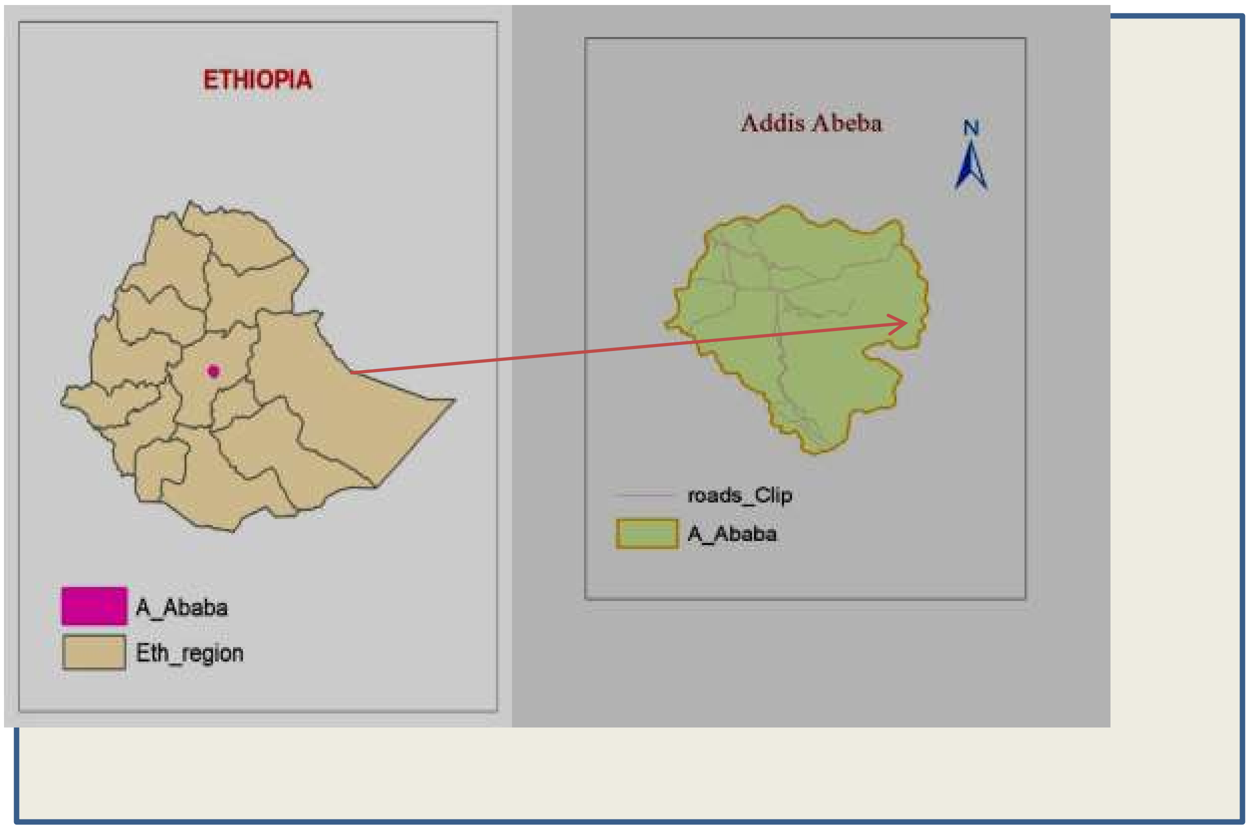

Figure.3.1. Location of the study area

3.2. Population

The population of this study includes concrete mixes produced by red ash as a coarse aggregate and fine aggregate and red ash as a coarse aggregate and natural sand (river sand) as a fine aggregate as well as mix with natural gravel and natural sand as a control mix with Dangote OPC 42.5 cement type.

3.3. Sampling techniques and sample size

The type of sample taken for this specific study is purposive sample. The mix proportion of light weight concrete and the control mix were designed based on ACI mix design standard and 5 mixes was conducted for this study. For one mix, there were 9 number of cubes were needed for 7, 14 and 28 different curing days. Totally 45 numbers of cubes of concrete were conducted.

Specifically this study find out the self-curing capacity of lightweight concrete by analyzing the compressive strength of fully replaced the natural coarse aggregate by red ash coarse aggregate and fully replaced of natural sand (river sand) by red ash fine aggregate using Dangote OPC 42.5 cement type and the mix of natural gravel coarse aggregate with natural sand by OPC cement as a control mix. The casted cubes of concrete had three different curing days to measure the compressive strength of the light weight concrete, that is for 7, 14 as well as for 28 curing days. The details are shown in table.

Table 3.1.Total No of samples of specimens.

S.No	mixes	Amount of cement per m^3	Number of curing days			Total No of samples
			7^{th}	14^{th}	28^{th}	
1	RRC 1	340	3	3	3	9
2	RNC 1	340	3	3	3	9
3	RRC 2	360	3	3	3	9
4	RNC 2	360	3	3	3	9
5	GNC 2	360	3	3	3	9
Total number of samples						45

3.4. Materials

3.4.1. Sources of materials

For this study, the Dangote cement that is OPC 42.5 was gotten from the market, red ash was found from Tullu Dimitu quarry site, which is found in Akaki-kality sub city of Addis Ababa, the natural sand (river sand) and the natural gravel coarse aggregate were from the market and the potable water was from laboratory of BUDSWS company and also the necessary tools and equipment's were from BUDSWS company.

Figure 3.2.Tulu Dimitu quarry site

3.4.2. Quality tests on material

3.4.2.1. Cement

For this study the cement used was from the recent known cement factory which is found in Ethiopian, Dangote cement factory. The following tests were conducted.

Setting time test –this test was conducted based on ASTM C 191, standard test method and ASTM C 1157 -03 standard specification.

Fineness –the fineness of OPC42.5 cement was conducted using ASTM C 430 standard test method and ASTM C 150 standard specification.

Mortar compressive strength – this test was conducted using ASTM C 191 standard test method and using ASTM C 1157 -03 standard specification.

3.4.2.2. Red ash (scoria)

A-Red ash coarse aggregate

Based on the ASTM C 330-05, standard specification for lightweight aggregates for structural concrete the following quality tests of the red ash coarse aggregate were conducted:

Quality tests	Standard used
Sieve analysis	ASTM C 136

Unit weight	ASTM C 29
Soundness	ASTM C 88
Resistance of degradation	ASTM C 131
Water absorption	ASTM C 127
Specific gravity	ASTM C 127

The material which has the grain size =< 25mm up to = > 4.75mm were conducted in the above quality tests of the red ash coarse aggregate.

Figure 3.3. Red ash coarse aggregate

B-Red ash fine aggregate

Based on the ASTM C 330-05, standard specification for lightweight aggregates for structural concrete different quality tests of the red ash fine aggregate was conducted using ASTM standard test methods as follow:

Quality tests	Standard used

Sieve analysis

Unit weight

Soundness

Water absorption

Organic impurities ASTM C 40

Specific gravity ASTM C 128

By doing the above red ash fine aggregate quality testes according to the standard starting from the size = < 4.75 up to = > 150μm for the purpose of lightweight concrete mixes.

Figure 3.4.Red ash fine aggregate

3.4.2.3. Natural sand (river sand)

By taking ASTM C 33-03, standard specification for concrete aggregates, the necessary quality tests of the natural sand (river sand) were takes place before mix done. The size of sand is based on the standard specification from = < 4.75 up to = > 150μm. These quality testes were:

Quality tests

- ✓ Sieve analysis
- ✓ Unit weight
- ✓ Specific gravity
- ✓ Water absorption

3.4.2.4. Natural gravel coarse aggregate

By taking ASTM C 33-03, standard specification for concrete aggregates, the necessary quality tests of the natural gravel were takes place before mix done. The material which has the grain size =< 25mm up to = > 4.75mm, the following quality tests were conducted for:

- ✓ Sieve analysis
- ✓ Unit weight
- ✓ Specific gravity
- ✓ Water absorption

3.4.3. Pre-wetted of aggregates

Using ACI 213R -03, guide for structural lightweight aggregate concrete and the ASTM C 330 -05 standard specification for lightweight aggregates of concrete, the red ash coarse aggregate, red ash fine aggregate, natural sand and natural gravel were pre-wetted for 24 hours before mixing.

3.4.4. Moisture adjustment

By referring ACI mix design method for the moisture adjustment, adjusting the weight of the aggregates due to the presence of water inside the aggregates and adjusting the amount of water for the mix due to the presence of water inside the aggregates were adjusted. In this study the red ash coarse aggregate, the red ash fine aggregate, the natural sand and the natural gravel moisture were adjusted due to the presence of water within the aggregates which were came from the pre-wetted aggregates.

3.4.5. Mix proportioning

The mix proportioning for C-25 grade concrete used for most construction work was designed as per ACI 211.2-98 and ACI 211.1-9.1. The mix proportioning were cement: sand (river sand and red ash sand) and coarse (red ash coarse aggregate and natural gravel).

3.4.5.1. Trial mix one

Table 3.2. Mix proportioning for the first trial

S.No	Mix type	W/C ratio	Volume of mixer (m3)	Mix proportion
1	RRC 1	0.52	0.03	1:1.70: 3.3
2	RNC 1	0.52	0.03	1:2 :3.10

3.4.5.2. Trial mix two

Table 3.3. Mix proportioning for the second trial

S.No	Mix type	W/C ratio	Volume of mixer (m3)	Mix proportion
1	RRC 2	0.48	0.03	1:1.47:3.04
2	RNC 2	0.48	0.03	1:1.73 :2.86
	Control mix			
3	GNC 2	0.48	0.03	1:2.18:2.91

3.4.6. Preparation of specimens and mixing procedure

Throughout the mixing process, the aggregates which were found nearby to the place of investigation conducted and also the cement, which is found in Ethiopia and produced by Dangote cement factory, was used.

The graded aggregates were fulfill ASTM C-330-05, standard specification for light weight aggregates for structural concrete and ASTM C-33, standard specification for concrete aggregates. Each ingredient amount for the mix was calculated according to ACI 211.2-98, standard practice for selecting proportions for structural lightweight Concrete and ACI 211.1-91, standard practice for selecting proportions for normal, heavyweight, and mass concrete.

The preparation of the constitute materials were made by using volume basis measurement. After determining the relative amount of material to be used for specimens, the aggregates and cement were mixed for three minutes in the mixer. After the addition of water, all the materials mixed for another four minutes. Immediately after mixing the concrete, the workability is measured using slump cone. The specimens were then put on a firm and level surface of prepared moulds by blowing 25 times per layer. The volume of mould is finished by three layers. After that the top surface was smooth and leveled using the standard steel rod and trowel.

3.4.7. Tests on fresh concrete

3.4.7.1. Slump

By taking ASTM C 143-05a, standard method for slump of hydraulic cement concrete as a base line, immediately after finishing the mix process, the slump test was taken by the wet cone which has 100mm diameter at the top, 200mm at the bottom (the base of the cone) with 300mm height to know the workability as well as the cohesiveness of the material within the concrete. At the time of slump test, first put the wet cone on the level place then one guy held firmly the cone and the other guy insert 1/3 volume of cone concrete then blow the layer by using straight steel rod which has 600mm in height with 16mm in diameter 25 times after that insert 2/3 volume of cone concrete, apply 25 number of blows on the inserted concrete, finally full the cone and apply the same number of blows and then heap the concrete and rolling by the rod, then pick up the cone straight up, finally take the difference of the concrete height after removing the cone and the height of the cone. By applying the same procedure all the total 5 types of mix slump measurement were taken.

Figure 3.5. Slump test

3.4.7.2. Air content

Using ASTM C 231 -04, the standard method for air content of freshly concrete, like the slump test, in order to take air content of the concrete, the concrete must be fresh before lose its workability. The measurement of the air content was conducted parallel to the measurement activity of slump. By following the ASTM test method, air content measurement is conducted for the all 5 types of mixes.

Figure 3.6. Air content test readings for different mixes

3.4.7.3. Unit weight of fresh concrete

One of the fresh quality tests of the concrete is the unit weight of fresh concrete. It used to know the unit weight of fresh concrete whether it fulfills the standard fresh concrete unit weight amount. Using ASTM C 138, standard test method of fresh concrete, first measure the empty weight of the standard cube which has the dimension 150x150x150mm, after that insert 1/3 of the volume of cube fresh concrete then blow it 25 times using the standard straight steel rod which has 16mm diameter and 600mm in height, again by inserting 2/3 of the volume of cube fresh concrete and applying 25 number of blows on the inserted concrete, finally by making full the remaining volume of cube by fresh concrete then blow it, then smooth by making rolling by steel rod and by using trowel. At the end, measure the fresh concrete within cube .Lastly, subtract the weight of the cube from the weight of fresh concrete plus weight of cube and divide the difference to the volume of the cube, which is 150x150x150mm. By followed the procedure and using the ASTM standard to measure fresh concrete unit weight, the all 5 types of mixes 'unit weight of fresh concrete were conducted.

3.4.8. Casting

A proper and good practice of mixing can lead to better performance with a better quality of concrete. After finishing the fresh concrete quality tests that were slump test, air content of the fresh concrete and unit weight of fresh concrete, immediately the specimens were cast after coated the standard mould which is 150x150x150mm size with oil to remove the specimens easily. The fresh concrete was placed in the oil coated moulds layer by layer.

The amount of first layer concrete volume inserted in the oil coated mould was 1/3 of volume concrete of cube by followed the standard test method procedure of ASTM C 138.After blew the first layer 25 times, then insert the second layer which is 2/3 volume concrete of cube again blow and finally full the remaining volume concrete of cube then rod it and followed rolling by the steel rod to make smooth and level the surface. The specimens were demoulded at the end of 24 hours after casting.

Figure3.7. concrete casting

3.4.9. Curing

Using the ASTM C 330 -05, standard specification for light weight aggregates for structural concrete and the ASTM C 192 -07, standard practice for making and curing concrete specimens, in the study after remolded at the end of 24 hours casting concrete, the specimens were left to the air without applying any curing materials for 3 different curing days these were for 7 days, 14 days and for 28 curing days to cured by using its internal moisture from aggregates.

Figure 3.8. Self-curing of concrete

3.4.10. Hardened concrete testing

3.4.10.1. Compressive strength

Using the standard specification for lightweight concrete ASTM C 330 as well as ASTM C 33 for the normal concrete that is for the control mix and the standard test method for compressive strength of concrete, the tests were carried out on the selected 45 cubes (150x150x150mm) size samples. One type of mix had 9 samples that is 3 for 7days, 3 for 14 days and 3 for 28 days. Totally there were 5 different types of mixes. The tests were carried after 7, 14 and 28 days using the compressive machine which has the capacity of 2000 KN per cross-sectional area of cube specimen.

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Figure 3.9. Mesuring of compressive strength

CHAPTER FOUR

RESULTS AND DISCUSSION

This section describes the properties of ingredients of concrete and properties of fresh concrete to determine the results presented and analyzed to better understand the technology of self or internal curing using:

- Full replacement of natural coarse aggregate by red ash coarse aggregate
- Full replacement of natural coarse aggregate and natural fine aggregate by red ash coarse and fine aggregate respectively.
- Natural gravel coarse aggregate and natural sand as a control mix.

4.1. Test results for the ingredients of concrete

4.1.1. Sieve analysis

The sieve analysis of red ash (scoria) coarse and fine aggregates was conducted as per ASTM C 330. And also the grading of the natural sand and natural gravel aggregate was conducted as per ASTM C33.

4.1.1.1 Red ash (Scoria)

For this study the red ash was used as a coarse and fine aggregate based on ASTM C 330 standard specification.

A. Red ash coarse aggregate

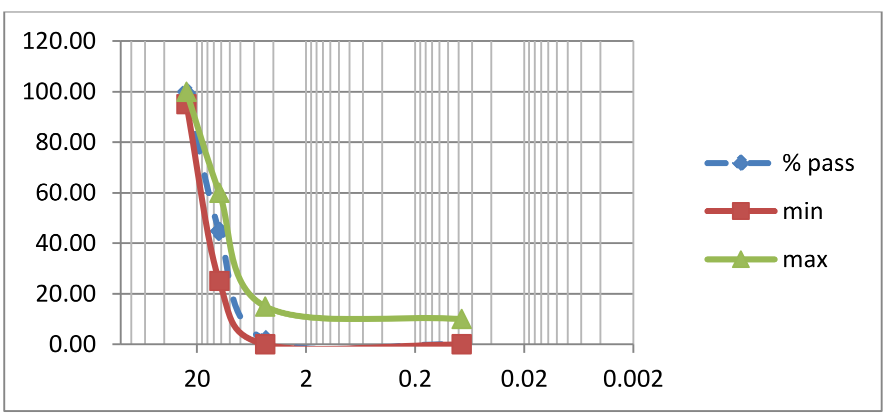

Figure 4.1. Sieve size of red ash coarse aggregate

As shown from the above figure 4.1, the gradation of red ash coarse aggregate is falls between the minimum and the maximum limit of specification. So as per ASTM C330 requirement for the gradation of light weight aggregate, the red ash coarse aggregate fulfill this limit.

B. Red ash fine aggregate

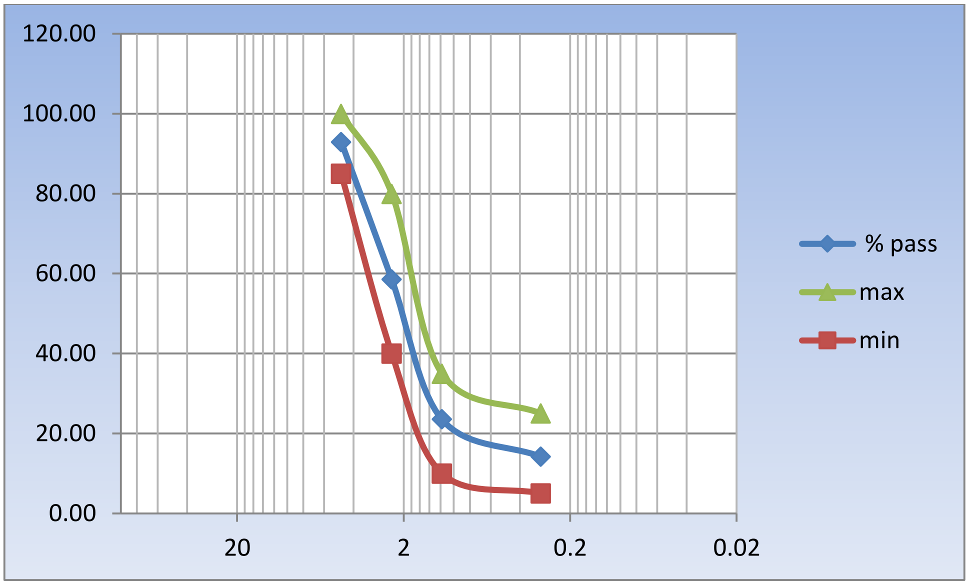

Figure 4.2. Sieve size of red ash fine aggregate

As shown from figure 4.2, the gradation of the red ash fine aggregate is falls between the minimum and maximum limit of grading requirements for light weight aggregate for structural concrete by ASTM C 330. Hence the red ash fine aggregate satisfies the standard maximum and minimum requirements of grade limit.

C. Natural sand

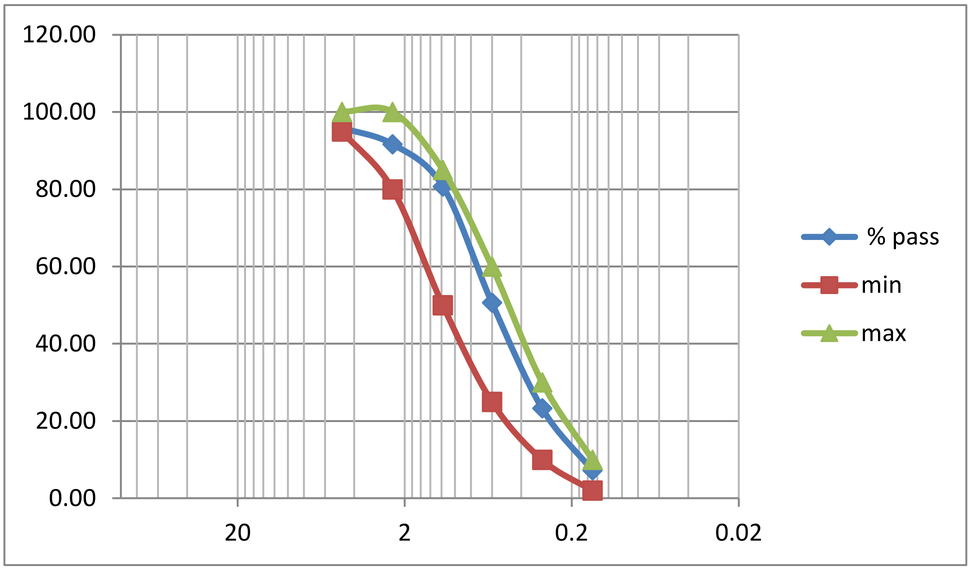

Figure 4.3.Sieve size of natural sand

As seen from the above figure 4.3, the gradation of the natural sand falls between the minimum and the maximum limit of ASTM C 33, standard grading requirements for natural sand specification limit. As a conclusion, the natural sand fulfills the grading requirement for natural sand per ASTM C 33. So it is ready for the required purpose.

D. Natural gravel

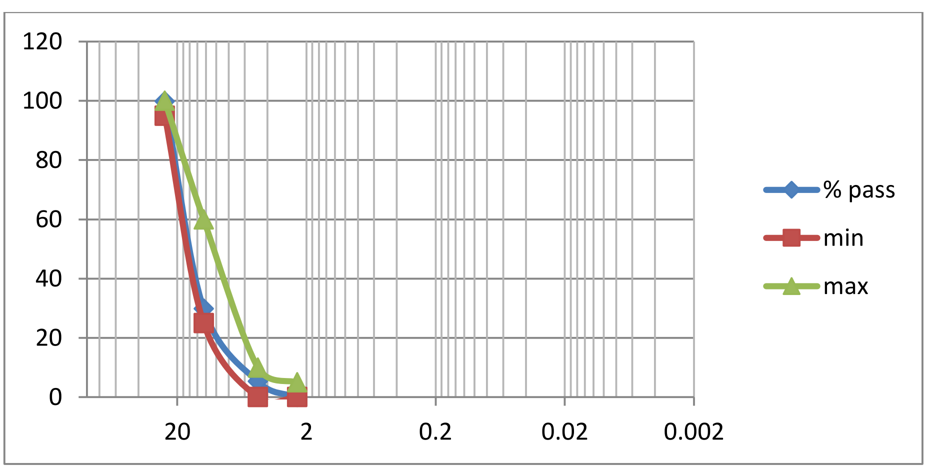

Figure 4.4.Sieve size of natural gravel

As seen from the above figure 4.1.1.1.4, the gradation of the natural gravel falls between the minimum and maximum limit of ASTM C 33, standard grading requirements for natural gravel specification limit. As a conclusion, the natural gravel fulfills the grading requirement for natural sand per ASTM C 33. So it is ready for the required purpose.

4.1.2. Unit weight of aggregates

A. Red ash coarse and fine aggregates' unit weight

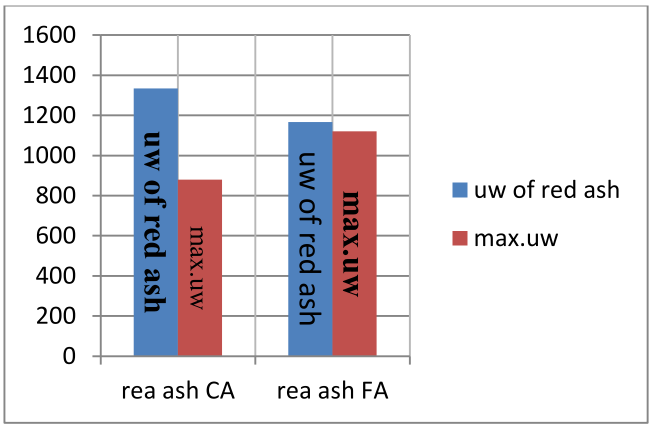

Figure 4.5. Unit weight of aggregates

As shown from the above figure 4.5, Red ash coarse aggregate and red ash fine aggregate has unit weight value 1335kg/m^3 and 1300kg/m^3 respectively. The light weight aggregate unit weight in the case of red ash aggregates for this study are greater than the maximum unit weight of ASTM C 330, unit weight for coarse and fine light weight aggregates, which is limited in the standard specification that is 880kg/m3 for light weight coarse aggregate and 1120kg/m3 for fine light weight aggregate. But the name of the light weight aggregate in the standard is the general name without considering the source of the material. Scoria (red ash) is usually heavier, darker and more crystalline with irregular in form and has the basic composition of basalt (Hossain, 2000). From this result, the source of material is one factor for the property difference of the material and also the colour of red ash which was used for this study was reddish rather than red in colour and has black shine spots inside it. The geologist who works in BUDSWS says "this is the other indication red ash has the Fe_2O_3 and MgO to be reddish and has a nearby property with the basalt".

4.1.3. Soundness

As per ASTM C 33, the test of soundness by sodium sulphate (Na_2SO_4) was conducted and has the result value less than 10%. The maximum ASTM C 33 allows 10% for sodium sulphate.As per the result of the test, it fulfills the requirement of the standard. So the red ash from Tullu Dimitu can resist the weathering action which is applied by the external condition.

4.1.4. Resistance of degradation

Resistance of degradation was conducted per ASTM designation E 11, using the Los Angeles Testing Machine and obtained 48%. The maximum ASTM C 33 resistance of degradation limit is 50%. The test result value of aggregate which is less than 37.5 mm sieve size can resist 48% of abrasion of the red ash aggregate.

4.1.5. Water absorption

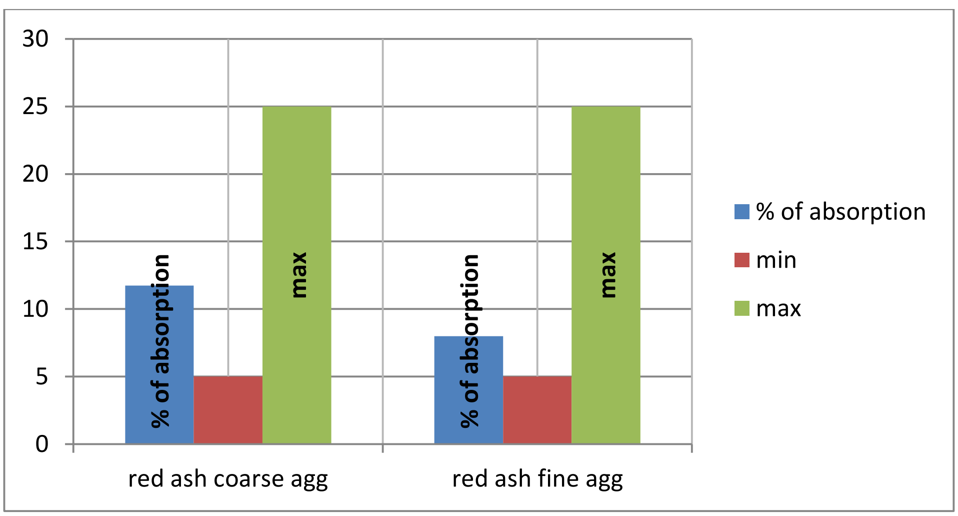

Figure 4.6.Absorption capacity of red ash aggregate

The absorption capacity of the light weight aggregate is higher than the normal weight aggregate. Even if there is only a definition on the light weight aggregate by saying, light weight aggregate has higher absorption capacity than normal aggregate without the minimum and maximum limit in number on the standard specification of light weight aggregate, but it describes on the ACI committee 213 as a general definition, the light weight aggregates absorb from 5 to 25 % by mass of dry aggregate, depending on the aggregate pore system. So this higher absorption value indicates that, great contribution for the internal curing of concrete when the concrete cures by its self without applying external curing agent for the curing. As shown in figure 4.6, it also satisfies the value limitation for light weight aggregate by ACI 213 committee. The red ash coarse aggregate has 11.75 % absorption capacity and the red ash fine aggregate has 7.99 % absorption capacity**.**

4.1.5. Specific gravity

For this study the specific gravity of red ash coarse aggregate, red ash fine aggregate and natural sand were conducted. From the conducted laboratory test results, the specific gravity of red ash coarse aggregate has 2.20, red ash fine aggregate has 2.35 and finally the result of natural sand and natural gravel has specific gravity value 2.5 and 2.87 respectively as shown from figure 4.7 below.

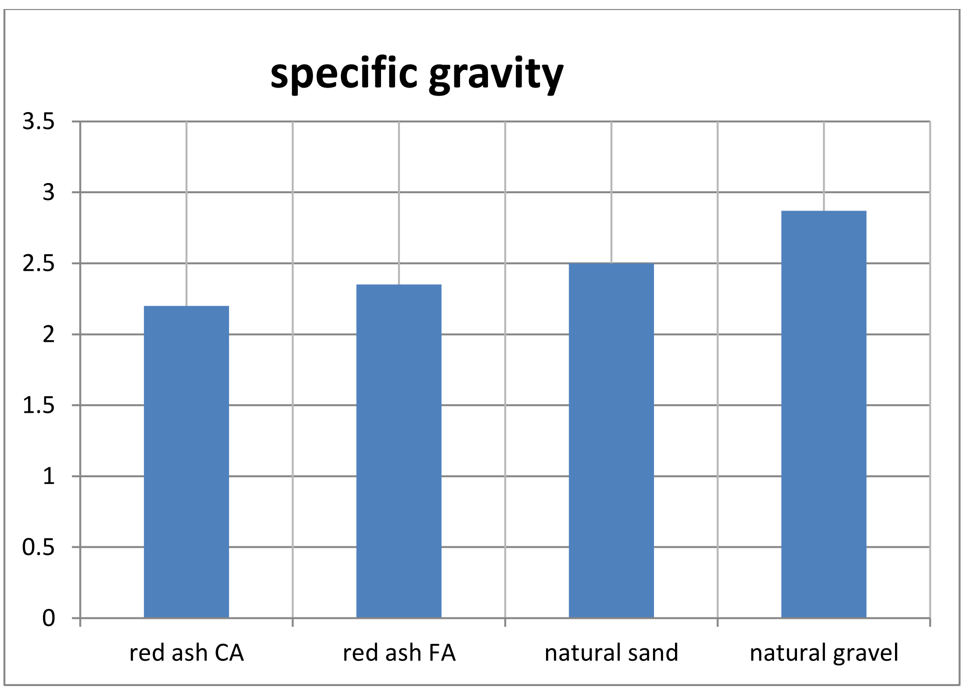

Figure 4.7. Specific gravity of aggregates

4.2. Properties of fresh light weight concrete

4.2.1. First trial

In the following table there are the results of the air content, unit weight and slump of light weight concrete.

Table 4.1.Properties results of fresh concrete

S.NO	Mix type	Slump (mm)	Air Content (%)	Unit Weight (kg/m3)
1	RRC 1	51	6.5	1986
2	RNC 1	38	5.0	2218

4.2.1.1. Slump

Results of slump test are listed in table 4.1 and are illustrated in figure 4.8. As can be seen in figure 4.8, the mix type with red ash as a coarse aggregate and natural sand as a fine aggregate has lower slump value which is 38mm than the mix type using red ash as a coarse aggregate and red ash as a fine aggregate which has the value 51mm. Slump value is the indication of the presence of water in the fresh concrete. The mix type with red ash coarse and fine aggregate has the higher slump value than the mix type with only red ash as a coarse aggregate in the portion of the concrete. There is no void inside the natural sand particle as compared to the red ash fine aggregate. Because of the absence of voids inside the natural sand particle, the mix type using the natural sand as a fine aggregate has a little bit higher capillary forces as compared to the mix type using red ash as a fine aggregate. This is due to the reduction of desorption of water at the time of mix from the portion of the red ash fine aggregate and due to the absence of additional internal water in the natural sand. The natural sand has a lower water absorption capacity than the red ash fine aggregate. That means the stored water inside the fresh concrete due to the water absorption capacity of aggregates is lower for the mix type using natural sand as a fine aggregate. This is due to the absence of additional water in the natural sand. And also slump test results show an important advantage of using pre- wetted coarse and fine red ash aggregates to enhance workability for ease concrete handling and finishing.

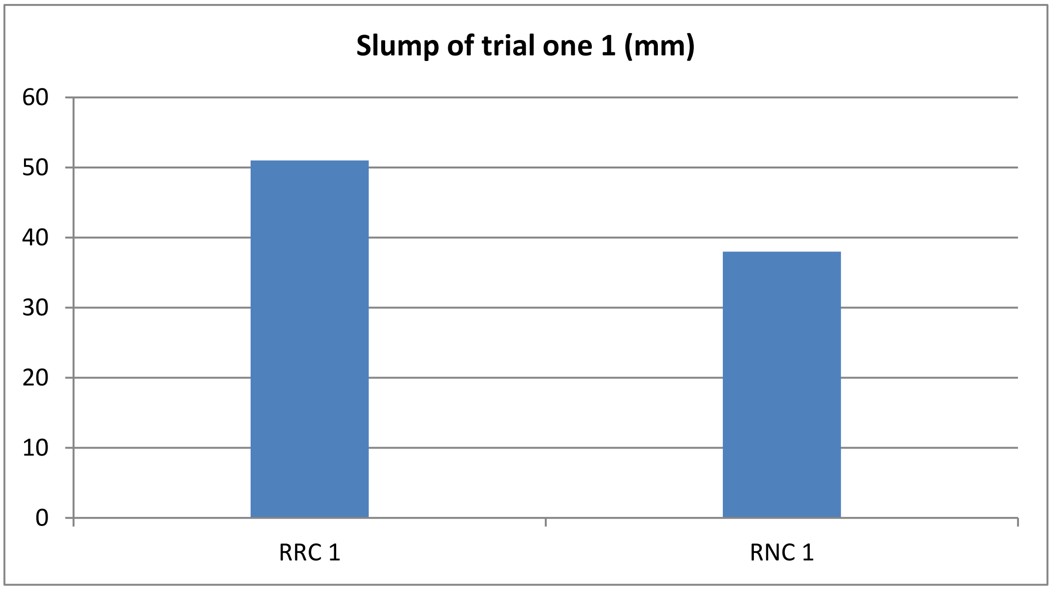

Figure 4.8: Slump tests results

As shown from the figure, desorption was lower for the concrete with natural sand compared to concrete with red ash coarse aggregate and red ash fine aggregate concrete.

4.2.1.2. Air content

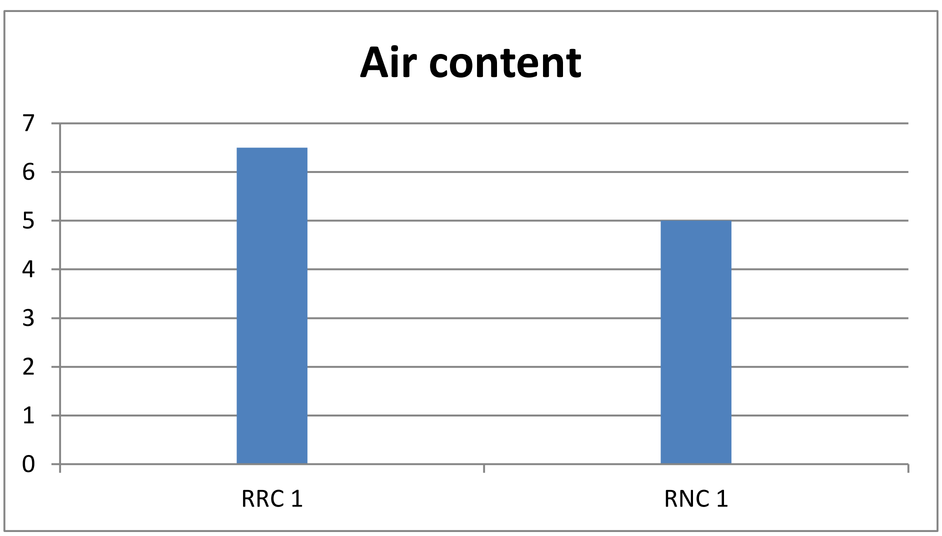

Figure 4.9: Air content results

Test results of air content are listed in table 4.1 and are illustrated in figure 4.9. As shown in the above figure 4.9, the air content percentage for the mix type using red ash as a coarse aggregate and red ash as a fine aggregate has higher air content with the value 6.5 % than the mix type using red ash as a coarse aggregate and natural sand as a fine aggregate which has the value 5 %.As a general understanding from the above table and figure results of air content of the fresh concrete, the concrete has a higher air content value which is mixes with both coarse and fine aggregate is replaced by pre-wetted red ash coarse and fine aggregate and the lower value of air content of concrete is from the mix of pre-wetted red ash coarse aggregate with natural sand. The results of air content of fresh concrete show that concrete with the full replacement of both coarse and fine aggregates by pre-wetted red ash coarse and fine aggregates have slightly higher air content than concrete with only one aggregate type replacement of concrete. Because in the replacement of both red ash coarse and red ash fine aggregates have more pores but natural sand has no pores compared to the red ash fine aggregate. So due to the replacement of the natural sand in the place of the red ash fine aggregate is the cause for the reduction of air content in the concrete.

4.2.1.3. Unit weight

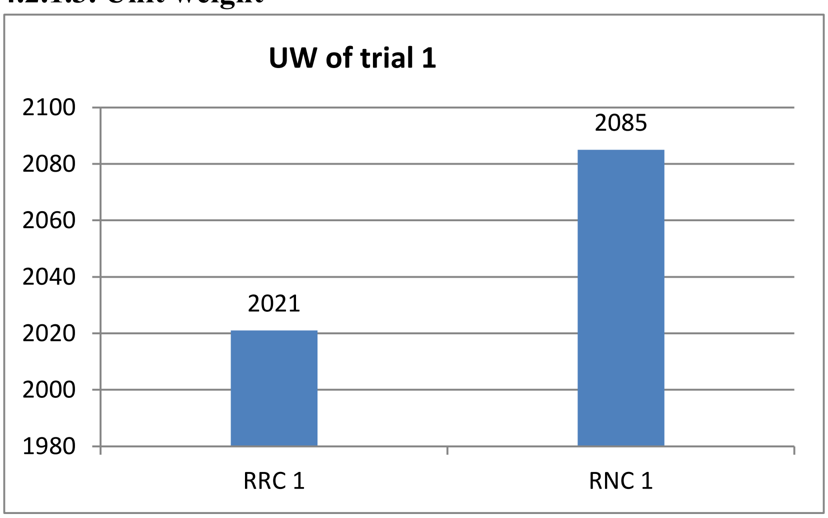

Figure 4.10: Unit weight of fresh concrete

Test results of unit weights of fresh concretes are listed in table 4.1 and are illustrated in figure 4.10; the unit weight of the fresh concrete with the mix type using red ash as a coarse aggregate and red ash as a fine aggregate as well as the mix type using red ash as a coarse aggregate and natural sand as a fine aggregate have the value 2021 kg/m^3 and 2085 kg/m^3 respectively. The higher value is obtained from concrete made with pre-wetted red ash coarse aggregate and natural sand. The unit weight of concrete with the full replacement of both the natural gravel coarse aggregate and natural sand by pre-wetted red ash coarse and fine aggregate has lower unit weight than one part of aggregate replacement of the fresh concrete. This behavior can be attributed to the increased porosity and decreased unit weight of the full replacement of both coarse and fine aggregate of concrete by pre-wetted red ash aggregates. But the difference of unit weight of full replacement of both natural coarse and fine aggregates by pre-wetted red ash aggregates and replacement of natural coarse aggregate only by pre-wetted red ash coarse aggregate is not exaggerated. This is due to the replaced aggregates were pre-wetted before mixing which makes such aggregates closer in density to the one which is slightly greater.

4.2.2. Second trial

By seeing the results from the first trial mix, by reducing water cement ratio and by adjusting the cement content the second and final results are shown in table below.

Table 4.2. Properties results of fresh concrete

S.NO	Mix type	Slump (mm)	Air Content (%)	Unit Weight (kg/m3)
1	RRC 2	42	5.3	2155
2	RNC 2	30	4.1	2264
3	GNC 2	27	1.8	2388

4.2.2.1. Slump

Results of slump test are listed in table 4.2 and are illustrated in figure 4.11. As can be seen in figure 4.11, the slump ranges from 27 to 42 mm. The highest slump value is obtained from the sample which has the mix type with red ash coarse and red ash fine aggregate followed by red ash coarse and natural sand of fresh concrete with the same trained as first trial. The lowest slump value is the fresh concrete made with natural gravel coarse aggregate and natural sand that is the control mix with the value 27 mm. This indicates that slump value increase with increase in replacement amount of the pre wetted red ash aggregates. The higher slump value of the pre wetted aggregate can be attributed to desorption property of aggregates or their ability to lose their internal water during mixing to an increase in the flow ability of the concrete. When the slump becomes decrease, the capacity of compressive strength becomes increase but it also depends on the curing condition of concrete and properties of ingredients of concrete. Because slump of the fresh concrete decrease means the amount of water within the concrete decrease and this condition is suitable for the fastness of hydration of concrete. As seen from the results of the slump value, the control mix which is mix using the natural gravel and the natural sand has the lowest slump value as compared from the mixes using pre-wetted red ash aggregates. This is due to the natural gravel coarse aggregate and the natural sand have less pores; because of this the natural gravel and the natural sand have low water absorption capacity as compared to the red ash aggregates. So the mix type using natural gravel coarse aggregate and natural sand has low desorption capacity of water during the mixing of concrete.

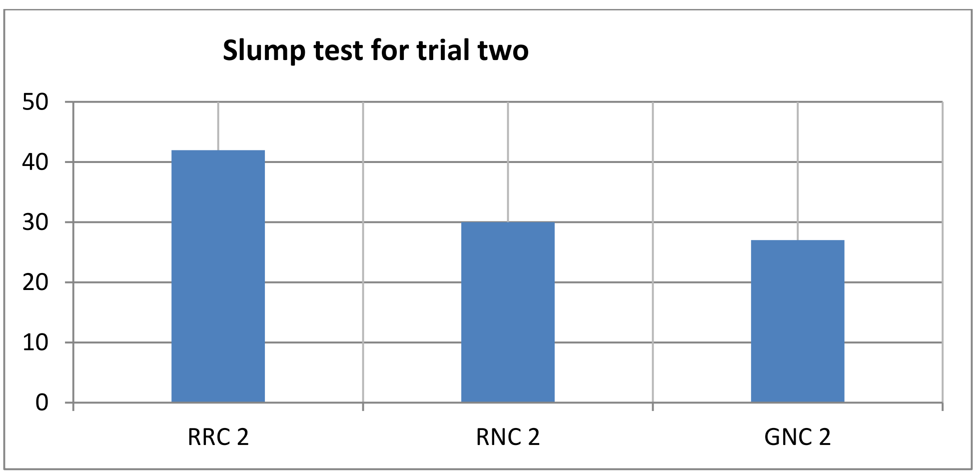

Figure 4.11.Slump tests results

As shown from the figure above , desorption is lowest for the concrete with natural gravel and natural sand compared to concrete with red ash coarse aggregate and red ash fine aggregate concrete. This is due to the lowest amount of additional water in the natural gravel and in the natural sand. And also slump test results show an important advantage of using pre- wetted red ash coarse and fine aggregates to enhance workability for ease concrete handling and finishing. But the advantage of workability must coincide with the capacity of compressive strength and curing capacity of concrete. So by considering these things, the final mix (second trial) of the study coincide the workability and curing capacity of concrete.

4.2.2.2. Air content

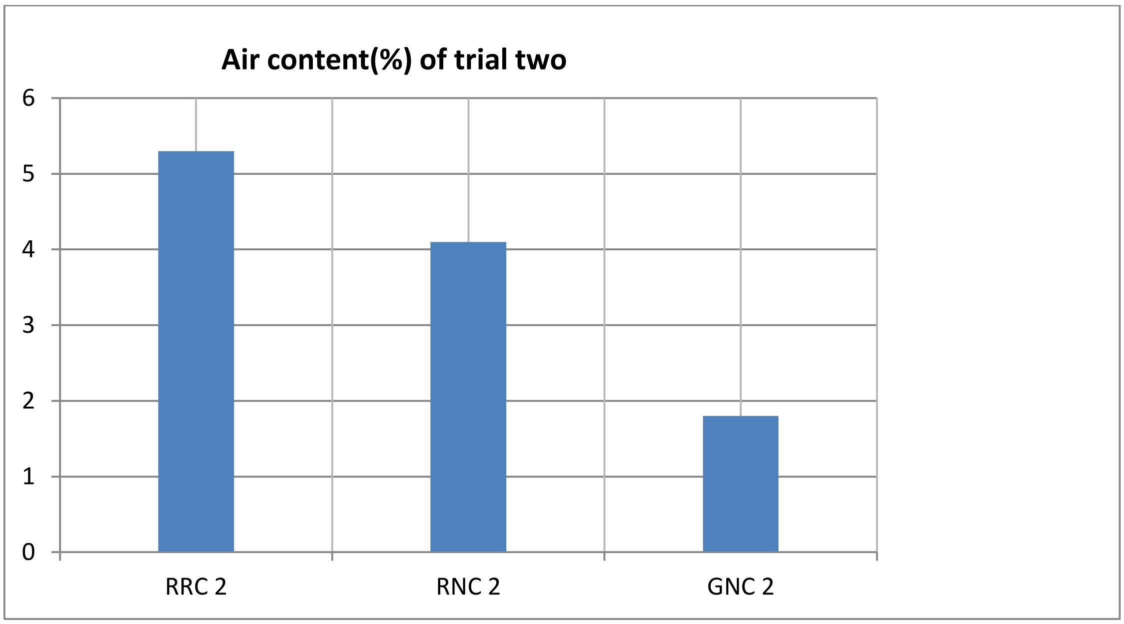

Figure 4.12: Air content results

Test results of air content are listed in table 4.2 and are illustrated in figure 4.12. As shown from the test results, the air content percentage ranges between 1.8 to 5.3 %. The highest value is obtained from fresh concrete with the mix of pre-wetted red ash coarse and fine aggregate. As a general understanding from the above table and figure results of air content of the fresh concrete, the fresh concrete has a highest air content value which is the mix both the natural gravel coarse aggregate and natural sand are replaced by pre-wetted red ash coarse and fine aggregate and the lowest value of air content of concrete is the mix of pre-wetted natural gravel with natural sand. The test results of air content of fresh concrete show that concrete with the full replacement of both coarse and fine red ash aggregates have slightly higher air content than concrete with only one aggregate type replacement of concrete and from the mix type with natural gravel and natural sand. Because in the replacement of both red ash coarse and red ash fine aggregates have more pores but natural sand and natural gravel have no much pores like red ash aggregates. So due to the replacement of the natural sand in the place of the red ash fine aggregate and replacement of natural gravel in the place of red ash coarse aggregate is the cause for the reduction of air content in the concrete.

4.2.2.3. Unit weight

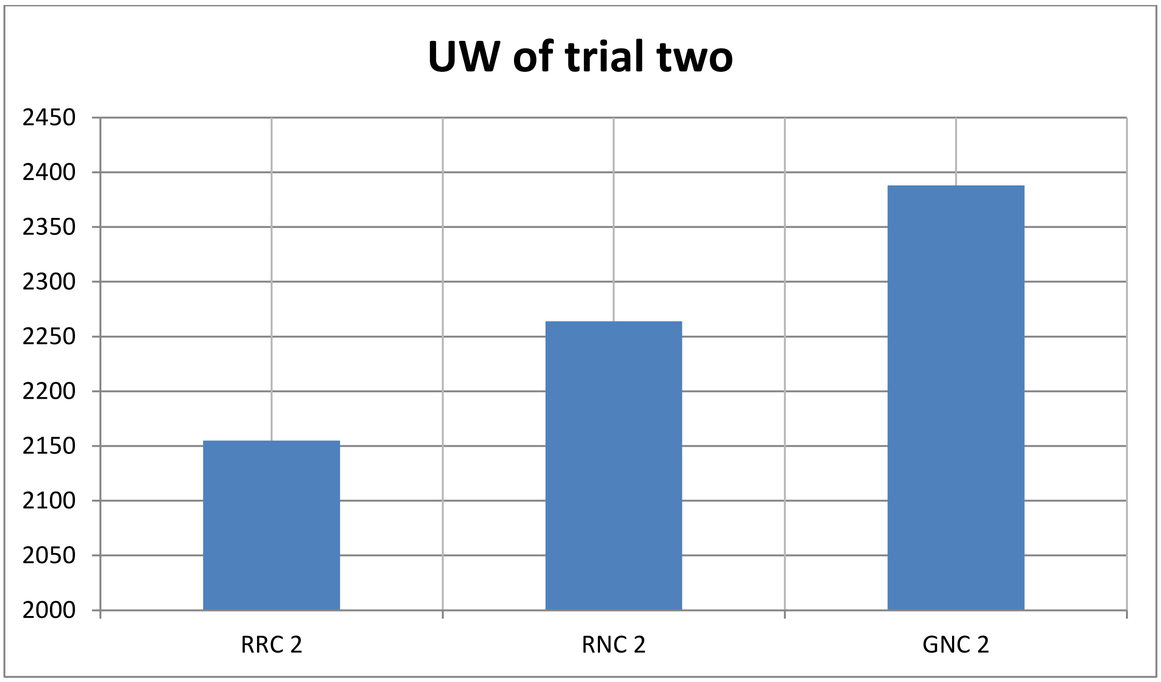

Figure 4.13: Unit weight of fresh concrete

Test results of unit weights of fresh concretes are listed in table 4.2 and are illustrated in figure 4.13; it ranges from 2155 kg/m3 to 2388 kg/m3. The highest value is obtained for concrete which is made with pre-wetted natural gravel and natural sand. The unit weight of concrete with full replacement of both the natural gravel and natural sand by the pre-wetted red ash coarse and fine aggregate has lower unit weight than only natural gravel coarse aggregate is replacement by pre-wetted red ash coarse aggregate of the fresh concrete and the control mix which is mixed by the natural gravel and natural sand. This behavior can be attributed to the increased porosity and decreased unit weight of the full replacement of both coarse and fine aggregate by red ash aggregates of concrete but the difference in unit weight of the mix type with both coarse and fine red ash aggregates and the mix type with red ash coarse aggregate and natural sand is not exaggerated. This is due to the replaced aggregates were pre-wetted before mixing, which makes such aggregates closer in density to the one which is slightly greater and also the decrease the slump of concrete, there is also increase the unit weight of concrete. This is due to when decrease the slump, the amount of air content also decrease. Generally, replacing conventional aggregates by red ash aggregates led to slight drop in unit weight in the concrete mixture.

4.3. Test results for the hardened concrete

4.3.1. Compressive strength

4.3.1.1. Compressive strength for mix trial one

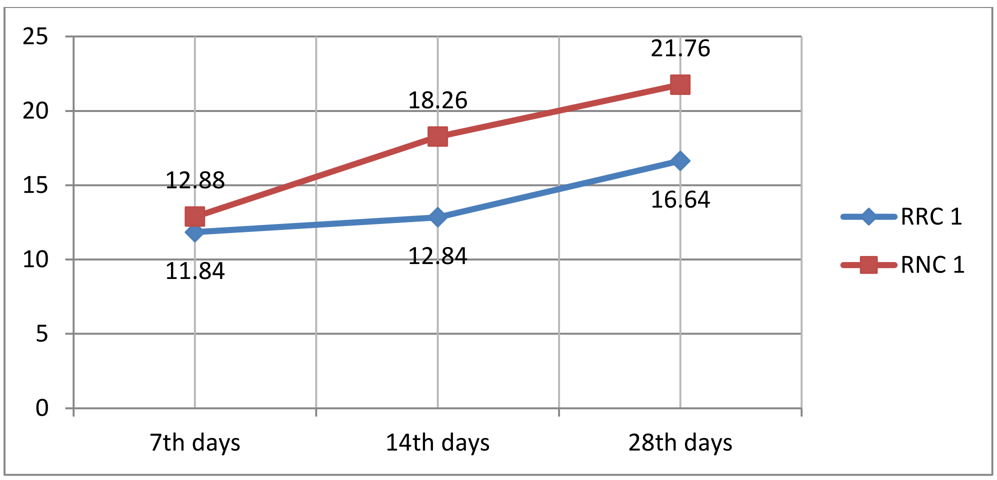

Figure 4.14. Compressive strength of red ash coarse and fine aggregate and red ash coarse aggregate with natural sand

As seen from the above figure, at the 7^{th} day curing period the mix type using red ash as a coarse aggregate and natural sand as a fine aggregate has a higher compressive strength capacity with the value 12.88 Mpa than the mix type using red ash as a coarse aggregate and red ash as a fine aggregate with the value 11.84 Mpa. The properties of the natural sand that are having less water absorption capacity than the red ash fine aggregate, having higher specific gravity than the red ash fine aggregate and having less pores particle by the implication of water absorption capacity than the red ash fine aggregate make the mix type which is using red ash as a coarse aggregate and natural sand as a fine aggregate has higher compressive strength capacity than the mix type using red ash as a coarse aggregate and red ash as a fine aggregate.

The mix type which is using the red ash as a coarse aggregate and natural sand as a fine aggregate has higher compressive strength capacity at the 14th day than the mix type using red ash as a coarse aggregate and red ash as a fine aggregate like occurred in the 7th curing day. Not only in the compressive strength, the mix type which is using red ash as a coarse aggregate and natural sand as a fine aggregate has also higher curing capacity which is 5.38 Mpa than the mix type using red ash as a coarse aggregate and red ash as a fine aggregate which has the curing capacity 1 Mpa at the 14th curing day. This is because the natural sand reduces the pores amount which exist due to the red ash fine aggregate in the mix type of red ash as a coarse aggregate and red ash as a fine aggregate. Due to the reduction of the pores amount means also reduction of the additional water amount inside the concrete which was stored at the time of pre-wetted of aggregates. So the increase of pre-wetted red ash amount within the concrete makes the concrete to have lower curing capacity than less amount of pre-wetted red ash aggregate.

At the 28th curing day of concrete, the mix type which is red ash as a coarse aggregate and natural sand as a fine aggregate has higher compressive strength than the mix type using red ash as a coarse aggregate and red ash as a fine aggregate. But it has lower curing capacity with the value 3.5 Mpa than the mix type using red ash as a coarse and as a fine aggregate which has the curing capacity value 3.8 Mpa. This is because, the amount of pre-wetted red ash aggregate decrease there is also decrease the hydration of the cement past due to the decrease the additional internal water from the pre-wetted red ash aggregates.

4.3.1.2. Compressive strength for mix trial two

These were the mixes of the second and the final trial mixes by adding the control mix for the determination of the self-curing capacity of the mixes for the full replacement of normal gravel coarse aggregate and natural sand by pre-wetted red ash coarse and fine aggregates and also the replacement of normal gravel coarse aggregate by the pre wetted red ash coarse aggregate as well as mix with natural gravel with natural sand as a control mix. Results of the compressive strength test are listed in table and are illustrated in figure.

Table 4.3. Compressive strength results of different mix types for trial two

Mix types	Compressive Strength (Mpa)		
	7 days	14 days	28 days
RRC 2	17.82	20.96	26.88
RNC 2	20.32	28.77	34.28
GNC 2	18.87	21.66	23.77

A. Mixes RRC 2 and RNC 2

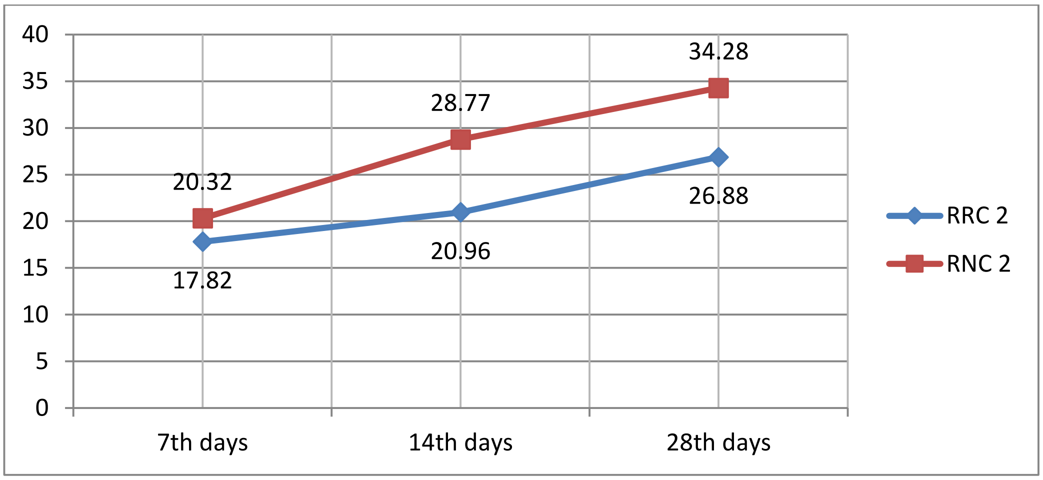

Figure 4.15.Compressive strength for mix RRC 2 and RNC 2

As seen from the above figure 4.15, as the same trained like trial one, at the 7th day curing period the mix type using red ash as a coarse aggregate and natural sand as a fine aggregate has a higher compressive strength capacity with the value 20.32 Mpa than the mix type using red ash as a coarse aggregate and red ash as a fine aggregate with the value 17.82 Mpa. The properties of the natural sand that are having less water absorption capacity than the red ash fine aggregate, having higher specific gravity than the red ash fine aggregate and having less pores particle by the implication of water absorption capacity than the red ash fine aggregate make the mix type which is using red ash as a coarse aggregate and natural sand as a fine aggregate has higher compressive strength capacity than the mix type using red ash as a coarse aggregate and red ash as a fine aggregate.

The mix type which is using the red ash as a coarse aggregate and natural sand as a fine aggregate has higher compressive strength capacity at the 14th day than the mix type using red ash as a coarse aggregate and red ash as a fine aggregate like occurred in the 7th curing day. Not only in the compressive strength, the mix type which is using red ash as a coarse aggregate and natural sand as a fine aggregate has also higher curing capacity which is 8.45 Mpa than the mix type using red ash as a coarse aggregate and red ash as a fine aggregate which has the curing capacity 3.14 Mpa at the 14th curing day. This is because the natural sand reduces the pores amount which exist due to the red ash fine aggregate in the mix type of red ash as a coarse aggregate and red ash as a fine aggregate. Due to the reduction of the pores amount means also reduction of the additional water amount inside the concrete which was stored at the time of pre-wetted of aggregates. So the increase of pre-wetted red ash amount within the concrete makes the concrete to have lower curing capacity than less amount of pre-wetted red ash aggregate.

At the 28th curing day of concrete, the mix type which is red ash as a coarse aggregate and natural sand as a fine aggregate has higher compressive strength with the value 34.28 Mpa than the mix type using red ash as a coarse aggregate and red ash as a fine aggregate with the value 26.88 Mpa. But it has lower curing capacity with the value 5.51Mpa than the mix type using red ash as a coarse and as a fine aggregate which has the curing capacity value 5.92 Mpa. This is because, the amount of pre-wetted red ash aggregate decrease there is also decrease the hydration of the cement past due to the decrease the additional internal water from the pre-wetted red ash aggregates.

B. Compressive strength of RRC 2 and GNC 2

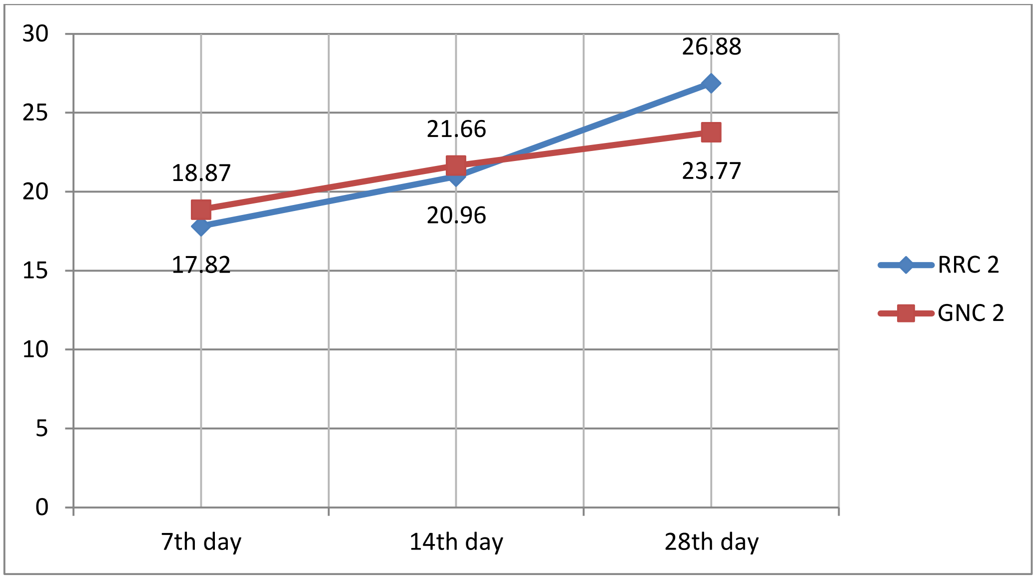

Figure 4.16. Compressive strength of mix with RRC 2 and GNC 2

As seen from the above figure 4.3.1.2.2, the compressive strength at the 7th day of the mix type using natural gravel coarse aggregate and natural sand that is the control mix has higher compressive strength which has the value 18.87 Mpa than the mix type by using the pre-wetted red ash as a coarse aggregate and as a fine aggregate with the value 17.82 Mpa. The properties of the natural gravel and the natural sand make the concrete to have higher compressive strength at the early age of curing time.

The concrete mix type using natural gravel and natural sand has a little bit higher compressive strength at the 14th curing day with the value 21.66 Mpa than the mix type using pre-wetted red ash as a coarse and as a fine aggregate with the value 20.96 Mpa. But the mix type which is using the pre-wetted red ash as a coarse and as a fine aggregate has higher curing capacity with the value 3.14 Mpa than the mix type using natural gravel and natural sand with the value 2.79 Mpa. This is because the stored water inside the concrete in the case of the mix type using natural gravel and natural sand is less than the amount of stored water by the mix type using pre-wetted red ash as a coarse and as a fine aggregate due to the red ash aggregates have much pores particle to stored much water inside the concrete than the concrete which is the mix of natural gravel and natural sand.

Due to the lower curing capacity at the 14th day, the compressive strength at 28th day of concrete which is mix by using natural gravel and natural sand with the value 23.77 Mpa is surpassed by the compressive strength of the concrete which is mix using the pre-wetted red ash coarse and fine aggregates with the value 26.88 Mpa. And also the curing capacity of concrete which is mix by using the pre-wetted red ash as a coarse and as a fine aggregates has higher curing capacity with the value 2.81 Mpa than the concrete type using natural gravel and natural sand with the value 2.11 Mpa.

C. Compressive strength of RNC 2 and GNC 2

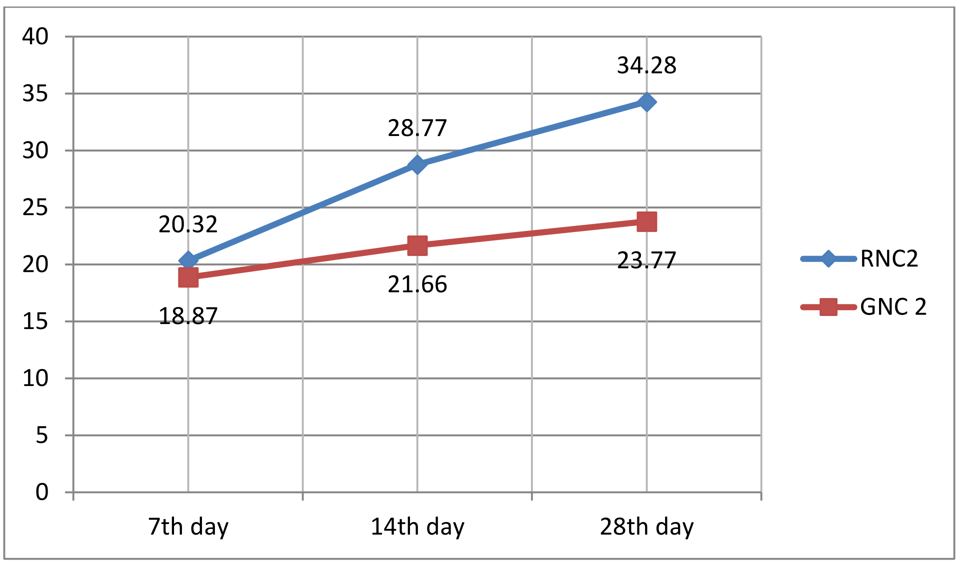

Figure 4.17.Compressive strength of mix with RNC 2 and GNC 2

As seen from the above figure 4.17, the concrete with the mix type using pre-wetted red as a coarse aggregate and natural sand as a fine aggregate is dominant both on the compressive strength as well as on the curing capacity of concrete. As seen from the above figure, at the 7th curing day the mix type using the pre-wetted red ash coarse and fine aggregate has higher compressive strength with the value 20.32 Mpa than the concrete type using natural gravel and natural sand with the value 18.87 Mpa. But at seen in the above figure 4.17, at the 7th day the compressive strength of concrete which is the mix type using natural gravel and natural sand is higher than the concrete using the pre-wetted red ash coarse and fine aggregate. But here, the mix type using pre-wetted red ash coarse aggregate and natural sand has higher compressive strength at the early curing age due to the reduction of the pores part of the concrete at the place of the red ash fine aggregate by the natural sand. By similar trained which is seen at the 7th day, the mix type using pre-wetted red ash coarse aggregate and natural sand surpassed in compressive strength with the value 28.77 Mpa at the 14th curing day than the mix type using the natural gravel and the natural sand with the value 21.66 Mpa and also the mix type using pre-wetted red ash coarse aggregate and natural sand surpassed in curing capacity with the value 8.45 Mpa than the mix type using natural gravel and natural sand with the value 2.79 Mpa.

At the 28th day also the mix type using pre-wetted red ash coarse aggregate and natural sand has the higher compressive strength with the value 34.28 Mpa than the mix type using natural gravel and natural sand with the value 23.77 Mpa. Not only in compressive strength but also higher in curing capacity with the value 5.51 Mpa than the mix type using natural gravel and natural sand with the value 2.11 Mpa. As a general understanding from the test results of this study, the aggregate type and properties of the aggregate in addition to the pre-wetted the aggregate are play a vital role for the attainment of compressive strength of concrete as well as to have better curing capacity in the desired period.

D. Compare concrete curing with natural sand and red ash fine aggregate and control mix

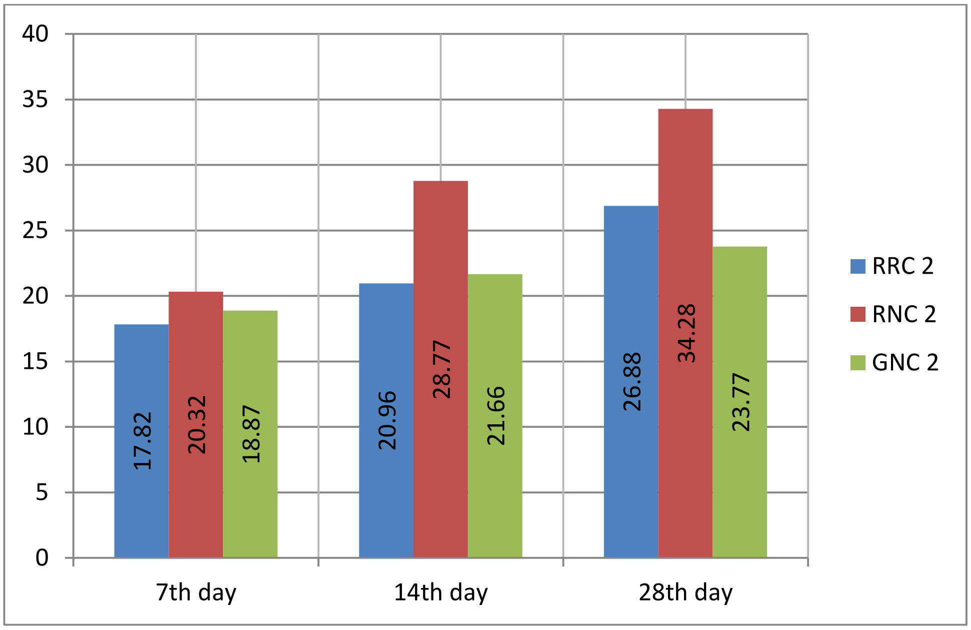

Figure 4.18. Compressive strength of mix with RNC 2 and GNC 2

As seen the all three types of mixes test results from the above figure 4.18, the mix type using pre-wetted red ash coarse aggregate and natural sand has the highest compressive strength starting from the 7th day curing of concrete up to 28th day curing of concrete from both the mix type using pre-wetted red ash coarse and natural sand as well as the control mix. Not only in compressive strength, this mix type also has the better curing capacity than the control mix as well as from the mix type using pre-wetted red ash coarse and fine aggregate for the desired curing period.

The curing capacity of concrete is analyzed by using the gap value of the compressive strength between the serious desired curing periods of concrete. To attain better compressive strength and curing capacity of concrete the type of aggregate, the properties of aggregate, dosage of pre-wetted red ash aggregates as well as the method of curing are important. As seen clearly from the test results of this study the full replacement of natural gravel and natural sand by pre-wetted red ash coarse aggregate and pre-wetted red ash fine aggregate respectively make the concrete to have less curing capacity and compressive strength due to increase in pores within the concrete. By reducing the pores part which is replacing the red ash fine aggregate by the natural sand of concrete to have better curing capacity as well as compressive strength as seen from the reveal of the results.

The properties of the natural gravel like less water absorption capacity and non-pores in nature compared to the red ash aggregate make the concrete to have less self-curing capacity as well as to have less compressive strength for the design capacity of concrete.

4.4. Effect of red ash aggregate on curing

As it's described in the methodology all the mixes in this study was cured by self (internal) curing method by putting the concrete specimens in open air to investigate the self or internal curing capacity of red ash by applying it in coarse and fine aggregate forms. Additionally the test was conducted by producing two trial mixes designed by ACI mix design method and the control mix.

4.4.1. Trial mix one

For this trial mix, 2 different concrete mix specimens were prepared

Table 4.4.Average 28th day compressive strength results of trial one mix specimens

Type of concrete mix	Average dry density in Kg/m^3	Average 28th day compressive strength in Mpa
RRC1	1867	16.64
RNC1	2212	21.76

Table 4.5. ASTM standard for minimum 28th day average compressive strength of light weight concrete

Calculated equilibrium density max, Kg/m^3	Average 28th day compressive strength.min.Mpa
All light weight aggregate	
1760	28
1680	21
1600	17
Sand/light weight aggregate	
1840	28
1760	21
1680	17

4.4.2. Trial mix two

Table 4.6. Average 28th day compressive strength results of trial two mix specimens

Type of concrete mix	Average dry density in Kg/m^3	Average 28th day compressive strength in Mpa
RRC 2	2152	26.88
RNC 2	2222	34.28
GNC 2	2311	23.77

As shown from the above trial one and trial two tables, the average dry density of both trial one and trial two is larger for all types of mixes from the dry density of ASTM standard which is put in table 4.5.The ASTM standard limits the dry density for both all light weight aggregate and sand/light weight aggregate for the minimum average 28th day compressive strength with the maximum curing capacity by conventional curing method of light weight concrete. But from the two trials condition, the densities of all specimens are greater than the densities which are put in ASTM standard as shown in table 4.5. So the specimens have greater dry density than ASTM standard dry density means, the specimens should have greater curing capacity than the curing capacity put in \ASTM standard. That is for the minimum average 28th compressive strength should be greater than 28 Mpa.

As shown from the results of trials, RNC 2 mix type with the value 34.28 Mpa fulfills the minimum ASTM standard requirement which is the average minimum 28th day compressive strength is 28 Mpa by the conventional method of curing. That means the mix type RNC 2 has maximum curing capacity from all specimens. The specimen is denser due to the portion of sand was natural sand. Due to this the porous part of red ash fine aggregate is reduced by the natural sand which is the non-porous with related to the red ash fine aggregate. So these things make the concrete to have better self-curing capacity within the desired curing time.

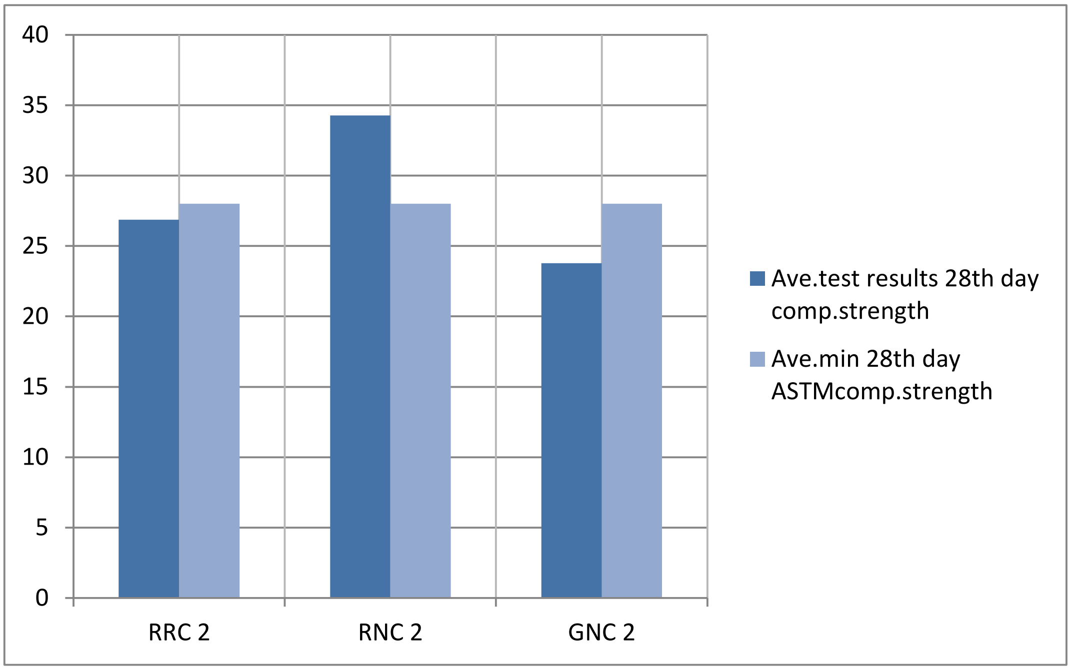

Figure 4.19. The mean 28th day compressive strength of specimens

In order to analyze the curing capacity of concrete between the serious of the design curing period, compressive strength of concrete is important as a tool. As seen from the figure the mix type RNC 2 satisfies not only the ASTM minimum compressive strength requirement for the light weight concrete at the 28thcuring day but it also fulfills the targeted compressive strength for C-25 grade of concrete with the value 33.3 Mpa by using the self or internal method of curing. Even if the mix type using both red ash coarse and fine aggregate has a little bit higher curing capacity than the mix type using red ash as a coarse and natural sand as a fine aggregate between 14th and 28th curing day but it is difficult to reach at the desired period compressive strength due to the slowness in hydration of concrete and also less attainment of compressive strength between 7th and 14th curing time.

In this study using the pre-wetted red ash aggregates as an ingredients of concrete in the portion of aggregates have better curing capacity in addition having higher compressive strength than the control mix which is the mix type using the natural gravel and the natural sand. From this generally conclude that, by using the optimum amount pre-wetted red ash aggregates by using the self or internal method of curing of concrete can get the better compressive strength by the application of better self curing capacity of concrete due to porous nature of the red ash to store the additional water to have better self-curing capacity of the concrete than the mix type using the natural gravel and the natural sand.

4.5. Cost analysis between red ash with natural gravel and natural sand

Table 4.7. Materials costs per meter cube

Mix type	Volume of materials/m^3 of concrete			Cost of materials Birr/m^3				Cost difference	
	Red ash CA	Red ash FA	Natural sand	Red ash CA(A)	Red ash FA(B)	N.Sand (C)	N.Gravel(D)	D-A	C-B
				55	55	350	370	315	295
RRC 2	0.449	0.21	-	24.70	11.55	73.50	166.13	141.43	61.95
RNC 2	0.419	-	0.24	23.05	13.20	84	155.03	131.98	70.80

As observed from the above table 4.7, volume of the material needed per one cubic meter for this study as a sample for two types of mixes and the cost of materials (for red ash coarse and fine aggregates as well as natural gravel and natural sand) per one cubic meter. It is clearly shown for 0.449 m3 of red ash coarse aggregate; it has the cost only Birr 24.70 but if it was natural gravel it will be have the cost Birr 166.13. From this small amount of cubic meter which is less than one cubic meter, the cost of the red ash coarse aggregate is about 7 times than the cost of natural gravel.

The costs of red ash coarse aggregate and red ash fine aggregate are equal, which is Birr 55 per cubic meter. As compare from the natural gravel coarse aggregate, the cost of red ash has 14.865% cost reduction within one cubic meter. The cost of natural sand increases by about 15.714% from the cost of red ash fine aggregate per one cubic meter.

For the replacement of natural gravel coarse aggregate by red ash coarse aggregate, the cost of material become reduce 14.865% per one cubic meter of material. The variation of this cost amount for large cubic meter is very wide. So the replacement of natural gravel aggregate is the better cost reduction regarding to the material cost for the production of concrete.

4.6. Total amount of water consumed by concrete

The total amount of water used for the purpose of pre-wet the red ash coarse and fine aggregate as well as for the mix of the concrete is listed in the table.

Table 4.8. Total water consumed by the concrete for the final mix

Types of mix	Amount of water (lit) for pre-wet of red ash	Amount of water (lit) for mix	Volume of concrete (m^3)	Total water consumed in lit (m^3)	Consumed Per m^3 of concrete in lit (m^3)
RRCO 2	5.16	4.42	0.03	9.58	319 (0.319)
RNCO 2	4.09	3.1	0.03	7.19	240 (0.240)

As shown from the above table 4.8, the volume of water need per one cubic meter of concrete for the recommended of mix type RNC 2 as per reveal of its total consumption from mixing to curing of concrete is $0.24m^3$ (Dayalan J.and Buellah M.,2014). says that "the use of self-curing is very important from the point of view that saving of water is a necessity every day. Each one cubic meter of concrete requires $3m^3$ of water in a construction, most of which is used for curing". As seen the volume of water amount list from the above table, the volume of water per cubic meter is less than one cubic meter for the all activities from mix up to curing of concrete. In addition to the reduction of material cost, red ash has an advantage by minimizing the waste of clean water for the purpose of curing.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

The unique properties of red ash (scoria), the self (internal) curing capacity of concrete by using red ash as an aggregate and as a fine aggregate, the use of making the aggregates pre-wetted before mixing for the self (internal) curing of concrete, the impacts of the amount of pre-wetted red ash on the self curing capacity with respect to compressive strength. In this chapter, conclusions are made and recommendations are forwarded.

5.1. Conclusion

1. When the portion of coarse and fine aggregate of concrete are replaced by pre-wetted red ash as a coarse aggregate and as a fine aggregate, there is an increase of air content and slump value. The increase of air content within the concrete is an indicator that the material has porous in nature. The material is pores mean it can absorb high amount of water. So by nature red ash has high water absorption capacity about 11.75% for coarse and 7.99% for fine aggregate..

2. The red ash coarse aggregate and red ash fine aggregate has slightly lower specific gravity than the natural gravel coarse aggregate and the natural sand (river sand) respectively.

3. The unit weight of red ash coarse aggregate and fine aggregate has slightly less unit weight than the natural gravel (basalt). The colour of the red ash which exists in Tullu Dimitu is not pure red in colour; it is reddish colour. So that is why the unit weight of red ash becomes nearby to the basalt unit weight.

4. The concrete with pre-wetted red ash aggregates has no bleaching of the past. This is the indication of the pre-wetted red ash has the capacity to prevent segregation of fresh concrete.

5. Pre-wetted red ash aggregates make the concrete to have good hydration for self cured concrete. The concrete used the internal moisture from the aggregates for the hydration process, get better self-curing capacity.

6. The amount of pre-wetted red ash aggregates and properties of natural sand influences the self-curing capacity of concrete.

7. Replacing the natural gravel (basalt) by pre-wetted red ash coarse aggregate can get more than 34 Mpa with 360 kg/m^3 cement amount by using self or internal method of curing. This is the sign of the concrete mix with pre-wetted red ash coarse aggregate and natural sand has high self or internal curing capacity.

8. The self-curing of concrete using pre-wetted red ash aggregate has a better compressive strength capacity than the compressive strength which is on ASTM standard compressive strength for light weight concrete by conventional method of curing and the compressive strength of the concrete mix with natural gravel and natural sand by the self or internal method of curing.

5.2. Recommendation

- Other quarries of red ash need to be examined to differentiate the unique properties of the material on that quarry.
- The government makes awareness for those who are involved in the activities of construction to use the red ash coarse aggregate as an alternate aggregate.
- Red ash coarse aggregate from Tullu Dimitu quarry site reduce cost of material for the owner of construction by substituting the normal gravel for the production of concrete.
- To decrease the waste of clean water and to alleviate the cost to the manpower for the curing purpose, self or internal curing is the best solution.
- Fire resistance should be tested to know the performance of self curing concrete in the resistance of fire by increasing the temperature.
- The durability of self cured concrete and also water permeability test should be tested to know how long the self cured light weight concrete can exist without any sign of faller and to justify the impermeability of concrete.

- Field trials are performed to be able to quantify benefits of technology to enable it to be more commonly used.

- Like the normal gravel aggregate crusher, based on the resistance of the crusher load, there must be exist a standard opening crusher in the quarry for light weight aggregates.

- As light weight aggregate being incorporated in to the mix proportion of concrete, the absorption capacity of the aggregate and the moisture content must be measured before the final proportion of concrete is done.

- Mixing of the pre-wetted light weight aggregates has the same standard procedure with conventional concrete mix procedure.

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APPENDIX A

Ethiopian Construction Design & Supervision Works Corporation

Building & Urban Design & Supervision Works Sector

Addis Abebe

Concrete testing laboratory

Laboratory test for coarse and fine aggregates

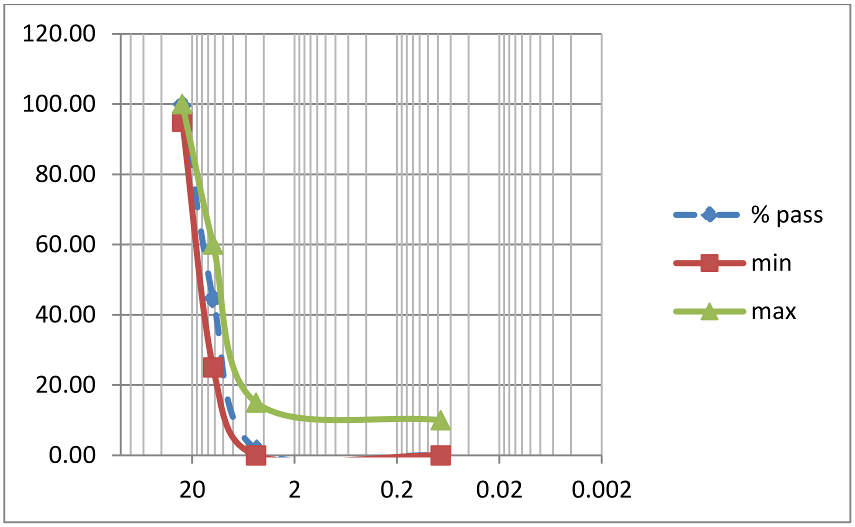
1. Gradation test for coarse & fine aggregates

Sample description ……sieve analysis

Test method……ASTM C 136

1. Red ash coarse aggregate

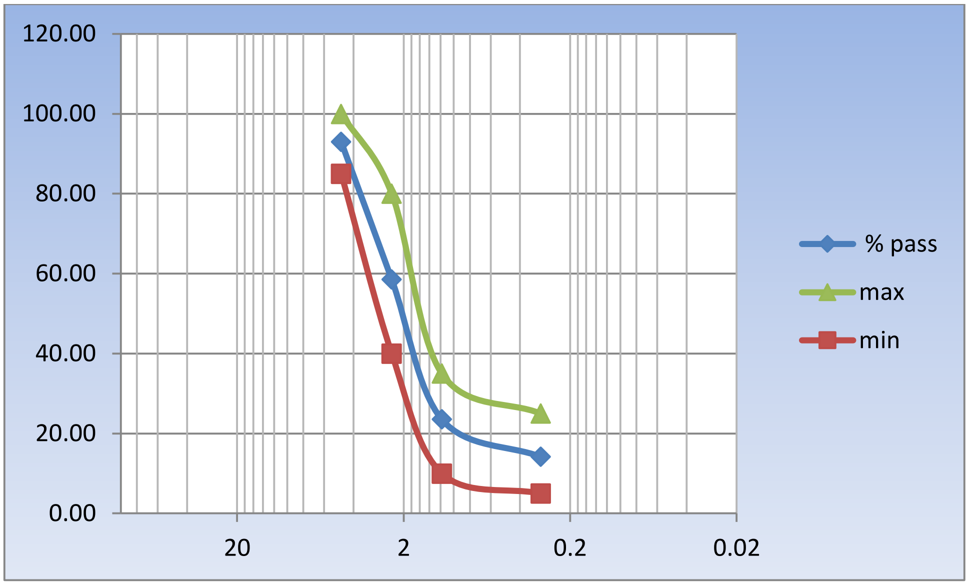
No	Sieve size(mm)	Wt. retained	% retained	commul, % retain	% pass	specification
	25	7.3	0.28	0.28	99.72	95-100
	19	78.80	3.01	3.29	96.71	…..
	12.5	1366.7	52.19	55.48	44.52	25-60
	9.5	576.30	22.01	77.48	22.52	…..
	4.75	543	20.73	98.22	1.78	0-10
	0.075	46.70	1.78	100	0.00	0-10



Sieve size of red ash coarse aggregate

2. Red ash fine aggregate

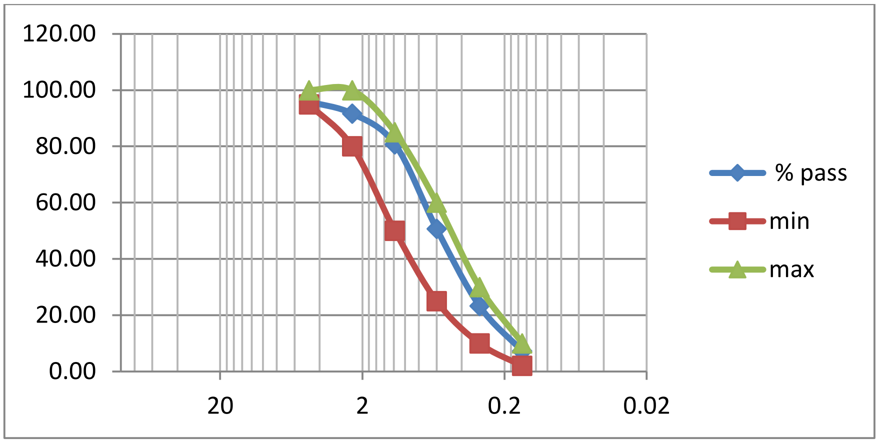
No	Sieve size(mm)	Wt. retained	% retained	commul, % retain	% pass	specification
	9.5	0	O	0	100	100
	4.75	70.30	7.03	7.03	92.97	85-100
	2.36	181.10	18.11	25.14	74.86	……
	1.18	163.00	16.3	41.44	58.56	40-80
	0.3	350	35	76.44	23.56	10-35
	0.15	93.60	9.36	85.80	14.20	0-10
	0.075	42.90	4.29		9.91	…….
	pan	99.10	9.91		0.00	



Sieve size of red ash fine aggregate

3. Natural sand sieve analysis

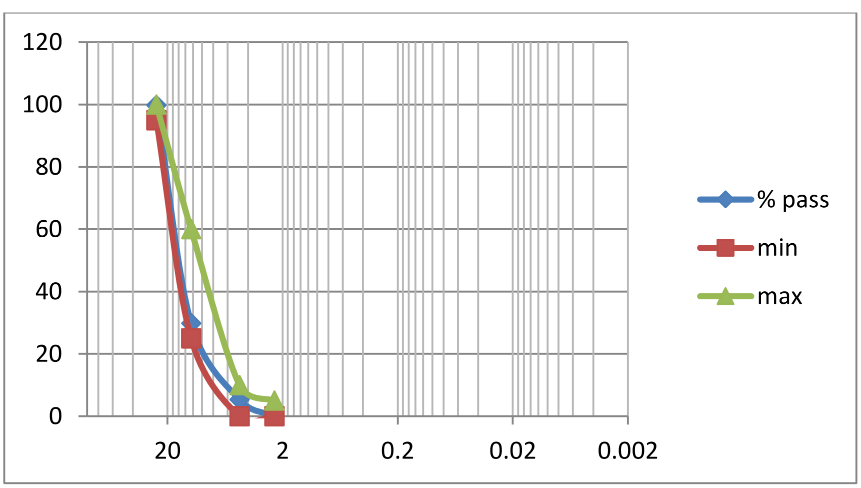
No	Sieve size(mm)	Wt. retained	% retained	commul, % retain	% pass	specification
	9.5	0	O	0	100	
	4.75	6	1.2	1.2	98.80	95-100
	2.36	14.50	2.9	4.1	95.90	50-85
	1.18	21.20	4.24	8.34	91.66	25-60
	0.3	54.60	10.92	19.26	80.74	10-30
	0.5	150.40	30.08	49.34	50.66	2-10
	0.25	136.90	27.38	76.72	23.28	
	0.125	80.30	16.06	92.78	7.22	
	0.075	19.50	3.9		3.32	
	pan	16.60	3.32		0	



Sieve size (mm) of natural sand

4. Natural gravel sieve analysis

No	Sieve size(mm)	Wt. retained	% retained	commul, % retain	% pass	specification
	25	7.3	0.19	0.19	99.81	95-100
	19	1748.5	44.39	44.58	55.42	…..
	12.5	1008.5	25.60	70.18	29.82	25-60
	9.5	386.9	9.82	80.00	20.00	…..
	4.75	579.6	14.71	94.71	5.29	0-10
	2.36	208.3	5.29	100	0.00	0-10



Sieve size (mm) of natural gravel

2. Specific Gravity & Water Absorption Of Aggregates
Sample description ……red ash fine aggregate
Test method ……ASTM Designation: C 128

.1. red ash fine aggregates	
Weight of Oven dry specimen (g) A =463	
Weight of pycknometer filled with water (g) B =1651.3	
Weight of pycknometer + sample + water (g) C = 1951	
1. Bulk specific gravity = A/(B+500-C) = 2.31	
2. Bulk specific gravity (SSD) = 500/(B+500-C) = 2.50	
3. Apparent specific gravity = A/(B+A-C) = 2.84	
4. Absorption percent = (500-A)/Ax100 = 7.99	
Specific Gravity & Water Absorption Of Aggregates **Sample description ……red ash coarse aggregate** **Test method …… ASTM Designation: C 127**	
2.Red ash coarse aggregates	
Weight of oven dry samples in air (g) A = 1641	
Weight of saturated surface dry specimen in air (g) B =1730.6	
Weight of saturated surface dry specimen in water (g) C =980.4	
1. Bulk specific gravity = (A/(B-C) = 2.20	
2. Bulk specific gravity (SSD) = (B/B-C) = 2.31	
3. Apparent specific gravity = (A/A-C) = 2.50	
4. Absorption percent = (B-A/A)x100 = 11.75	

3.natural sand	
Weight of Oven dry specimen (g) A =485.4	
Weight of pycknometer filled with water (g) B =1651.3	
Weight of pycknometer + sample + water (g) C = 1956	
1. Bulk specific gravity = A/(B+500-C) = 2.50	
2. Bulk specific gravity (SSD) = 500/(B+500-C) = 2.56	
3. Apparent specific gravity = A/(B+A-C) = 2.69	
4. Absorption percent = (500-A)/Ax100 = 3.01	

Specific Gravity & Water Absorption Of Aggregates **Sample description ……natural gravel aggregate** **Test method …… ASTM Designation: C 127**	
2.Red ash coarse aggregates	
Weight of oven dry samples in air (g) A = 1643	
Weight of saturated surface dry specimen in air (g) B =1743.6	
Weight of saturated surface dry specimen in water (g) C =1171.99	
1. Bulk specific gravity = (A/(B-C) = 2.87	
2. Bulk specific gravity (SSD) = (B/B-C) = 3.05	
3. Apparent specific gravity = (A/A-C) = 3.49	
4. Absorption percent = (B-A/A)x100 = 1.23	

2. Unit weight

Sample description ……red ash coarse aggregate

Test method …… ASTM Designation: C 29

1. **Red ash coarse aggregate**

1. Loosely Filled				
Trial Nº	**1**	**2**	**3**	**Average**
A. Weight of Container (kg)	**4.65**	**4.65**	**4.65**	**4.65**
B. Weight of Container + sample (kg)	**14**	**13.95**	**14.05**	**14**
B-A Weight of sample (Kg)				**9.35**
C. Volume of Container (m^3)	**0.007**	**0.007**	**0.007**	**0.007**
Unit weight, (kg/m3)= B-A/C				**1335.77**

2. Compacted				
Trial Nº	**1**	**2**	**3**	**Average**
A. Weight of Container (kg)	**4.65**	**4.65**	**4.65**	**4.65**
B. Weight of Container + sample (kg)	**14.8**	**14.91**	**14.9**	**14.87**
B-A Weight of sample (Kg)				**10.22**
C. Volume of Container (m^3)	**0.007**	**0.007**	**0.007**	**0.007**
Unit weight, (kg/m3)= B-A/C				**1460**

2. Sample description ……red ash fine aggregate

Test method ……ASTM Designation: C 29

1. Loosely Filled				
Trial Nº	**1**	**2**	**3**	**Average**
A. Weight of Container (kg)	**3.1**	**3.1**	**3.1**	**3.1**
B. Weight of Container + sample (kg)	**6.8**	**6.4**	**6.6**	**6.6**
B-A Weight of sample (Kg)				**3.5**
C. Volume of Container (m^3)				**0.003**
Unit weight, (kg/m3)= B-A/C				**1167**

2. Compacted				
Trial Nº	**1**	**2**	**3**	**Average**
A. Weight of Container (kg)	**3.1**	**3.1**	**3.1**	**3.1**
B. Weight of Container + sample (kg)	**6.9**	**7.0**	**7.1**	**7.0**
B-A Weight of sample (Kg)				**3.9**
C. Volume of Container (m^3)				**0.003**
Unit weight, (kg/m3)= B-A/C				**1300**

3. Sample description ……….. Natural sand

Test method ……ASTM Designation: C 29

1. Loosely Filled				
Trial Nº	**1**	**2**	**3**	**Average**
A. Weight of Container (kg)	**3.1**	**3.1**	**3.1**	**3.1**
B. Weight of Container + sample (kg)	**7.3**	**7.1**	**7.1**	**7.2**
B-A Weight of sample (Kg)				**4.1**

C. Volume of Container (m^3)				**0.003**
Unit weight, (kg/m3)= B-A/C				**1367**
2. Compacted				
Trial Nº	**1**	**2**	**3**	**Average**
A. Weight of Container (kg)	**3.1**	**3.1**	**3.1**	**3.1**
B. Weight of Container + sample (kg)	**7.8**	**7.6**	**7.7**	**7.7**
B-A Weight of sample (Kg)				**4.6**
C. Volume of Container (m^3)				**0.003**
Unit weight, (kg/m3)= B-A/C				**1533**

3. Sample description ……….. Natural gravel

Test method ……ASTM Designation: C 29

1. Loosely Filled				
Trial Nº	**1**	**2**	**3**	**Average**
A. Weight of Container (kg)	**4.65**	**4.65**	**4.65**	**4.65**
B. Weight of Container + sample (kg)	**14.6**	**14.10**	**14.8**	**14.8**
B-A Weight of sample (Kg)	**9.95**	**9.45**	**10.15**	**10.15**
C. Volume of Container (m^3)	**0.007**	**0.007**	**0.007**	**0.007**
Unit weight, (kg/m3)= B-A/C				**1450**

2. Compacted				
Trial Nº	**1**	**2**	**3**	**Average**
A. Weight of Container (kg)	**4.65**	**4.65**	**4.65**	**4.65**
B. Weight of Container + sample (kg)	**15.33**	**15.43**	**15.53**	**15.43**
B-A Weight of sample (Kg)	**10.68**	**10.78**	**10.88**	**10.78**

C. Volume of Container (m^3)	**0.007**	**0.007**	**0.007**	**0.007**
Unit weight, (kg/m3)= B-A/C				**1540**

3. Soundness of aggregates by sodium sulphate

. Sample description ……….. Red ash aggregates

Test method ……ASTM designation C 88

	Soundness By Sodium Sulphate					
Sieve size	**Wt.retained**	**% retained**	**Wt.retained**	**%pass**	**% Loss**	**Maximum**
(mm)	**before test**	**before test**	**after test**	**designated**	**(AxB)/100**	**Allowable**
	(g)	**(A)**	**(g)**	**sieve (B)**		**(%) Loss**
25.00	**1012**	**31.32**	**980**	**68.68**	**9.51**	**10**
19.00	**513**	**15.88**	**390**	**52.80**	**8.38**	**10**
12.50	**675**	**20.89**	**536.5**	**31.91**	**6.67**	**10**
9.50	**333**	**10.31**	**264.8**	**21.60**	**2.23**	**10**
4.75	**298**	**9.22**	**264.6**	**12.38**	**1.14**	**10**
2.36	**100**	**3.10**	**74.5**	**9.29**	**0.29**	**10**
1.18	**100**	**3.10**	**65.5**	**6.19**	**0.19**	**10**
0.30	**100**	**3.10**	**79.2**	**3.10**	**0.10**	**10**
0.15	**100**	**3.10**	**82.3**	**0.00**	**0.00**	**10**
	3231					

5. Resistance to degradation of small size coarse aggregate in the los angeles machine

Sample description …compressive strength trial two

Test method …….. (ASTM Designation: C 131)

original sample (g)	retained on 1.7mm after abration (g)	% of degraded
A= 5000	B= 2410.7	(A-B)/A*100 =48 %

6. Fineness of cements

Sample description …fineness

Test method …… (ASTM Designation: C 204)

Types of cement	Fineness (%)
OPC	4.6

7. Setting time

Sample description …setting time of cement

Test method …… (ASTM Designation: C 191)

Types of cement	W/C	Initial setting time (min)	Final setting time (min)
OPC	0.28	125	200

8. Soundness of cement past

Sample description …soundness of cement

Test method …… (ASTM Designation: C 430)

9. Mortar strength of cement

Sample description …compressive strength of OPC mortar

Test method …… (ASTM Designation: C 190)

				SPECIMENTS					
				1	2	3	4	5	6
Weight of cement (g)				500	500	500	500	500	500
Weight of standard sand (g)				1375	1375	1375	137 5	1375	137 5
Weight of water (g)				242	242	242	242	242	242
Size of sample (L) (mm)				70	70	70	70	70	70
(B)				70	70	70	70	70	70
(h)				70	70	70	70	70	70
Area of specimen (A) (mm^2)									
Compressive strength									
	Age :	3 days	(kN/m^2)	86	92	90			
		7 days	(kN/m^2)	140	136	138			
Average strength			KN/m^2 (kg/cm^2)	3 days	7 days				
				89.33KN/m^2 =186.11Kg/cm^2	138 KN/m2 =287.5Kg/cm^2				

Appendix B

1. **Mix proportioning**

Sample description …mix proportion

Test method …… ACI 211.2-98

1. **Trial one**

Concrete type	Concrete class	Cement amount (Kg/m^3)	W/C	Water (liter)	R or N FA (Kg/m^3)	R CA (Kg/m^3)
RRC 1	C-25	340	0.52	170	544	1094
RNC 1	C-25	340	0.52	170	673	1030

2. **Trial two**

Concrete type	Concrete class	Cement amount (Kg/m^3)	W/C	Water (liter)	Red ash or Natural FA (Kg/m^3)	Red ash CA (Kg/m^3) or natural gravel
RRC 2	**C-25**	**360**	**0.48**	**170**	**529**	**1094**
RNC 2	**C-25**	**360**	**0.48**	**170**	**622**	**1030**
GNC 2	**C-25**	**360**	**0.48**	**170**	**805**	**1088**

Appendix C

1. **Compressive strength of concrete**

1. Trial one

Sample description ……compressive strength trial one

Test method ……(ASTM Designation: C 39

		compressive strength (mpa)			
		7th DAYS			AVERAGE
s.no	mix type	1	2	3	
1	RRC 1	11.59946	11.91663	12.00725	11.84111
	14th DAYS				
	RRC 1	12.2338	13.59311	12.68691	12.83794
	28th DAYS				
	RRC 1	17.08201	16.5836	16.26643	16.64
	7th DAYS				
2	RNC 1	14.36339	12.64159	11.64477	12.88325
	14th DAYS				
	RNC 1	18.57725	17.8976	18.3507	18.27519
	28th DAYS				
	RNC 1	21.79429	21.3865	22.11146	21.76
	7th DAYS				

2. Trial two

Sample description …compressive strength trialtwo

Test method ……(ASTM Designation: C 39

		compressive strength (Mpa)			
		7th DAYS			AVERAGE
s.no	mix type	1	2	3	
1	RRC 2	18.81	19.26	19.49	19.18667
	14th DAYS				
	RRC 2	19.94	21.98	20.95	20.95667
	28th DAYS				
	RRC 2	26.73312	27.63933	26.28002	26.88
	7th DAYS				
2	RNC 2	22.66	19.94	18.35	20.31667
	14th DAYS				
	RNC2	29.46	28.32	28.52	28.76667
	28th DAYS				
	RNC2	34.20933	33.75623	34.88899	34.28

	7th DAYS				
3	**GNC 2**	**18.2**	**18.43**	**19.99**	**18.87**
	14th DAYS				
	GNC 2	**21.11**	**22.02**	**21.85**	**21.66**
	28th DAYS				
	GNC 2	**23.23**	**24.45**	**23.63**	**23.77**