JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

INVESTIGATION ON THE PROPERTY OF SELF-CONSOLIDATING LIGHTWEIGHT CONCRETE USING SCORIA AS COARSE 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 (Construction Engineering and Management)

By

Beyashi Taresa Humnasa

March 2021
Jimma, Ethiopia

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APPROVED BY BOARD OF EXAMINERS

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DECLARATION

I declare that this thesis entitled **"Investigation on the property of self-consolidating lightweight concrete using scoria as coarse aggregate**" is my original work and has not been submitted as a requirement for the award of any degree at Jimma University or elsewhere.

Beyashi Taresa Humnasa	________________	________________
Name	Signature	Date

As research Adviser, I hereby certify that I have read and evaluated this thesis paper prepared under my guidance, by Beyashi Taresa Humnasa entitled "**Investigation on the property of self-consolidating lightweight concrete using scoria as coarse aggregate**" and recommend and would be accepted as a fulfilling requirement for the Degree Master of Science in Construction Engineering and Management.

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Advisor	Signature	Date
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ABSTRACT

Concrete is a construction material that consists of a mixture of fine aggregate, coarse aggregate, cement, and water. Now a day, the shortage of conventional concrete material needs a quick solution in the production of concrete mix. Hence this study was aimed to investigate the effects of using scoria as coarse aggregate in the production of self-consolidate lightweight concrete. The study used a purposive method of sampling materials. An experimental research method was used to investigate the partial and full replacement of scoria in the concrete mix based on the concrete mix design method. In order to achieve the objective, concrete was classified in to five groups; a control group, a self-consolidating lightweight concrete(SCLWC) with 25%, 50% ,75% ,100% scoria. The chemical composition analysis indicated the scoria can be classified as a class – N pozzolana. The ratio of ingredients for samples was 1:1.763:1.743 with differing aggregate and scoria content. To determine a fresh property of the mix; slump flow and flow table tests. Also compressive and split tensile strength was conducted on the 7th, 14th, and 28th day. The results of these properties of concrete in this study the suitable SCLWC mixtures for further use in construction projects. It also plays a great role in minimizing the consumption of aggregate in concrete by utilizing scoria.The fresh property test result shows, all the different percentage replacement of scoria fulfilled American Concrete Institute (ACI) specification requirement, which is 600mm diameter. Also, the hardened property of self- consolidates lightweight concrete resulted in better compressive strength than C-25 concrete. The maximum compressive and split tensile strength were obtained with 25% scoria replacement, which is 35.17MPa and 3.72MPa respectively. The percentage replacements of scoria from 25 to 100% in self- consolidate lightweight concrete had a better strength than the control group. The SCLWC with scoria replacement developed better split tensile strength compared to control concrete on the 28th days. The concrete unit weight was decreased as the contents of Scoria increased. The decrease in the unit weight of the concrete shows as the specific gravity of Scoria is less than the specific gravity gravel coarse aggregate.

Finally, it can be concluded that scoria can be used either as a full replacement or in combination with gravel coarse aggregates to produce SCLWC structures with a superplasticizer. Further study on durability, economic analysis, with different gradation is recommended.

Keywords*: Lightweight concrete,pozolona,scoria,self-consolidating.*

ACKNOWLEDGMENT

First of all, I would like to thank the almighty God for the life strength and courage that he has granted me thought out this study.

Next, I would like to express my sincere and deepest gratitude to my Advisor Dr.Getachew Kebede and Engr. Fitsum Alemayehu for all their limitless efforts in guiding me through my work and for providing me useful reference materials.

I would like to extend special thanks to the Ethiopian Road Authority (ERA) and Jimma University Institute of Technology for their kind support and sponsoring of my MSc. And also I would like to thanks the Laboratory technician and Construction Engineering Management Chair Holder for their kind support of material and laboratory assistance.

Finally, I would like to express my sincere respect and love to my families and friends for their kind support, patience, and standing with me.

My warm appreciation and gratefulness also extend to all those who supported and encouraged me, but are not mentioned above by name, for their concern and kindness.

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ACRONYMS

ACI	American Concrete Institute
ASTM	American society for testing and materials
CA	Coarse aggregate
CC	Conventional concrete
CVC	Conventionl vibrated concrete
EBCS	Ethiopian building code standard
EFNARC	European Federation of National Trade Associations Research Center
ERA	Ethiopia Road Authority
FA	Fine agggregate
GCA	Gravel coarse aggregate
HRWR	High Range Water Reducing
JIT	Jimma Institute of Technology
LL	Lower limit
LWAC	Lightweight aggregate concrete
LWC	Light Weight Concrete
NVC	Normal Vibrated Concrete
NWC	Normal weight concrete
PPC	Pozzolana portland cement
SCA	Scoria coarse aggregate
SCC	Self-consolidating concrete
SCLWC	Self-consolidating lightweight concrete
UL	Upper limit

CHAPTER ONE

INTRODUCTION

1.1 Background

Concrete is a composite material that consists of cement, fine aggregate, and coarse aggregates. The construction industry in Ethiopia is becoming wide, such as the construction of a building, road and highway structures like bridge, slab culvert, culvert, etc. are found in ongoing status. But the culture of using alternative ingredients to produce concrete is weak in the construction industry.

Lightweight aggregate concrete is not a new invention in concrete technology. It has been known since ancient times, so it is possible to find a good number of references in connection with the use of LWAC. Natural volcanic aggregates such as pumice, scoria, and other materials were used to create it. In the third millennium B.C., the Sumerians used this to create Babylon. With the increase in the demand for LWAC and the unavailability of aggregates, technology for producing lightweight aggregates has been developed (Masoodi, et al., 2018).

Scoria, a result of explosive volcanic eruptions, has been used as a building material around the world for centuries. Scoria used as a coarse aggregate was found to be very useful in the production of lightweight concrete, with sufficient strength giving it the advantage of reducing the dead load in building structures Scoria is also used as a lightweight aggregate with silica fume and fly ash mineral admixture in the manufacture of lightweight structural concrete, with excellent results in terms of strength to unit weight ratio (Getachew, et al., 2019).

Nowadays self-consolidating concrete (SCC) is the unavoidable solution to most workability problems. SCC is a new type of concrete that has the capabilities of flowing easily, filling the formwork, and making full compaction under its weight, eliminates the vibration process, improves the environmental consideration, and reduces the labor works. Besides, SCC has proven advantages enhancing construction productivity, reducing the overall cost of the structure, achieving sustainable characteristics, increasing the practically allowable reinforcement rate, and increasing the construction rate and overall quality of the cast structures (Vakhshouri & Nejadi, 2015).

The use of lightweight aggregates in the production of self-consolidating concrete (SCC) combines the favorable properties of lightweight concrete and SCC in self-consolidating lightweight concrete (SCLWC). SCLWC is high flowable concrete, which can be placed and compacted under its weight in complex or dense reinforced formworks without any segregation or bleeding (Wu, et al., 2009) Obvious problems with unsuitable vibration of lightweight concrete are reported for inefficient distribution of lightweight aggregates the can be solved by using SCLWC

The use of SCLC can be advantageous for structures due to significant reduction in dead loads provided that the strength and durability characteristics of SCLWC are comparable to normal weight SCC. This reduction in the self-weight of structures can result in reduced member sections and, therefore, it will save on overall construction (Esmaeili, et al., 2015).

This study investigates the effects of using scoria as coarse aggregate in the production of self-consolidate lightweight concrete.

1.2 Statement of the Problem

The concrete production type in Ethiopia is usually limited to conventional concrete and less attention is given to producing special concrete in the construction industry of the country. In the production of concrete cement, fine aggregate and coarse aggregates are using as material. However, production consumes natural resources, which brings great pressure on the decreasing resources. One of the main problems in the production of concrete is the scarcity of conventional material. On the other hand, high production costs and environmental pollution are the other concern.

Recently researchers investigated different industrial waste materials as an alternative material in the concrete mix. However, these industrial waste products need care, long period to store and obtain sufficient quantity. Therefore, it is mandatory to find an alternative non-conventional concrete material that is locally available and ecofriendly. Hence, the use of scoria is found an alternative option for replacing gravel coarse aggregate as material in concrete.

Therefore, this study analyzes how to produce SCLWC that lacks vibration and compaction and fulfills flowability and characteristic compressive strength of C-25 concrete. And also to forward alternative use of ingredients of construction material with better compaction method of concrete.

1.3 Research Questions

1. What is the effect of using scoria as coarse aggregate on workability in self-consolidated lightweight concrete production?
2. What is the effect of using scoria as coarse aggregate on hardend properties of self-consolidated lightweight concrete production?
3. What is the optimum replacement of scoria as coarse aggregate in self-consolidating lightweight concrete production?

1.4 Objectives of the Study

1.4.1 General Objective

The main objective of this study is to investigate the effects of using scoria as coarse aggregate in the production of self-consolidate lightweight concrete.

1.4.2 Specific Objectives

The specific objectives of the study are:

1. To evaluate the workability of self-consolidating lightweight concrete using scoria as Course aggregate.
2. To evaluate the hardend properties of self-consolidating lightweight concrete using scoria as coarse aggregate.
3. To determine the optimum replacement of scoria as coarse aggregate in self-consolidating lightweight concrete production.

1.5 Scope of the study

The study is limited to the investigation of workability, compressive, and Split tensile strength properties of fresh and hardened concrete in using scoria as coarse aggregate in the production of self-consolidate lightweight concrete.

1.6 Significance of the Study

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

The contribution of this study is to makes the concrete have better self-consolidating capacity than the conventional consolidating method by applying the self-consolidating method of lightweight concrete and reduce the waste of time compaction and until the material reaches other places.

1.7. Justification of the Study

The rationale for conducting this study was, provides locally available materials to decrease the scarcity of conventional materials with environmentally friendly and economically feasible. Hence, the use of this alternative material in concrete reduces production cost, time, and environmental pollution, it is very important in giving attention to the effective use of locally available materials in the construction industry. This study benefits the construction industry, government, local community, and further researchers for further investigation on scoria in the concrete mix. Also, this study provides the ground basis for other countries with abundant volcanic material.

Different construction sites are placed were difficult to use or uncomfortable to use vibration equipment and some construction site may require pumping equipment to transport fresh concrete from mixing place to casting place. So, if the place is not comfortable enough to use vibration equipment and, if the concrete should have to be fluid to be pumped easily, self-consolidating lightweight concrete might be the best solution to solve such quality matters. Since, it is a high fluid, self-compactable, and achieves the desired strength.

CHAPTER TWO

LITERATURE REVIEW

2.1 General

The levels of problems are unequal, in construction work different problems are happening. 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 side is human factors. Many literatures imply that most of the construction industry did not completed by its project budget. The factor that affects the cost overrun of the project is the increasing of material cost time in time. The way of discouraging this problem is the making of deferent methods to reduce the availability and cost of the material with the good quality by best cost.

SCLWC incorporates the benefits of both LWC and SCC.These LWC advantages can be greatly utilized by incorporating lightweight aggregates in the SCC mix design. SCLWC may be prompted as a new generation of high-performance concrete in construction if its strength, mechanical, and durability characteristics are comparable to normal weight SCC.Thus, it is believed that incorporating lightweight aggregate in self-consolidating concrete can enhance quality and produce high-strength lightweight concrete while preventing the segregation of lightweight aggregate (Hwang & Hung, 2005).

2.2 Concrete

Concrete is a composite material made up of a cement paste and fine and coarse aggregates of different sizes found within it. It contains some amount of entrapped air and may contain purposely entrained air by the use of air-entraining admixtures. Various chemical admixtures and/or finely divided mineral admixtures are commonly used in the manufacture of concrete to strengthen or change its properties, or to produce a more cost-effective concrete (Masoodi, et al., 2018).

2.3. Materials for Concrete

To produce Lightweight concrete, Lightweight concrete making materials is an essential thing. Lightweight Concrete is produced by the following materials: Portland cement, Aggregates (Scoria), and Water. In addition to these, a fourth component, an additive may be added to improve the workability and self-consolidating of the concrete mix if it’s necessary.

2.3.1 Cement

Cement is a broad word that encompasses all binders.There is a wide variety of types of cement that are used to some extent in the construction and building industries or to solve special problems. The chemical composition of these types of cement can be quite diverse, but by far the greatest amount of concrete used today is made with Portland cement. The term "cement paste" refers to a mixture of cement and water.The function of the cement paste in concrete is to cover the surfaces of the aggregate particles, to fill the spaces between the particles, and produce a compact mass by binding the aggregates particles (Masoodi, et al., 2018).

According to the American Society for Testing and Materials (ASTM), a type of Portland cement in construction is classified into five types (Steven, et al., 2003).

Table 2. 1: Five Types of Portland Cements as American Society for Testing and Materials (ASTM).

Type	Classification	Uses
Type I	Normal Portland Cement	Suitable for normal application.
Type II	Modified Portland Cement	It provided better resistant alkali attack and less heat of hydration than type I.
Type III	High early strength Portland Cement	It uses for early removal of form and in cold weather concreting.
Type IV	Low heat Portland Cement	It uses for massive structures as dams
Type V	Sulphate resistance Portland Cement	It needed if concrete has direct contct with soil or water that contain high sulfate concentration.

2.3.2. Aggregates

Aggregate is one of the concrete making materials. Aggregate could be fine aggregate or coarse according to its size. Depending on their origins, aggregates may be categorized as natural or artificial. Natural aggregates come from quarries where crushed rocks are processed or from riverbeds, while artificial aggregates come from industrial by-products. Natural aggregates are the most common and are important for the Ethiopian construction industry since artificial aggregates are rarely made(Abebe, 2005).

Classification of Aggregates

Aggregates can be divided into several categories according to different criteria cement (Neville & Brooks, 2010)

i. Based on the size:

- Coarse aggregate: Aggregates predominately retained on the No. 4 (4.75 mm) sieve.

Fine aggregate (sand): Aggregates that reach the No.4 (4.75 mm) sieve and are often kept on the No.4 sieve.

ii. Based on unit weight

- Lightweight aggregate: The unit weight of aggregate is less than 1120 kg/m3. The corresponding concrete has a bulk density of less than 1800 kg/m3.
  - Normal weight aggregate: The aggregate has a unit weight of 1520-1680 kg/m3. The bulk density of concrete made with this form of aggregate is 2300-2400 kg/m3. Heavyweight aggregate: The unit weight is greater than 2100 kg/m3. The corresponding concrete has a bulk density of more than 3200 kg/m3.

iii. Based on the sources:

  - Natural aggregates: These are aggregates that are extracted from natural deposits without being altered in any way during the manufacturing process, such as crushing and grinding.
  - Manufactured aggregates: This is a kind of man-made material produced as the main product or an industrial by-product.

2.3.3 Lightweight aggregate

The term lightweight aggregate is defined as aggregate with a relatively low specific gravity. Many types of aggregate available are classed as lightweight and their properties cover wide ranges. Elastic properties, compressive and tensile strength, time-dependent properties, durability, fire resistance and other properties of lightweight aggregate concrete are dependent on the type of lightweight aggregate utilized in the concrete. The lightweight aggregate can be natural aggregates such as pumice, scoria, and all those of volcanic origin or the artificial aggregate such as expanded blast-furnace slag vermiculite and coal cinder aggregate. This lightweight aggregate's main feature is its high porosity, which results in a low specific gravity. Lightweight aggregate concrete is fully compacted similar to that of the normal reinforced concrete of dense aggregate. It can be used with steel reinforcement to have a good bond between the steel and the concrete. The lightweight aggregate concrete should provide adequate protection against the corrosion of the steel. Lightweight aggregate, due to its cellular structure, can absorb more water than the normal-weight aggregate. In a 24-hour absorption test, they generally absorb 5 to 20% by mass of dry aggregate, depending on the pore structure of the aggregate. (Kumar & Venkatadinesh, 2018)

A lightweight aggregate is important in the construction industry. Many architects, engineers, and contractors recognized the inherent economies and advantages offered by the many impressive lightweight concrete structures found today throughout the world (ACI213R., 1987). Aggregates with an oven-dry particle density less than 2000 kg/m3 or an oven-dry loose bulk density less than 1200 kg/m3 are called lightweight aggregates. A maximum limit for the bulk density, which is 1120 kg/m3 and 880 kg/m3 for fine and coarse lightweight aggregate, respectively (ASTMC330/330M, 2010).

Classification Lightweight aggregates

According to (Kumar & Venkatadinesh, 2018)Lightweight aggregates are divided into two categories according to their sources:

1. Natural lightweight aggregate

Pumice, Scoria, Volcanic cinders, Palm oil shells

2. Artificial lightweight aggregate

   Coal cinders, Sintered fly ash, Exfoliated vermiculite, expanded perlite, Foamed slag, bloated clay, Thermos coal beads, expanded

   Shale and slate

Natural lightweight aggregates are obtained by processing volcanic rocks. Pumice, scoria, tuff, and perlite are some of the examples which fall in this category. Pumice is a light-colored porous glass with elongated voids. Scoria is a dark-colored porous glass with spherical voids. Tuff is a porous glass formation of consolidated volcanic ash. Perlite is a porous glass with high silica content. It generally contains 2-5% water (Mehta & Monteiro, 2006).

Synthetic lightweight aggregates are expanded forms of materials such as clay, shale, slate, perlite, and vermiculite, produced by heat treatment, generally around 1000^{o}C. The materials are either reduced to the desired size before calcination or crushed after the calcination process. The expansion results from the entrapment of gases, which are generated during heat treatment, inside the processed material (Neville & Brooks, 2010).

2.3.4 Water

Clean water is important for the same reasons that clean aggregate is; any impurities can weaken the bond between the paste and the aggregate. Concrete can be made out of almost any drinkable water.Drinking water with a noticeable taste or odor should not be used until it is tested for organic impurities (Steven, et al., 2003).

2.3.5 Admixtures

Admixtures are chemicals that are added to the mix to achieve special purposes Other than cement, water, and aggregates, admixtures are ingredients applied to a concrete mixture to change its properties.

Admixtures are used to obtain acceptable SCC performance based upon the physical and chemical properties of the cement type. Admixtures can reduce water content, improve deformability and stability, increase air content, accelerate strength development and retard setting time. High Range Water Reducer (HRWR) and viscosity altering admixtures are the most commonly used admixtures for SCC (VMA). The amount of these admixtures added is determined by SCC mixture parameters including w/c and binder form. HRWR, for example, can be added to freshly mixed SCC in small amounts to boost its workability for around 30 minutes. HRWR can be also added to mixtures with low w/c to obtain higher fluidity and higher strength (Torres, 2016).

According to (ASTMC494/C, 2001), there are seven types of admixtures that are used in the construction industry to improve the properties of concrete in its fresh state. Water-reducing admixtures, retarding admixtures, accelerating admixtures, Water-reducing and retarding admixtures, Water-reducing and accelerating admixtures, Water-reducing and accelerating admixtures, Water-reducing, high range admixtures, and Water-reducing, high range, and retarding admixtures are only a few examples.

2.4. Materials Used as aggregate Replacement

2.4.1 Scoria

Scoria is a volcanic cinder that generally has a porous nature and rough surface and whose color ranges from red to black. Scoria is formed as a result of cooled and solidified lava in which a large volume of gasses has been formed The loose spongy structure of the solidified lava induces this mode of formation. Scoria is abundantly distributed in Ethiopia, especially in the Great Rift Valley which crosses the north-eastern part of the country (Shiferaw & Negussie, 1984).

Scoria used as a coarse aggregate was found to be very useful in the production of lightweight concrete, with sufficient strength giving it the advantage of reducing the dead load in building structures. Scoria has also been used as a lightweight aggregate in the manufacture of lightweight structural concrete with silica fume and fly ash mineral admixture, with excellent results in terms of strength to unit weight ratio. Improvements in the mechanical strength of mortar were also observed when using volcanic scoria as sand in the production of Portland cement mortar (Getachew, et al., 2019)

Scoria is formed of vesicular fine to coarse fragments, reddish or black in color and light in weight. Scoria can be utilized in several industrial applications including the manufacturing of lightweight concrete, as a source of pozzolan to manufacture Portland-pozzolan cement additive, as a heat-insulating material, in addition to other uses such as low-cost fillers, filter materials, absorbents, and other architectural applications (Khandaker & Anwar, 2015).

Figure 2. 1**:**Scoria aggregates: Source Journal (Khandaker & Anwar, 2015)

2.4.2 Properties of scoria lightweight concrete

The lightness of scoria is due to the porousness of the material that is highly sensitive to water content and high water absorption compared to granite crush rock aggregate. Because of the porous nature of the aggregate, it provides more interlocking locations for the cement paste to penetrate and form thick, uniform interfacial zones between the aggregate.This strong interfacial bond compensates for the strength loss in lightweight aggregate due to its porosity relative to normal gravel aggregate (Lau, et al., 2014).

Lightweight concrete (LWC) is favorable over normal weight concrete (NWC) for earthquake-prone areas as LWC reduces a 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). Moreover, the reduction in self-weight will reduce reinforcements, transportation, and handling cost (Topcu, 1997).

2.4.3 Chemical Composition of scoria

According to (Getachew, et al., 2019), the scoria contains a greater amount of silicon dioxide (52.53%), which is followed by aluminate and ferrite, with a percentage of 15.49% and 11.00%, respectively. The summation of these three oxide compositions was found to be 79.02%, and the material is classified as class F pozzolanic material

Table 2. 2 Chemical composition of scoria (Getachew, et al., 2019)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI
52.53	15.49	11.0	10.1	4.4	2.56	<0.1	0.18	0.17	0.88	0.64	0.85

2.5 Lightweight concrete

Structural lightweight aggregate concrete has been used in both reinforced and pre-stressed concretes. Structural lightweight concrete has a density of less than 1840 kgm3. For structural application concrete compressive strength should be greater than 17.2 MPa at 28 days according to ACI318 requirements The concrete mixture is produced with lightweight coarse aggregate. At some time portion of the entire fine aggregate may be a lightweight product (ACI318, 2005).

The main use of structural lightweight concrete is to reduce the dead load of the concrete structure. Lightweight aggregate concrete results in an overall saving of 10-20% of the total cost of the equivalent normal weight concrete. It allows for the structural designer to reduce the size of the columns, footings, and other load-bearing elements. Increasing the space availability by a reduction in the sizes of structural elements. The high cost of the structural lightweight concrete is offset by size reduction of structural elements, less reinforcing steel, and reduced volume of concrete resulting in less overall cost (Lotfy, 2012).

Structural lightweight concrete provides higher fire-rated concrete structures. The porosity of the lightweight aggregate provides a source of water for internal curing of the concrete that provides continued development of concrete strength and durability. Lightweight concrete considers as high thermal insulation and provides better heat and sound insulation than normal weight concrete (Hossain & Anwar, 2015). Structural lightweight concrete is well suitable for high earthquake regions sincere reduced internal mass results in a lesser internal force.

The air content of the lightweight concrete is to be closely monitored and controlled to ensure that the density requirements are being achieved. Virtually all lightweight concrete is air-entrained. Finishing the lightweight concrete requires proper attention to detail. An excessive amount of water will cause the lightweight aggregate to segregate from the mortar Due to the higher overall moisture content, it takes longer for heavy-weight concrete to dry to standards suitable for the application of floor covering material(Hossain & Ahmed, 2010).

Lightweight aggregate batched at a high degree of saturation may be substituted for normal-weight aggregate to provide internal curing in concrete containing a high volume of cementitious materials. The benefits of internal curing are increasingly important when pozzolans such as silica fume, fly ash, volcanic ash, pumice, scoria metakaolin, calcined shales, clays, and slates, as well as the fines of lightweight aggregate (LWA) are included in the mixture. It is well known that the pozzolanic reaction of finely divided alumina-silicates with calcium hydroxide liberated as cement hydrates are contingent upon the availability of moisture. Additionally, internal curing provided by absorbed water minimizes the plastic shrinkage due to rapid drying of concrete exposed to unfavorable drying conditions (Holm, 1980)

Generally, Lightweight concrete has been broadly used in production technology for lightweight aggregates. The benefit of lightweight concrete is reduced dead load for structures. Thus, the required cross-section of columns, amount of steel, and foundation load can decrease, given that lightweight concrete has suitable performance in terms of strength.

2.6 Properties Lightweight concrete

2.6.1 Fresh Properties Lightweight concrete

In contrast to conventional concrete, SCC's fresh properties are critical in determining whether it can be placed satisfactorily. To ensure that its ability to be positioned remains appropriate, the different factors of workability that regulate its Filling ability, Passing ability, and

Segregation resistance must all be carefully controlled (EFNARC, 2002). If concrete rehometer were not available, the three primary characteristics that define SCC performances: filling ability, passing ability, and stability. Fresh properties concrete could be easily measured simply as follows: (Daczako, 2012). (Pavan, et al., 2017) also states that a concrete mix can only be classified as Self-Compacting Concrete if it has the following characteristics: Filling ability, Passing ability, and Segregation resistance. Several test methods have been developed in attempts to characterize these properties of Self-Compacting Concrete. The very common test methods were described herein.

A. Filling Ability

Filling ability is the ability of the fresh concrete mixture to flow into and fill formwork. This property of SCC could be determined by the slump flow test method. Another very important parameter that can be assessed along with the slump flow is the visual stability index (VSI) rating. (Daczako, 2012).

B. Passing Ability

(Daczako, 2012) Passing ability refers to the ability of an SCC mixture to flow through restricted spaces without blocking. This property is generally concerned with aggregate flowing through reinforcement; however, it can also refer to flow through narrowing sections in formwork this property of SCC could be determined by the J-Ring and L- Box test method.

C. Slump flow test

The slump flow test is a common procedure used to determine the horizontal free-flow characteristics of SCC in the absence of obstruction. According to (ASTMC-1611, 2007)), a self-compacting concrete with a slump flow diameter ranging from 450mm to 760mm was considered to be a good self-compactable and good flowable concrete. The higher the slump flow, the farther the SCC can travel under its mass from a given discharge point, and the faster it can fill a form or mold.

2.6.2 Hardened Properties Lightweight concrete

A. Compressive strength of lightweight concrete

The structural lightweight concrete mixture can be designed to achieve similar strength as normal-weight concrete. There is no reliable correlation between aggregate strength and concrete strength indicating that strength is more dependent on the cementitious matrix (ACI213R, 2003).

(Dayalan & Buellah, 2014) concluded that Compressive strength findings show that internally cured specimens have greater strength at 21 and 28 days, but have lower strength at 7 days 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 the hydration process, increasing the concrete's strength and durability.

The compressive strength of lightweight 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 (ACI213R., 1987).

The strength ceiling is influenced predominantly by the coarse aggregate and may be quite high for certain lightweight aggregates, approaching that of some normal-weight aggregates. This ceiling can be increased appreciably by reducing the maximum size of the coarse aggregate for most lightweight aggregates, especially the weaker and more friable ones. This reduction of particle size reduces the stress concentration around the aggregate and also allows for a more homogenous concrete matrix to be produced (Gerritse, 1981).

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

B. Tensile strength of lightweight concrete

The tensile strength of concrete is only a fraction of its compressive strength and is dependent on the tensile strength of the coarse aggregate and mortar phases, and the degree to which the two phases are securely bonded. Traditionally, this value has been defined as a function of compressive strength. This should only be taken as a first approximation since it does not reflect the aggregate particle strength, surface characteristics of the aggregates, or the concrete’s moisture content and distribution (ACI213R, 2003). For a given lightweight aggregate, the tensile strength may also not increase in a manner comparable to the increase in compressive strength. Increases in tensile strength tend to occur at a slower rate relative to increases in compressive strength. This becomes more pronounced as compressive strength increases beyond 35 MPa with tensile strengths being over-predicted. Replacing lightweight, fine aggregate with normal weight fine aggregate will also normally increase tensile strength (Juan, 2011).

Concrete tensile strengths can be measured through direct tensile tests or indirectly via splitting tensile tests or flexural tensile tests. Due to the weak and brittle nature of concrete under tension, indirect tensile tests are easier to perform and tensile splitting strengths and/or modulus of rupture values from flexural tensile tests are preferred. However, these values are influenced by moisture content and specimen storage conditions before the test as well as the different stress distributions within the specimen as the test are carried out (FIP, 1983). Splitting tensile strength of lightweight aggregate concrete has a larger scatter than that of normal weight concrete due to the influence of the aggregate and the influence of curing method The interfacial transition zone between the mortar and the aggregate also improved properties compared to normal weight aggregate. As the cement paste hydrates, the matrix is available to form inside the pores of the lightweight aggregate thus gripping the aggregate and producing a good bond between the phases (Kokilan.S., 2016).

2.7 Self-consolidating concrete

SCC (self-consolidating concrete) is a relatively new technology with a high workability.SCC easily fills the congested spaces between the reinforcement (both mild reinforcement and prestressing steel) and the formwork under the influence of its mass and without any additional consolidation. Eliminating the large air voids enhances the strength and reduces the permeability of the concrete, which is essential for longevity. Consolidation would be required in traditional concrete to remove these large air voids. Easy flowing SCC permits convenient and fast concrete placement and easy elimination of large air voids. Reduced labor requirements and construction speed, improved mechanical properties and reliability characteristics, ease of installation in heavily reinforced and congested areas typical of beams with strands and shear reinforcement, consolidation without vibration and segregation, and reduced noise levels at manufacturing plants and construction sites are only a few of the advantages. However, there are some concerns with SCC: the degree of uniformity, potential for segregation and increased shrinkage, quality of the air-void

System and the protection from cycles of freezing and thawing, and bond quality between strands and concrete (Ozyildirim, 2014).

According to other researchers, the relation between cement paste and aggregates is very important in the mix design of concrete. Self-consolidating concrete has a higher paste amount than conventional concrete and lightweight concrete to facilitate the flowing of aggregates to fill any voids inside the formwork. Paste coating of aggregates to reduce the friction and direct touching between aggregates can improve the workability of fresh concrete. Controlling the water to cement ratio results in a denser and improve strength of concrete (Vakhshouri & Nejadi, 2015). To save the equilibrium among the proportions of lightweight self-consolidating concrete is therefore important to attain the required workability in the fresh state and the planned density and strength in the hardened state.

2.8 Lightweight Self-consolidating concrete

Lightweight Self-consolidating concrete (LWSCC) as a combination of Light Weight Concrete (LWC) and Self-Compacting Concrete (SCC) is a result of advances in concrete technology to come over the limits in concrete structures. Using LWC may result in smaller dimensions and lighter elements that both decrease the total weight of the structure and the lateral loads that is a major problem in most parts of the world (Vakhshouri & Nejadi, 2015).

In general, the compressive strength of SCLWC is used to calculate its other mechanical properties.Despite available studies on the advantages of SCLWC associated with its high performance in the fresh state, there are fewer available studies regarding the expected hardened properties for mechanical responses like compressive strength. SCLWC is highly sensitive to changes in mix component properties and their proportions; therefore, it requires increased quality control. The typical properties of SCLWC mix proportions, which are needed to ensure adequate fresh properties, can have a major impact on hardened concrete properties such as strength and dimensional stability.

CHAPTER THREE

METHODOLOGY

3.1 Sampling area

The Aggregate (scoria) samples were collected from Waliso Area which is located in the southwest shewa zone of the Oromia region in Ethiopia, 114km southwest of Addis Ababa. It has a latitude and longitude of 8.5330N and 37.9670E with an elevation of 2063 meters above sea level. Waliso is the administrative center of this zone (Source: Google)

Figure 3. 1 Geographical Location map of waliso; Source Google Map

3.2 Study Design

The research was experimental and investigated the properties of Self-consolidating lightweight concrete using scoria. The study was made by conducting different experimental works on the properties of materials and test on the result of the concrete specimens. The properties of the ingredient materials for the concrete were studied to prove the suitability of the materials for the concreting work and finally the properties of the concrete specimens were made to decide the conclusion and recommend the feasible concrete types that should be adopted for the future in our construction industry.

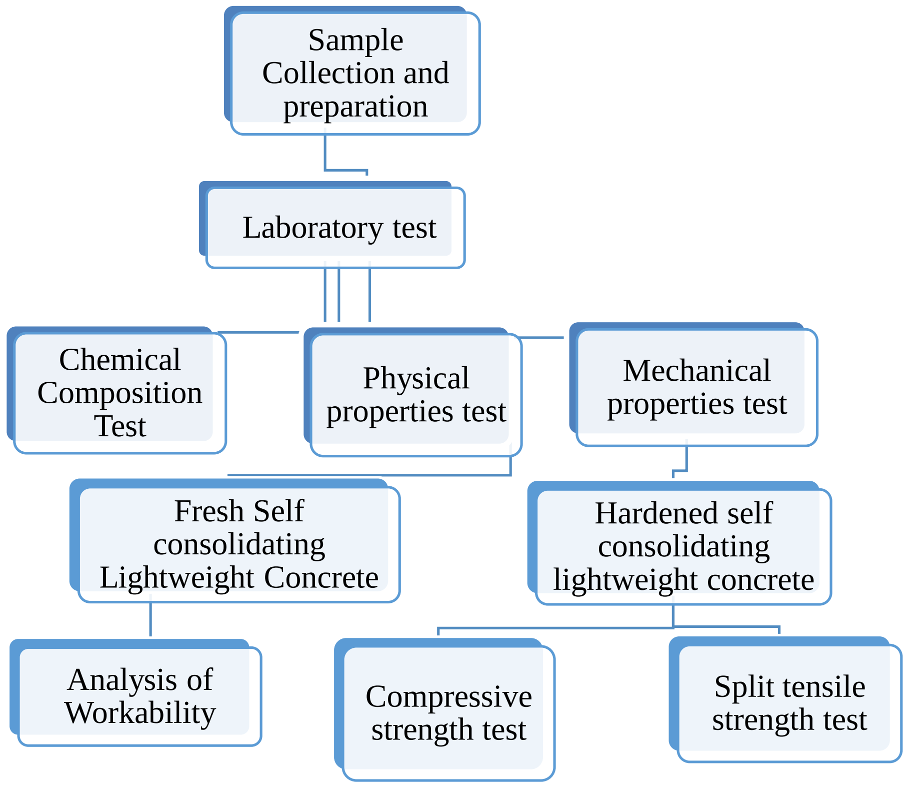

Figure 3. 2: Method and procedure of the study

3.3 Sample size and sampling procedures

The sampling technique that was conducted was purposive sampling, and the sampling procedure was taken according to ASTM standard, and the material proportion for self-consolidating lightweight concrete was designed according to the standards of the EFNARC manual and ACI. The samples for the compressive strength of the control group was nine (9) for the 7th day, 14th day, and for the 28th day with a cube sample of $15cm* 15cm* 15cm$. The compressive strength samples or cube samples for self-consolidating lightweight concrete with scoria were a total of 45 samples. Nine cube samples for 25% scoria replacement, nine for 50% scoria replacement, nine for 75% scoria replacement, and nine for 100% scoria replacement, and 9 samples for normal vibrated concrete were also made. The samples for the split tensile strength of the control group were nine (9) for the 7th day, 14th day, and for the 28th day with a cylinder sample of 100mm*200mm. The split tensile strength samples or cylinder samples for self-consolidating lightweight concrete with scoria were a total of 45 samples. Nine cylinder samples for 25% scoria replacement, nine for 50% scoria replacement, nine for 75% scoria replacement, and nine for 100% scoria replacement, and 9 samples for normal vibrated concrete were also made. For all self-consolidating lightweight concrete samples, the quantity of admixture was 2% superplasticizer.

For the fresh property of self-consolidating lightweight concretes, there were slump flow table test conducted and test for the stability of concrete or segregation resistance was checked by the naked eye for the whole self-consolidating lightweight concrete samples.

Table 3. 1:Total no of samples of specimens for compressive and split tensile strength

List of Groups	Types of Mix	7th day	14th day	28th day
Normal Concrete		3	3	3
Group 1	Control group (with 0% scoria)	3	3	3
Group 2	SCC (with 25% scoria)	3	3	3
Group 3	SCC (with 50% scoria)	3	3	3
Group 4	SCC (with 75% scoria)	3	3	3
Group 5	SCC(with 100% scoria)	3	3	3

3.4 Methods of Data Collection

From the early development of this Study topic, various data were collected and processed to achieve the objective of this study. These were conducted first by reviewing previous related literature and different international & local standard specification, secondly by laboratory tests regarding the preparation of SCLWC. Specifically, both primary and secondary data were used in this study.

3.4.1 Primary Source of Data

These sources of data were obtained through laboratory tests on SCLWC Property’s results.

3.4.1 Secondary Source of Data

The secondary data were collected from previous studies, scientific researches, national and international design manuals & standards.

3.5. Study Variable

3.5.1. Dependent Variable

- Investigation SCLWC using scoria

3.5.2. Independent Variable

- Compressive Strength
- Split tensile strength
- Physical properties and chemical compositions
- Workability

3.6. Materials Used for the Study

3.6.1. Cement

For this study, the type of cement used to produce the samples was pozzolana Portland cement (PPC) which is available in the market, and the Dangote cement factory.

3.6.2. Aggregates

Aggregates for concrete construction should be hard and strong, free of undesirable impurities, and chemically stable. If the aggregates are not good, the properties of concrete will be risked. As of the fresh property of concrete, such as; workability, filling ability, and segregation resistance was depending on the aggregates property; the moisture content of aggregate, water absorption, silt content, specific gravity, and fineness modulus of the materials were conducted. Since to determine the aggregate proportion in concrete, the unit weight of coarse and fine aggregate is necessary and their tests were also conducted.

3.6.3 Properties of Fine Aggregate

The fine aggregate used in the concrete productions is natural sand quarried from Warabe and brought Jimma for selling was chosen. To determine its property and to know the suitability of the material which includes silt content, sieve analysis, and fineness modules, specific gravity and absorption capacity, moisture content, and unit weight.

A. Silt Content

The material in fine aggregates which is finer than 75µm is generally regarded as silt. This silt in the fine aggregate for the concrete affects the quality of concrete. It mainly affects the workability of concrete and also results in the reduction of strength.

According to the Ethiopian Standard, it is recommended to wash the sand or reject if the silt content exceeds a value of 6% (Abebe, 2002) and ASTM C33 limits deleterious (material finer than a 75µm sieve) substance in fine aggregate to 5%. In this study, fine aggregate that used have a silt content of 2.9% and this value was within the range of the standard and it passes the requirement.

B. Sieve Analysis and Fineness Modulus

Sieve analysis is a procedure for the determination of the particle size distribution of the aggregates using a series of square or round meshes. It is also used to determine the fineness modulus [FM] on the index to the fineness coarseness and uniformity of aggregates. These properties of the aggregate greatly affect the property of the concrete (ASTMC136, 2001). According to ASTM C33, sand with a fineness modulus between 2.3 and 3.1 is considered to be good sand or a good fine aggregate. In this study, the fine aggregate that was used has a fineness modulus of 3.02 and this was within the range of ASTM standard.

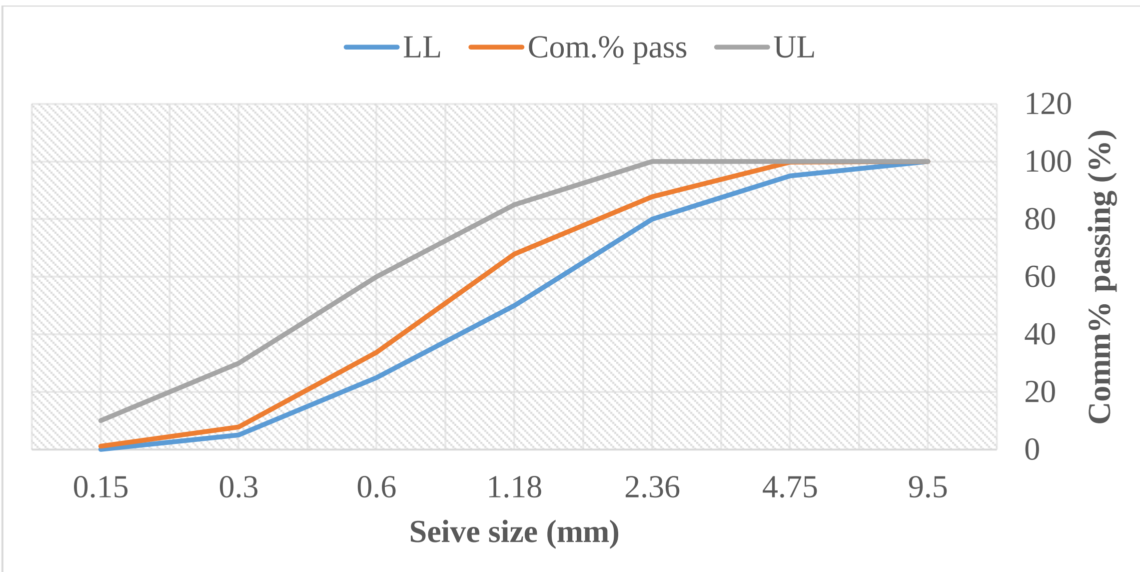

Figure 3. 3:Graph for sieve analysis of fine aggregate

As seen from the above figure 3.3, the gradation of the fine aggregate falls between the upper and the lower limit of ASTM C 33, standard grading requirements for fine aggregate specification limit. In a conclusion, the natural sand fulfills the grading requirement for natural sand per ASTM C 33. So it is ready for the required purpose.

C. Specific Gravity and Absorption Capacity of Fine Aggregate

A substance's real gravity is the weight of the substance divided by the weight of the same amount of water. Aggregates, however, have pores that are both permeable and impermeable; whose structure (size, number, and continuity pattern) affects water absorption and the specific gravity of the aggregates (Abebe, 2002). The Specific Gravity and Absorption Capacity of Fine Aggregate calculated as the equation:

Bulk specific gravity (SSD) =A/B+500-C = 500/1538+500-1845 = 2.6……………..………...1

Apparent specific gravity =A/B+A-C =491/1538+500-1845 = 2.54……………………..…... 2

Absorption capacity = 500-A/A*100 = (500-491/491) *100 = 1.83…………….………...…. 3

According to ASTM C 128 (2011), the limitation for absorption capacity ranges from 0.2 to 2 % for fine aggregates. As a consequence, the aggregate meets ASTM requirements.

D. Moisture Content of Fine Aggregate

It is important to know the moisture content of Fine aggregates to control the amount of water to be added for mixing concrete. For this study, absorption and surface moisture of aggregates were determined to determine the amount of mixing water to be added to the mix according to ASTM C 70. So, to know the required quantity of water that is necessary to get the desired compressive strength and the workability of fresh concrete, the tests should have to be conducted.

The moisture content of fine aggregate was determined by taking samples and oven-dry them with an adjusted temperature for 24 hours. The moisture content of sand used has a value of 2.9%.

E. Unit Weight of Fine Aggregate

The weight of a given volume of graded aggregate is known as unit weight. As a result, it is a mass calculation that is often referred to as bulk density.The unit weight effectively measures the volume that the graded aggregate will occupy in concrete and includes both the solid aggregate particles and the voids between them (Abebe, 2002).

The rodded bulk density of aggregates used for normal weight concrete generally ranges from 1200 to 1760 kg/m3 (ACI318, 2005) The unit weight of fine aggregate used in this study, fulfills the requirements of aggregates for normal-weight concrete.

Bulk unit weight = $\frac{(B-A)}{C}$…………………………………………………………….……..4

Table 3. 2:Table for Unit Weight Fine Aggregate

Description	Trial 1	Trial 2	Average
Weight of Container in kg (A)	1.06	1.06	1.06
Weight of Container + sample in kg(B)	8.13	8.16	8.14
weight of Sand	7.07	7.1	7.08
Volume of Container in m3 (C)	0.005	0.005	0.005

Density of Sand = $\frac{\text{weight of sand}}{\text{volume of container}} = \frac{7.08}{0.005}$ = 1416kg/m^3……………………..…………..….5

3.6.4. Properties of Gravel Coarse Aggregate

A Gravel coarse aggregate used in this study was purchased from the supplier Jimma town. Physical properties of coarse aggregate affect the properties of fresh and hardened concrete. So, to avoid the later fall of concrete, laboratory tests for coarse aggregate was directed as per the reference of the standards. The coarse aggregates used are with maximum aggregate sizes of 20mm.

In this study, laboratory tests were carried out to identify the physical properties of the coarse aggregate such as Sieve Analysis, specific gravity, and absorption capacity, moisture content, and unit weight.

A. Sieve Analysis

The gradation or particle size distribution of aggregate for concrete was done by sieve analysis test in which the particles are divided into various sizes by the standard sieve. The analysis was made by (ASTMC136, 2001).

As seen from the figure 3.4, the gradation of the gravel Coarse Aggregate falls between the upper and lower limit, standard grading requirements for gravel Coarse Aggregate specification limit. In a conclusion, the gravel Coarse Aggregate fulfills the grading requirement for natural sand per ASTM. So it is ready for the required purpose

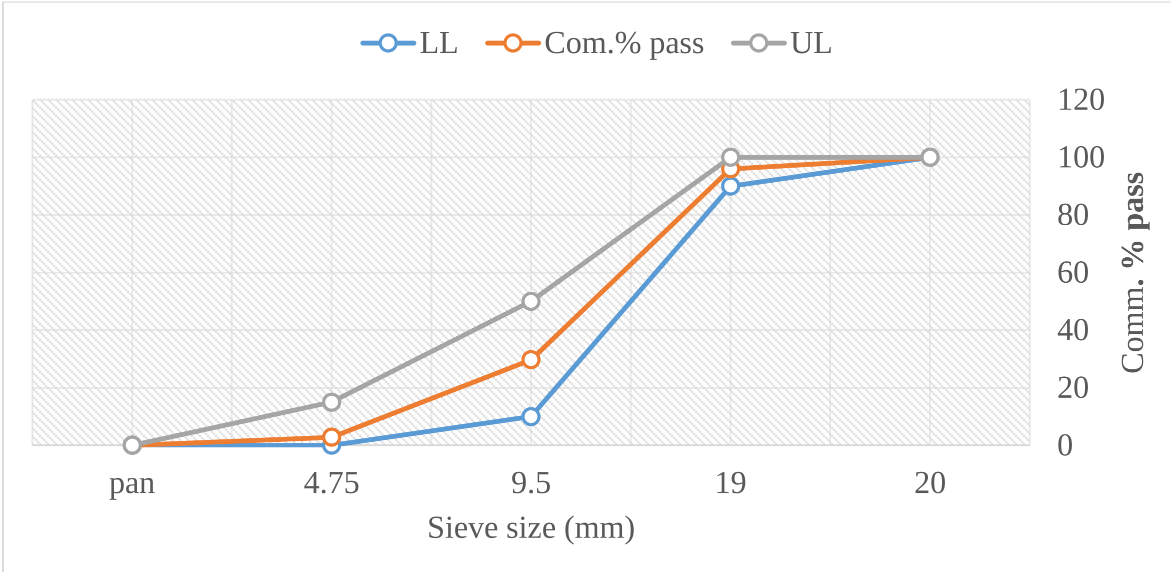

Figure 3. 4: Gradation Curve for gravel Coarse Aggregate

.B. Specific Gravity and Absorption Capacity of Coarse Aggregate

The specific gravity of the coarse aggregates was determined using the displacement method. First, approximately 2 kg of two samples of the coarse aggregate sample was taken and submerged in water for 24 hours. After that, the aggregates were removed and their surfaces were dried with a towel to eliminate any excess moisture.After determining their masses, the aggregates were carefully immersed into a beaker filled with water, after which the volume of the displaced water was measured. The bulk specific gravity is calculated as an equation:

Bulk specific gravity = $\frac{A}{B-C}$……………………………………………………………...…..6

Bulk specific gravity (SSD) = $\frac{B}{B-C}$……………………………………..……………………7

Where: A = the mass of oven-dry sample in air, B = the mass of saturated surface-dry sample in air, C = the apparent mass of saturated sample immersed in water.

$C = (A2 - A1)$ ………………………………………………………….………………..…. ……… 8

A1 = Weight of empty basket in water

A2 = Weight of aggregate and basket in water

According to (ASTMC-127, 2001)Absorption; The aggregate is considered "dry" when it has been maintained at a temperature of 110 + 5°C for sufficient time to remove all uncombined water. So, absorption capacity could be calculated by the below equation.

% of Absorption = $\frac{B-A}{A}$ *100…………………………………………………………………...9

Table 3. 3:Summary Test Results for Gravel Coarse Aggregate

No.	Test Description		Test result
1	Maximum Aggregate Size (mm)		20
2	Moisture content (%)		1.2
3	Unit Weight (Kg/m^3)		1670
4	Absorption Capacity(%)		1.24
5	specific gravity	Bulk specific gravity	2.58
		Bulk (SSD) specific gravity	2.62
		Apparent specific gravity	2.67

Generally, according to (ASTMC330/330M, 2010)) the limitation for bulk specific gravity (SSD) is from 2.4 to 3.0, and absorption capacity ranges from 0.2 % to 4 %, for coarse aggregates. Accordingly, the aggregates are within ASTM limitations.

3.6.5 Water

Concrete is produced by mixing binding materials (cementitious materials) and inert materials (fine and coarse aggregates) with water. In this study, water was used for mixing the concrete and curing the specimens. The water type that was used was potable water which tests done is only physical water quality test.

3.6.6 Superplasticizer

Polycarboxylic ether (PCE) based super-plasticizer approves to (ASTMC-494/494, 2001)in the aqueous form to improve workability and water retention was used. High Range Water reducing and accelerating admixture was used to increase slump flow for the produced SCC samples and reduce consumption of water.

3.7 Scoria

Scoria is one type of lightweight aggregate used for the production of concrete. Scoria aggregates used for the study were bought from scoria deposit in Waliso area. For this study, the scoria was used as a coarse aggregate based on ASTM C 330 standard specification.

3.7.1 Properties of Scoria Coarse Aggregate

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

Sieve analysis, silt content, absorption capacity, and unit weight of the scoria were tasted before any trial mix and compared with standards.

A. Sieve Analysis

The maximum size of the scoria was 20mm in diameter. Therefore, to get the maximum size of scoria needed for the production of concrete sieved with a sieve size of 20mm. The sieve analysis of scoria coarse aggregates was conducted as per ASTM C 136.

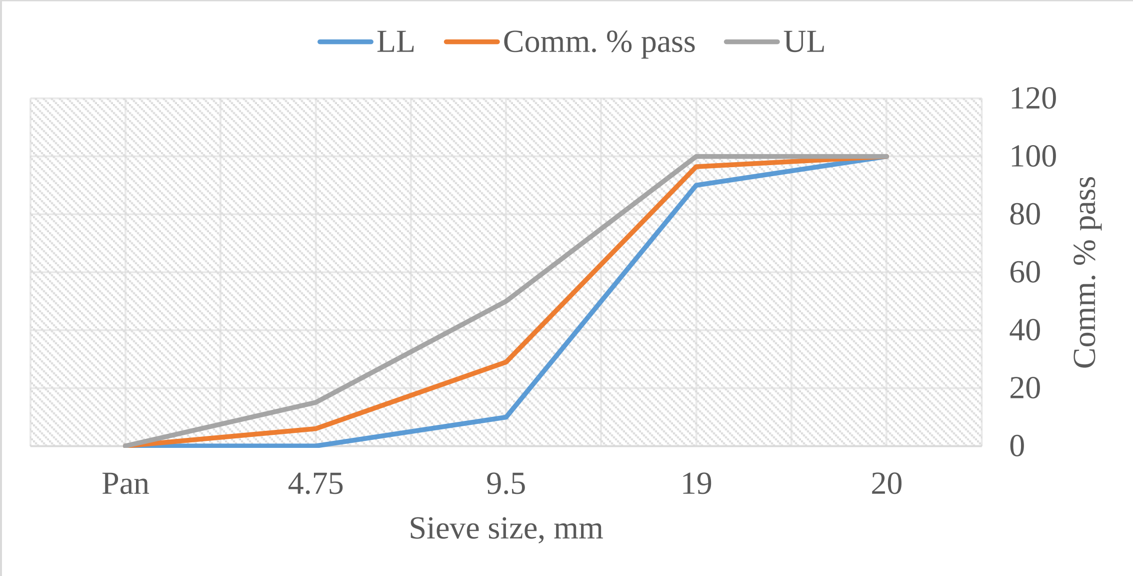

Figure 3.5:Gradation Curve for Scoria Coarse Aggregate

As shown from the above figure 3.5, the gradation of scoria coarse aggregate is fallen between the upper and the lower limit of the specification. So as per ASTM C330 requirement for the gradation of lightweight aggregate, the scorria coarse aggregate fulfill this limit.

B. **Specific Gravity and Absorption Capacity of Scoria coarse aggregate**

According to (ASTMC330/330M, 2010)) the limitation for bulk specific gravity (SSD) is from 2.4 to 3.0. The absorption capacity of the light-weight aggregate is higher than the normal weight aggregate. Even if there is only a definition on the lightweight aggregate by saying, lightweight aggregate has higher absorption capacity than normal aggregate without the minimum and maximum limit in number on the standard specification of lightweight aggregate, but it describes on the ACI committee 213 as a general definition, the lightweight aggregates absorb from 5 to 25 % by mass of dry aggregate, depending on the aggregate pore system. As shown in the table below it also satisfies the value limitation for lightweight aggregate by ACI 213 committee. The scoria coarse aggregate has a 10.69 % absorption capacity.

Table 3.4:Summary Test Results for Scoria Coarse Aggregate

No.	Test Description		Test Result
1	Maximum Aggregate Size (mm)		20
2	Moisture content (%)		8.08
3	Unit Weight (kg/m^3)		990
4	Absorption Capacity(%)		10.69
5	Specific Gravity	Bulk	2.3
		Bulk (SSD)	2.5
		Apparent	3.05

3.7.2 Chemical Composition of Scoria

Scoria that was collected from waliso area checked in its chemical composition. The result of the chemical analysis of scoria was determined at the geological survey of Ethiopia.

The chemical composition of the scoria aggregate was determined at the Laboratory of Geological Survey of Ethiopia. The mineral composition of the scoria aggregate and the obtained result is shown in Table 4.1. From the result, the scoria contains a greater amount of silicon dioxide (54.4%), aluminate (13.92), and ferrite (11.88). The summation of these three oxide compositions was found to be 80.2%, and the material is classified as a class -N pozzolanic material according to (ASTMC-618, 2000).

3.8 Material Quantity Used to Produce Concrete Specimens

In this study, different material proportions were used. A conventional vibrated concrete does have the same ingredient proportion and a self-consolidating lightweight concrete does have different material proportion of scoria content. Since, a self- consolidating lightweight concrete has four different types of scoria replacement.

Table 3.5:Ingredients Quantity

Types of materials	LWSCC with 25%	LWSCC With 50%	LWSCC with 75%	LWSCC with 100%	CVC
Cement	450Kg/m^3	450Kg/m^3	450Kg/m^3	450Kg/m^3	450Kg/m^3
Sand	793.42Kg/m^3	793.42Kg/^{m3}	793.42Kg/m^3	793.42Kg/m^3	793.42Kg/m^3
Coarse Aggregate	588.234 Kg/m^3	392.156 Kg/m^3	196.078 Kg/m^3	0 Kg/m^3	784.312Kg/m^3
scoria	196.07 Kg/m^3	392.156 Kg/m^3	588.234 Kg/m^3	784.312Kg/m^3	0 Kg/m^3
Admixture	9 Kg/m^3	9 Kg/m^3	9 Kg/m^3	9 Kg/m^3	0 Kg/m^3
Water	178.87 Kg/m^3	183.79 Kg/m^3	188.80 Kg/m^3	193.82 Kg/m^3	173.43 Kg/m^3

3.9 Laboratory Test of Material Property

For this study different laboratory testing of materials for their property as per ASTM manual. Those tests conducted to study the properties of the fine and coarse aggregate and for the fresh and hardened property of concrete and the property of scoria.

Table 3.6:Sample of Test Methods and Their standards

No.	Standards	Test types
1	ASTM C136	Standard Test Method for Fine and Coarse Aggregate Sieve Analysis
2	ASTM C127	Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate
3	ASTM C29	Unit weight and voids in aggregates
4	ASTM C127	Specific gravity and Absorption of coarse aggregate
5	ASTM C128	Specific gravity and absorption of fine aggregate
6	ASTM C566	Test Method for total moisture content of aggregates
7	ASTM C143	Standard Test Method for Slump of Hydraulic-Cement Concrete
8	ASTM C39	Standard Test Method for Cylindrical Concrete Specimen Compressive Strength
9	ASTM C40	Organic impurities

3.10 Properties of self-consolidate lightweight concrete

3.10.1 Test Methods of Fresh Concrete

A. Slump flow test

This test is used to measure the free horizontal flow of SCC on a plain surface without any obstacle. Fresh SCC properties including filling ability, passing ability, and resistance to segregation at required levels. The filling ability is the ability of the SCC to flow into all spaces within the formwork under its weight. Without vibrating the concrete, SCC has to fill any space within the formwork and it has to flow in horizontal and vertical directions without keeping air entrapped inside the concrete or at the surface. Passing ability is the ability of the SCC to flow through tight openings such as spaces between steel reinforcing bars, under its weight. To ensure a homogeneous distribution of SCC components in the vicinity of obstacles, passing ability is required. The resistance to segregation is the resistance of the components of SCC to migration or separation and remains uniform throughout the process of transport and placing. (Arulsivanantham & Gokulan, 2017)

3.10.2 Test Methods of Hardened Concrete

A. Compressive strength

Using the standard specification for lightweight concrete (ASTMC330/330M, 2010)as well as (ASTMC-33, 2001)for the conventional 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 are 3 for 7days, 3 for 14 days, and 3 for 28 days. There were 5 different types of mixes. The tests were carried after 7, 14, and 28 days using the compressive machine.

Figure 3. 6:Measuring of compressive strength

B. Tensile strength

According to (ASTMC-496, 1996), This test method consists of applying a diametric compressive force along the length of a cylindrical concrete specimen at a rate that is within a prescribed range until failure occurs. This loading causes tensile stresses in the plane containing the applied load and relatively high compressive stresses in the area immediately surrounding it.Because the areas of load application are in a state of triaxial compression, tensile failure occurs rather than compressive failure, allowing them to withstand much higher compressive stresses than would be indicated by a uniaxial compressive strength test result.

Figure 3. 7: Measuring split tensile strength

An indirect tension test is a common method of determining the tensile strength of concrete.The splitting tensile test is carried out on a standard cylinder tested on its side in diametric compression.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Chemical Composition of Scoria

The chemical compositions of scoria determined by complete silicate analysis are given in Table 4.1. The combined ingredients by weight of silica (SiO_2), aluminum (Al_2O_3) and iron oxides (Fe_2O_3) is 80.2% which reveals that the material is classified as Class-N Pozzolana. The result of the loss on ignition is 1.85% which shows that the material is not sensitive to weather action. The moisture content of scoria is 0.67% which is less than 3%. Therefore, the complete silicate analysis resulted from scoria can be classified as Class-N Pozzolana. Hence, the material had no significant effect on the aggregate intergranular bondage in the concrete mixture.

Table 4.1 Chemical Composition of scoria (*Appendix D*)

Composition	Weight (%)	Class - N Pozzolana (ASTM C618)	Remarks
SiO_2	54.4	-	
Al_2O_3	13.92	-	
Fe_2O_3	11.88	-	
$SiO_2 + Al_2O_3 + Fe_3O_3$	80.2	≥ 70 %	OK
Cao	4.36	-	
MgO	9.12	-	
Na_2O	0.01	-	
K_2O	1.68	-	
MnO	0.2	-	
P_2O_5	0.69	-	
TiO_2	0.68	-	
H_2O	0.67	≤ 3%	OK
LOI	1.85	≤ 10 %	OK

4.2 Fresh Property of Self-consolidating lightweight Concrete

4.2.1. Slump flow test

The slump of a control concrete was 50mm and the slump flow diameter of self-consolidating lightweight concrete was 600 mm for SCLWC with scoria and superplasticizers. The control concrete type used in this study was workable concrete with its considered water per cement ratio. But, self-consolidating lightweight concrete samples were better with slump flow table value than normal vibrated concrete. The slump flow table value of all SCLWC samples was equal diameter, this indicates that, if SCLWC would use in a construction project, the workability of fresh concrete enhances the construction duration.

Figure 4.1: Measuring slump flow table taste

4.3. Hardened Properties of Self-consolidating lightweight Concrete

4.3.1. Compressive Strength

Compressive strength is a property of concrete tested at a hardened state. The hardened property of the concrete specimens was checked by their 7th, 14^{th,} and 28th compressive strength result. For a good result of compressive strength curing period of concrete plays a main role. For this case, a curing effect of self-consolidating of lightweight concrete and normal vibrated concretes was known.

A. Compressive Strength of Control Concrete

The compressive strength results of control concrete samples were conducted on the 7th, 14th, and 28th day. The compressive strength of the control concrete result was not the objective of the study. But to compare with self-consolidating lightweight concrete specimens. The compressive strength of control concrete is shown in figure 4.2. The result was 20.44MPa, 24.99MPa, and 28.99MPa for the curing period of the 7th, 14^{th,} and 28th day respectively. The results indicated that the mixture on the 28th day met the specification strength of C-25MPa control concrete.

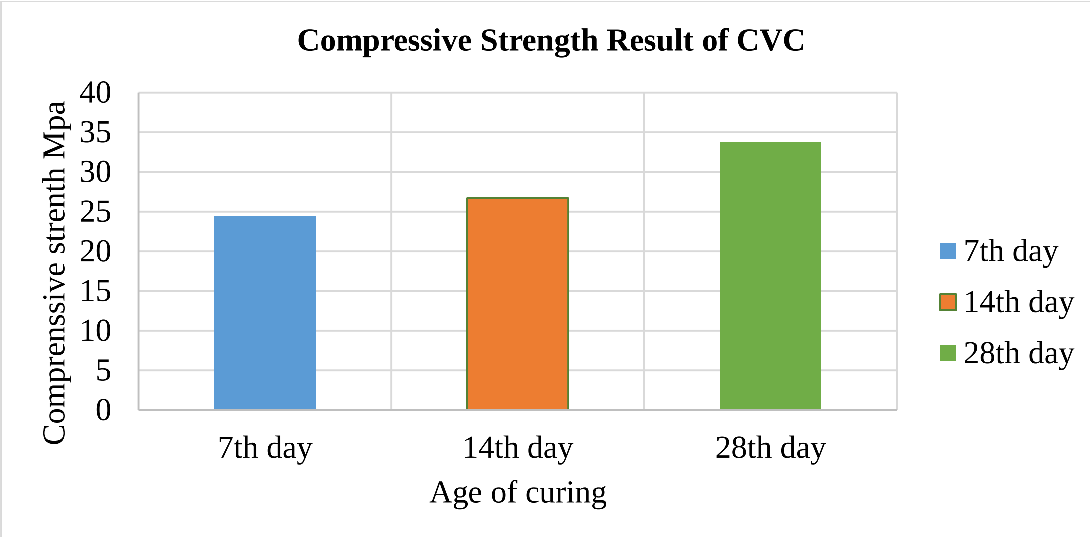

Figure 4.2 Compressive Strength Result of CVC

B. Compressive Strength for SCLWC

i. 7th-day Compressive Strength Test Result

The compressive strength test results of the 7th day for SCLWC with 25, 50, 75, and 100% scoria was 27.07, 26.86, 26.24, and 25.37Mpa respectively. The outcome of the test shows that; a higher compressive strength was obtained from SCLWC with 25% Scoria. The compressive strength result for an SCLWC with 100% Scoria indicated lower results. But a compressive strength result for an SCLWC with 100% Scoria is higher than the compressive strength result of control concrete of 7th days. The results of SCLWC with Scoria at this period achieved the desired strength.

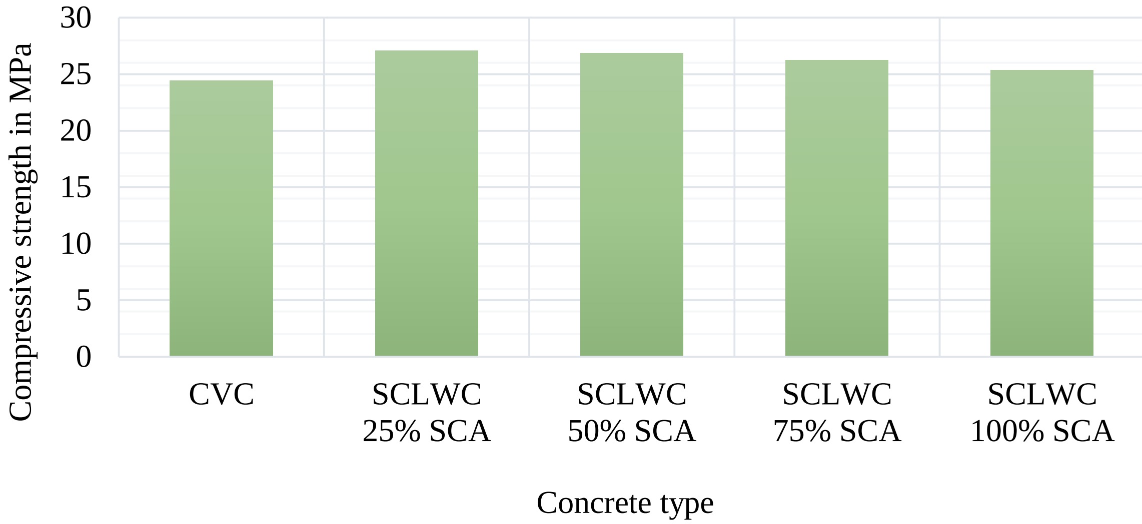

Figure 4.3: 7^{th}-day compressive strength

ii. 14th-day Compressive Strength Test Result

The compressive strength test results of the 14th day with Scoria are shown in figure 4.3. The result of 26.7, 29.8, 29.1, 28.4, and 27.5MPa for CVC,25 ,50, 75 and 100% scoria was obtained respectively. The result of 100% scoria is higher than that of CVC and Maximum strength was obtained with 25% Scoria. But, the compressive strength test result of the control concrete is smaller than the other. It is seen that self-consolidate concrete with scoria developed better compressive strength than control concrete.

The compressive strength test results on the 14^{th} day increased in value than the 7^{th-}day result. Results of 14^{th} day increased by 9.25, 10.08, 8.33, 8.23 and 8.39% for CC, 25, 50, 75, and 100% Scoria respectively from 7^{th} day strength. However, the mixture with 25% Scoria showed better improvement on the 14th day.

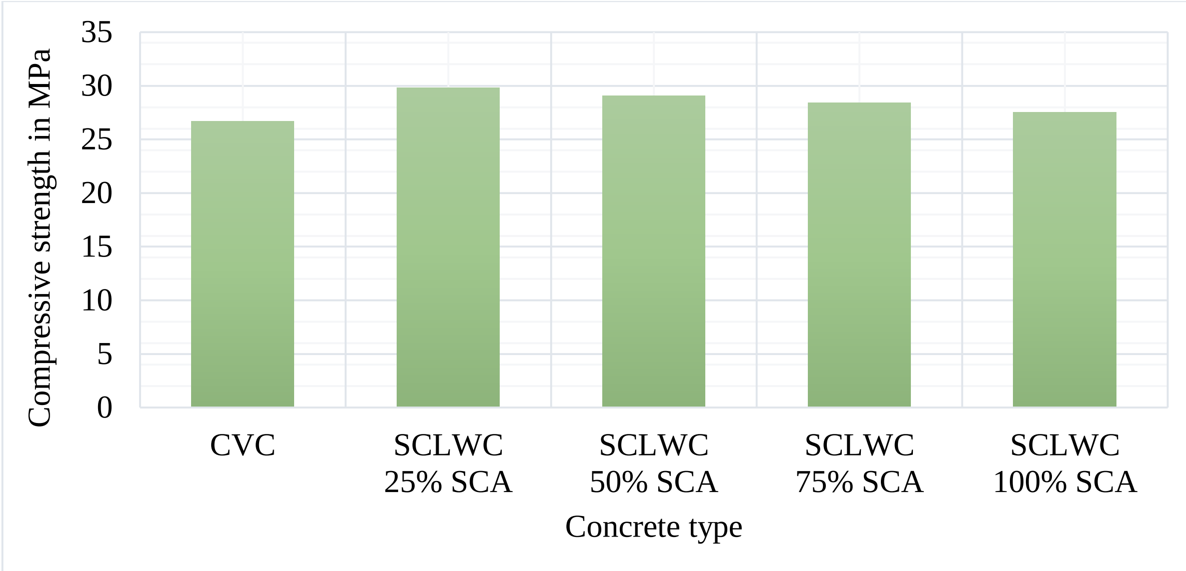

Figure 4. 4: 14th-day compressive strength

iii. 28th-day Compressive Strength Test Result

The compressive strength test result of concrete with scoria on the 28th day is as shown in figure 4.5. As indicated in the figure the results of 33.7,35.17,34.1,33.3 and 31.68MPa were obtained for CVC, 25,50,75, and 100% respectively. The results for the 28th day showed higher compressive strength than the 7th and 14th days.

As the diagram showed, SCLWC with 25% of scoria resulted in the highest compressive strength than others. The percentage development of the 7th to 28th day was, 19.47, 29.92, 26.95,26.90, and 24.87% for CVC, , 50, 75, and 100% scoria respectively. It was observed that samples up to 50% scoria showed better improvement than the control group and the mix with 75 and 100% scoria resulted in a lower value than the control group but all the results satisfied the specification limit.

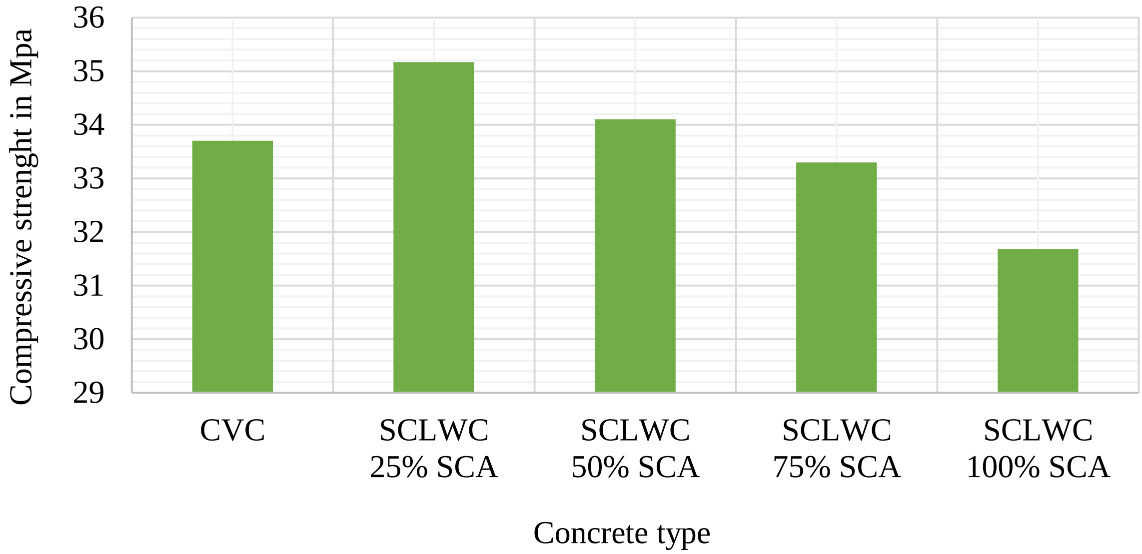

Figure 4. 5: 28th-day compressive strength

4.3.2 Split Tensile Strength

Split tensile strength is a property of concrete tested at a hardened state. The hardened property of the concrete specimens was checked on the 7th, 14th and 28th day split tensile strength result. For the good result of split tensile strength curing period of concrete plays a main role. For this case, a curing effect of self-consolidating of lightweight concrete and normal vibrated concretes was known.

A. Split Tensile Strength for SCLWC

i. 7th day Split Tensile Strength

The Split tensile strength test results of 7th day for CVC, , 50, 75, and 100% scoria is 2.01, 3.06, 3, 2.72 & 2.46Mpa respectively. The outcome of the test result showed that a higher split tensile strength was obtained with 25% scoria. But all the split tensile strength with Scoria showed a better result than the control concrete on the 7th days.

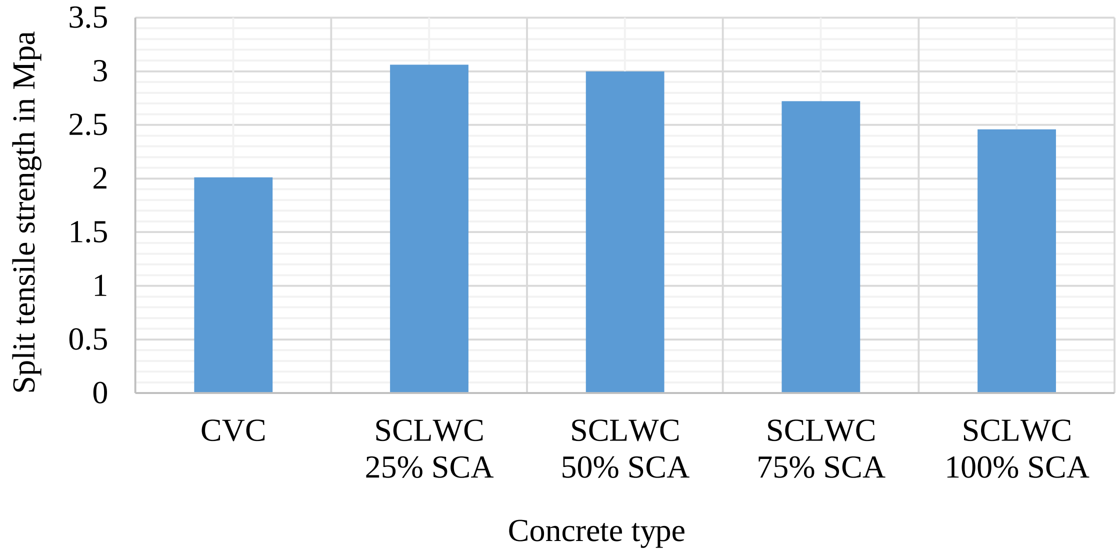

Figure 4. 6: 7th day Split Tensile strength

ii. 14th day Split Tensile Strength

The split tensile strength test results shown in figure 4.7 on the 14th day with Scoria are slightly higher than that of CC and 25% Scoria was higher than the others. But, the split tensile strength test result of the control concrete was smaller than the other. It is seen that SCLWC with scoria developed better split tensile strength than control concrete.

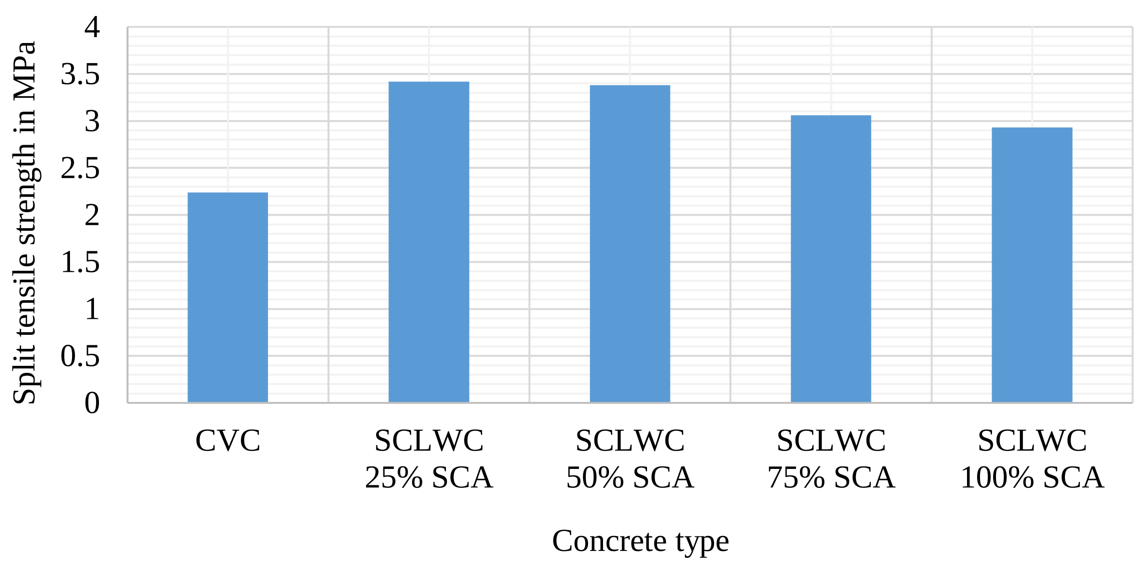

Figure 4. 7: 14th day Split Tensile strength test result

iii. 28th day Split Tensile Strength

The split tensile strength at the 28th day with different proportions of scoria at 0 to 100% at 25% increments are shown in figure 4.8. The results indicated better split tensile strength for self-consolidating lightweight concrete.

As the diagram is shown, a self-consolidating lightweight concrete with 25% of scoria resulted in the highest split tensile strength. It was observed that samples with scoria showed better improvement than the control group and replacement of course aggregate with scoria displayed good results at a later age than the control group.

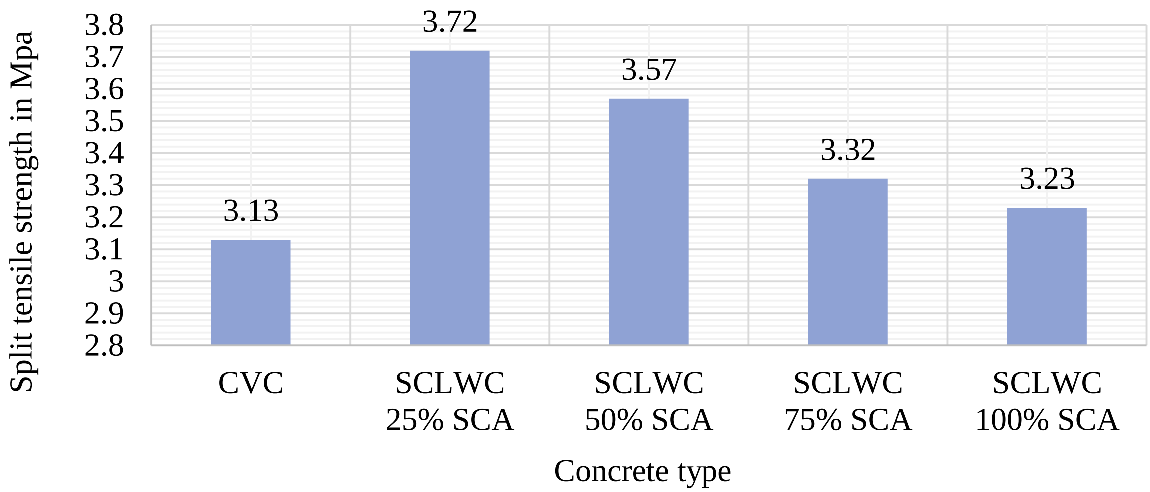

Figure 4. 8: 28th day split tensile strength

4.4. Density of SCLWC

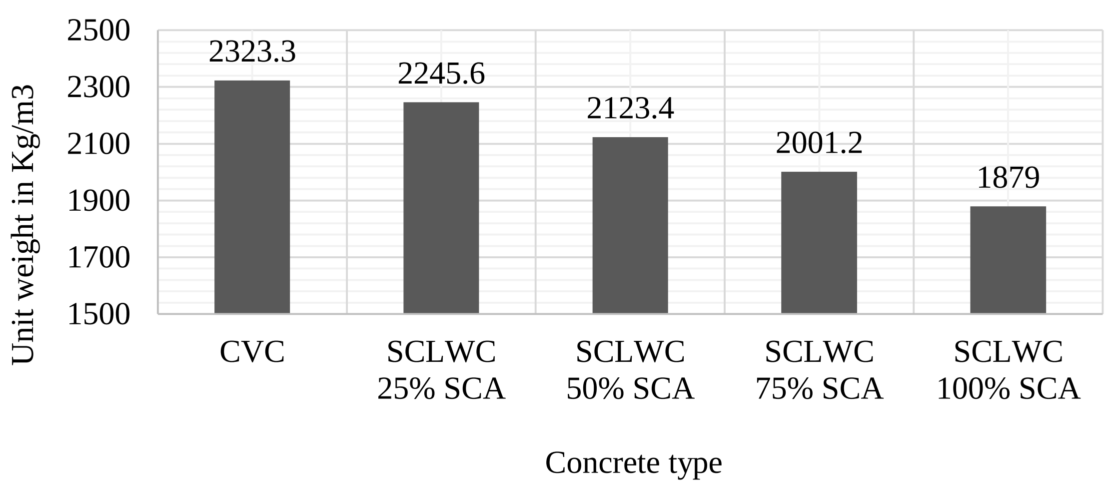

Figure 4.9: Unit weight of SCLWC at a different percentage of scoria

The concrete unit weight was decreased as the contents of Scoria were increased. The decrease in the unit weight of the concrete shows as the specific gravity of Scoria was less than the specific gravity gravel coarse aggregate.

Generally, scoria as coarse aggregate in concrete shows lower density concrete which was beneficial in many ways over a high-density concrete. This is why the lighter concrete reduces the size of structural members and also reduces the pressure on formworks. Therefore, the replacement of course aggregate in concrete by scoria reduces the weight of concrete and dead load of the structure compared to control concrete.

4.5. Optimum Percentage of scoria

In this study, the coarse aggregate was replaced by scoria to produce SCLWC. The percentage replacement of scoria was 25, 50,75, and 100% by the weight of aggregate content The results of the study were good, in its fresh property as well as hardened property.

The fresh property of SCLWC performed by slump flow table result was within the range of the EFNARC guidelines. As the result of fresh property showed, the replacement of course aggregates with scoria increased by the percentage at constant slump flow diameter. The compressive strength split tensile strength results of SCLWC samples were increased when their curing period is increased. An optimum percentage of scoria replacement either at the fresh property or compressive strength couldn't be found out.

From the result of the compressive strength and split tensile strength at 28th days, an SCLWC with 25% scoria has the largest value than other specimens. To decide the optimum one, the value of scoria replaced should have greater than the control group at some percentage of scoria.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The study aimed to investigate the effects of using scoria as coarse aggregate in the production of self-consolidate lightweight concrete.

The workability, compressive strength, and split tensile strength of scoria at different proportions showed higher results than the control group. The percentage replacement of scoria doesn't affect the workability because water adjustment and supper plasticizer improve workability. Also, the water absorption increased with an increase in percentage replacement of scoria. The maximum compression strength and split tensile strength were obtained at 25% replacement of scoria. However, the compressive strength and split tensile strength of 50,75 and 100% scoria satisfied the desired strength for C-25MPa. The compressive strength development of SCLWC from 7th to 28th days, with 25,50, 75 and 100% scoria increased by 29.92, 26.95,26.90 and 24.87% respectively. But, the control group increased by 19.47%.

The SCLWC with scoria replacement developed better split tensile strength compared to control concrete on the 28th days. The concrete unit weight was decreased as the contents of Scoria increased. The decrease in the unit weight of the concrete shows as the specific gravity of Scoria is less than the specific gravity gravel coarse aggregate.

Finally, it was concluded that scoria can be used either as a full replacement or in combination with gravel coarse aggregates to produce SCLWC structures with a superplasticizer.

5.2. Recommendation

In Ethiopia, construction is still in the infant stage and needs much more effort to make construction materials. The awareness about the different alternative locally available, economically feasible as well as environmentally friendly materials and their advantages is negligible. Therefore, based on the findings of this study, the following recommendations are forwarded:

Scoria can be used as a coarse aggregate in SCLWC either fully replacing or in combination with gravel.

Scoria investigated in this study can be used as gravel replacement in the production of SCLWC with superplasticizer. Therefore, concerned government and private companies like contractors and consultants should have to make awareness about.

The following further investigations are required:

- Suitability of scoria at the different grades of aggregates without superplasticizer.
- The durability of SCLWC with scoria
- The economic analysis on the use of Scoria as an alternative material
- Analysis of pozzolanic reaction and chemical structure of scoria

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Appendix A

Concrete mix design

Normal vibrated concrete

The mix design for C-25 non-air entrained normal vibrated concrete and the procedures were done according to ACI 211.1 concrete mix design procedure manual.

Step 1: - Choice of Slump: Consistent with the method of placing the slump was set to be 25-50mm and the maximum value was taken.

Step 2: - Maximum Size of Aggregate: maximum aggregate size was 20mm crushed aggregate.

Step 3: - Target Mean Strength

According to ACI 301 table, target means strength for 21MPa up to 35Mpa concrete was done by adding (1.64*4). So, 25MPa was within the range and the target mean strength is 25MPa+8.3=33.3Mpa.

Step 4: - Mixing Water Requirement

Workability or air content	Water content (kg/m^3) of concrete for indicated maximum aggregate size in (mm)							
	10	12.5	20	25	40	50	70	150
Slump	Non-air entrained concrete							
30-50mm	205	200	185	180	160	155	145	125
80-100mm	225	215	200	195	175	170	160	140
150-180mm	240	230	210	205	185	180	170	--
Approximate entrapped air content(%)	3	2.5	2	1.5	1	0.5	0.3	0.2

Mixing water for 50 mm slump value, 20 mm maximum aggregate size, and for non-air entrained concrete was 185mm.

Step 5: - Water to Cement Ratio

Water/cement ratio for 33.3MPa was found by interpolating from 30MPa and 35MPa. And the water per cement ratio was35−31.5 /31.5−30 = 0.48−X/ X−0.55, X = 0.53. For exposure Condition the maximum water per cement ratio is 0.50, therefore adopt a w/c ratio of 0.50.

Step 6: - Determining Cement Content

Water/Cement = 0.50,185/C = 0.50. So, Cement = 185/0.50 = 370kg

Step 7: - Estimation of Coarse Aggregate

The dry mass of coarse-aggregate required for a cubic meter of concrete is equal to the value from ACI 211-Table 3.11 multiplied by the dry-rodded unit mass of the aggregate in kilograms per cubic meter. The fineness modulus of fine aggregate was 3 and the maximum size of aggregate was 20mm.

MAS	**Bulk volume of dry rodded coarse aggregate**			
Fineness modulus	2.4	2.6	2.8	3.0
10	0.5	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
20	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
40	0.75	0.73	0.71	0.69
50	0.78	0.76	0.74	0.72
70	0.82	0.80	0.78	0.76
150	0.87	0.85	0.83	0.81

The weight of coarse aggregate was calculated by multiplying the dry bulk volume of rodded coarse aggregate and unit weight of coarse aggregate 1670 kg/m^3 * 0.6=1002 kg/m^3

Maximam size of aggregate(mm)	**First estimate of density (unit weight)of fresh concrete(Kg/m^3)**	
	Non-Air entrained	**Air entrained**
10	2285	2190
12.5	2315	2235
20	2355	2280
25	2375	2315
40	2420	2355
50	2445	2375
70	2465	2400
150	2505	2435

For Non-Air entrained, 20mm aggregate size, the density of fresh concrete was 2355kg/m^3

Fine Aggregate = 2355kg/m^3 - (185kg/m^3 + 370kg/m^3 + 1002 kg/m^3) = 798 kg/m^3

SELF-COMPACTING LIGHTWEIGHT CONCRETE

Step1: - Air Content: Mostly 2% is taken as air content for self-compacting non-air-entrained concrete

Step 2: - Determination of Coarse Aggregate Volume

Wt. of C.A = $1 - A * G/Glim * ɤd = (1 - 0.02) * 0.50 * 1600 kg/m^3 = 784 kg/m^3$

Where A: air content: ɤd dry rodded bulk density of coarse aggregate &G/ Glim is 0.50

Step3: - Fine Aggregate Content

Select a value of Vs /Vm according to passing ability and segregation resistance and the optimum volume content of sand in the mortar varies between 40% to 50% depending on the paste properties.

Vs = (1− A – Vg) ∗ Vs/ Vm = (1 − 0.02 −784/ 2650) ∗ 0.45 = 0.3078 where Vs/ Vm= 0.4 − 0.47

Weight of F.A = 0.3078 ∗ 2600 = 800.3kg/m^3

Step 4: - Check Paste Volume

Volume of paste = 1 − volume of sand − volume of coarse aggregate

volume of paste = 1 −800.3/ 2600−784 /2650= 0. 3963.therefore,0.3963 > 0.38 its okay

Step 5: - Selection of water/cement ratio

Assume the proportion of PFA to be 30%, then according to the equation the specific Gravity of this powder combination is 2.9.

Strength requirement

Target strength = 25+(1.64*4.3) =33MPa

$$fc = \frac{Kg*RC}{\left(1+3.1\frac{W+A}{C(1+K1+K2)+GGBS}\right)2}*1.25=33\text{MPa},$$

$$\frac{W+A}{C(1+K1+K2)+GGBS} = 0.35$$

$\frac{W}{C(1+K1+K2)+GGBS}(the\ effective\ binder\ retio) + \frac{A}{C(1+K1+K2)+GGBS}$ = 0.35 Assume the amount of effective binder 450kg/m^3

$\frac{W/p}{0.7(1+0.4+0.3/0.7)+20/450}$ =0.39 which is less than 0.459 (durability requirement)

Volume of water /Volume of Powder = W/ P ∗ Specific gravity of powder

(Volume of Water) ⁄ (Volume of powder) = 0.39 ∗ 2.9 = 1.102

Specific Gravity of Powder = 100/ ((P1/ (S.G P1) + P2/ (S.G P2)))

= 100/ ((70/3.1 + 30/2.5)) = 2.9

Step6: - Water Content

Volume of Water = (0.39 − 0.02) ∗ 1.102/ 1+1.102 = 0.180 = 180kg/m^3

Step7: - Powder Content

Volume of Powder $=\frac{vw}{\frac{vw}{vp}}$ and Weight of Powder = Vp$*$ S.Gp $*$ ɤw = 0.180/ 1.102 = 0.1552

Weight of Powder = 0.1552 $*$ 2.9$*$ 1000 = 450kg/m^3

Adjustments of the ingredients according to their property

	Powder (kg/m^3)	Water (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m3)	Total (kg/m^3)
Quantity per M^3	450	180	800.3	784	
Moisture Content (%)			2.9	1.2	
Absorption Capacity (%)			1.83	1.24	
Adjustment		16.33-23.21+ 9.722-9.41= -6.568	-23.21+16.33 = -6.88	-9.41+9.722 =0.312	
Adjusted	450	173.432	793.42	784.312	2201.164
Ratio	1	0.3854	1.763	1.743	

Appendix B

Material Properties

Table 1: Sieve analysis of fine aggregate

Sieve size	Weight of Retained(kg)	Retained (%)	Cumulative Retained(%)	Cumulative passing(%)	Specification(%)	UL
9.5	0	0	0	100	100	100
4.75	0.0035	0.175	0.175	99.825	95	100
2.36	0.24	12	12.175	87.825	80	100
1.18	0.4	20	32.175	67.825	50	85
0.6	0.681	34.05	66.225	33.775	25	60
0.3	0.518	25.9	92.125	7.875	5	30
0.15	0.135	6.75	98.875	1.125	0	10
Pan	0.0225	1.125	100			

Table 2: Sieve analysis of coarse aggregate

Sieve size	Weight of Retained(kg)	Retained (%)	Cumulative Retained(%)	Cumulative passing(%)	Specification(%)	
20	0	0	0	100	100	100
19	0.2	4	4	96	90	100
12.5	1.775	35.5	39.5	60.5	---	---
9.5	1.539	30.78	70.28	29.72	10	50
4.75	1.346	26.92	97.2	2.8	0	15
Pan	0.14	2.8	100	0	0	0

Table 3: Sieve analysis of scoria coarse aggregate

Sieve size	Weight of Retained(kg)	Retained (%)	Cumulative Retained(%)	Cumulative passing(%)	Specification(%)	UL
20	0	0	0	100	100	100
19	0.176	3.52	3.52	96.48	90	100
12.5	1.947	38.94	42.46	57.54	---	---
9.5	1.428	28.56	71.02	28.98	10	50
4.75	1.149	22.98	94	6	0	15
Pan	0.3	6	100	0	0	0

NO.	Test Type	Test Material	
		Fine Aggregate	
1	Unit weight	Average weight of sand = 8.143 Volume of container = 0.005 Unit weight $= \frac{8.143}{0.005}$ = 1417.95	
2	Silt content of fine aggregate	A = percentage of materials finer than 75µm(No.200) by sieve washing, g, B = Original dry mass of sample = 1000g C = Oven dry mass of the sample after washing = 971.2g Silt content (%) A = $\frac{B-C}{B} * 100$ = $\frac{1000-971.2}{1000}$ *100 = 2.88%	
3	Specific gravity	A = Weight of oven-dry specimen in air = 491g B = Weight $_{\text{pycnometer + water}}$ = 1538g C = Weight $_{\text{pycnometer + water +sample}}$ =1845g S = Weight of saturated surface dry specimen = 500g	
		Bulk specific gravity	$\frac{A}{B+500-C}$ = 2.6
		Apparent specific gravity	$\frac{A}{B+A-C}$ = 2.54
		Water absorption	$\frac{500-A}{A} * 100$ = 1.83%
4	Fineness Modulus	Fm = $\sum\frac{cummulative\ coarser}{100}$ = $\frac{302}{100}$ = 3.02	
		Gravel Coarse Aggregate	
1	Moisture content	Weight of original air-dry sample(A) = 2Kg	

		Weight of oven dried sample(B) = 1.977kg MC(%) = $\frac{A-B}{B}$ = $\frac{2-1.977}{1.977}$ = 1.2%	
2	Specific gravity	Mass of oven-dried sample (A) = 1.982kg Mass of surface saturated dry (B) = 2.0065kg Mass of sample in water (C) = 1.62kg	
		Bulk specific gravity (SSD basis)	$= \frac{B}{B-C} = \frac{2.0065}{2.0065-1.24} = 2.62$
		Bulk specific gravity	$= \frac{A}{B-C} = \frac{1.982}{2.0065-1.24} = 2.58$
		Apparent specific gravity	$= \frac{A}{A-C} = \frac{1.982}{1.982-1.24} = 2.67$
		Absorption Capacity	$= \frac{B-A}{A} * 100 = \frac{2.0065-1.982}{1.982}$ *100 = 1.2%
3	Unit Weight	Weight of container (A) = 1.678kg Average weight of sample and container(B) = 18.378kg Volume of container(C) = 0.01M^3 Unit weight of CA = $\frac{B-A}{C} = \frac{18.37-1.67}{0.01}$ = 1670kg/m^3	
4	Fineness Modulus	Fm = $\sum\frac{commulative\ coarser}{100} = \frac{322.26}{100}$= 3.2226	
		Scoria coarse aggregate	
1	Moisture content	Weight of original air-dry sample(A) = 2Kg Weight of oven dried sample(B) = 1.8505kg MC(%) = $\frac{A-B}{B} = \frac{2-1.8505}{1.8505}$ = 8.08	

2	Specific gravity	Mass of oven-dried sample (A) = 1.970kg Mass of surface saturated dry (B) = 2.1805kg Mass of sample in water (C) = 1.325kg	
		Bulk specific gravity (SSD basis)	$= \frac{B}{B-C} = \frac{2.1805}{2.1805-1.325} = 2.55$
		Bulk specific gravity	$= \frac{A}{B-C} = \frac{1.97}{2..1805-1.325} = 2.3$
		Apparent specific gravity	$= \frac{A}{A-C} = \frac{1.97}{1.97-1.325} = 3.05$
		Absorption Capacity	$= \frac{B-A}{A} * 100 = \frac{2.1805-1.97}{1.97} *100$ $= 10.685\%$
3	Unit Weight	Weight of container (A) = 1.678kg Average weight of sample and container(B) = 11.678kg Volume of container(C) = 0.01M^3 Unit weight of CA = $\frac{B-A}{C} = \frac{11.678-1.678}{0.01} = 1000$kg/m^3	

Appendix C

Test Result

WORKABILITY

Table C1 Workability result test

Scoria rep.(%)	Cement (kg)	FA(kg)	CA(kg)	Scoria (kg)	Water(kg/m^3)	2%SP	workability mm
0	450	793.42	784.31	0	173.43	0	50(ACI)
25	450	793.42	588.23	196.08	178.87	9	600
50	450	793.42	392.16	392.16	183.79	9	600
75	450	793.42	196.08	588.23	188.80	9	600
100	450	793.42	0	784.31	193.822	9	600

COMPRESSIVE STRENGTH

Table C2 7th Day control concrete Compressive strength

Concrete Group	**Sample No.**	**Area (m^2)**	**Weight(kg)**	**Failure Load(KN)**	**Compressive Strength(KN/m^2**
Control group	1	0.0225	7.895	540.19	23.46
	2	0.0225	8.02	562.23	24.44
	3	0.0225	8.145	584.27	25.42
Compressive Strength Mean = 24.44					

Table C3 7th Day SCLWC (25% Scoria) Compressive Strength

Concrete Group	**Sample No.**	**Area (m^2)**	**Weight(kg)**	**Failure Load(KN)**	**Compressive Strength(KN/m^2**
SCLWC with 25% Scoria	1	0.0225	7.81	573.17	25.56
	2	0.0225	7.822	578.05	25.69
	3	0.0225	7.601	674.01	29.96
Compressive Strength Mean = 27.07					

Table C4 7th-day SCLWC (50% Scoria) compressive strength

Concrete Group	**Sample No.**	**Area (m^2)**	**Weight(kg)**	**Failure Load(KN)**	**Compressive Strength(KN/m^2**
SCLWC with 50% Scoria	1	0.0225	7.543	653.83	29.06
	2	0.0225	7.492	603.06	26.81
	3	0.0225	7.451	555.70	24.70
Compressive Strength Mean = 26.86					

Table C5 7th-day SCLWC (75% Scoria) compressive strength

Concrete Group	**Sample No.**	**Area (m^2)**	**Weight(kg)**	**Failure Load(KN)**	**Compressive Strength(KN/m^2**
SCLWC with 75% Scoria	1	0.0225	7.348	597.41	26.56
	2	0.0225	7.360	589.06	26.18
	3	0.0225	7.268	584.61	25.99
Compressive Strength Mean = 26.24					

Table C6 7th-day SCLWC (100% Scoria) compressive strength

Concrete Group	**Sample No.**	**Area (m^2)**	**Weight(kg)**	**Failure Load(KN)**	**Compressive Strength(KN/m^2**
SCLWC with 100% Scoria	1	0.0225	7.057	595.08	26.45
	2	0.0225	7.013	587.39	26.11
	3	0.0225	7.166	529.99	23.56
Compressive Strength Mean = 25.37					

Table C7 14th Day control concrete Compressive strength

Concrete Group	**Sample No.**	**Area (m^2)**	**Weight(kg)**	**Failure Load(KN)**	**Compressive Strength(KN/m^2**
Control group	1	0.0225	7.895	600.7	26.7
	2	0.0225	8.145	615.1	27.34
	3	0.0225	8.020	586.3	26.06
Compressive Strength Mean = 26.7					

Table C8 14th Day SCLWC (25% Scoria) Compressive Strength

Concrete Group	Sample No.	Area (m^2)	Weight(kg)	Failure Load(KN)	Compressive Strength(KN/m^2
SCLWC with 25% Scoria	1	0.0225	7.850	676.41	30.07
	2	0.0225	7.815	672.59	29.9
	3	0.0225	7.697	662	29.43
Compressive Strength Mean = 29.8					

Table C9 14th day SCLWC (50% Scoria) compressive strength

Concrete Group	Sample No.	Area (m^2)	Weight(kg)	Failure Load(KN)	Compressive Strength(KN/m^2
SCLWC with 50% Scoria	1	0.0225	7.516	664.58	29.55
	2	0.0225	7.480	647	28.96
	3	0.0225	7.530	566.84	28.8
Compressive Strength Mean = 29.1					

Table C10 14th day SCLWC (75% Scoria) compressive strength

Concrete Group	Sample No.	Area (m^2)	Weight(kg)	Failure Load(KN)	Compressive Strength(KN/m^2
SCLWC with 75% Scoria	1	0.0225	7.308	668.25	29.7
	2	0.0225	7.389	631.38	28.07
	3	0.0225	7.205	617.26	27.44
Compressive Strength Mean = 28.4					

Table C11 14th day SCLWC (100% Scoria) compressive strength

Concrete Group	Sample No.	Area (m^2)	Weight(kg)	Failure Load(KN)	Compressive Strength(KN/m^2
SCLWC with 100% Scoria	1	0.0225	7.014	623.41	27.71
	2	0.0225	7.118	585.59	26.03
	3	0.0225	7.022	646.53	28.75
Compressive Strength Mean = 27.5					

Table C12 28th Day control concrete Compressive strength

Concrete Group	**Sample No.**	**Area (m^2)**	**Weight(kg)**	**Failure Load(KN)**	**Compressive Strength(KN/m²**
Control group	1	0.0225	8.085	739.34	32.87
	2	0.0225	7.964	771.05	34.28
	3	0.0225	8.112	764.53	33.99
Compressive Strength Mean = 33.7					

Table C13 28th Day SCLWC (25% Scoria) Compressive Strength

Concrete Group	**Sample No.**	**Area (m^2)**	**Weight(kg)**	**Failure Load(KN)**	**Compressive Strength(KN/m²**
SCLWC with 25% Scoria	1	0.0225	7.775	869.89	38.66
	2	0.0225	7.655	843.61	37.5
	3	0.0225	7.759	789.73	35.1
Compressive Strength Mean = 37.16					

Table C14 28th day SCLWC (50% Scoria) compressive strength

Concrete Group	**Sample No.**	**Area (m^2)**	**Weight(kg)**	**Failure Load(KN)**	**Compressive Strength(KN/m²**
SCLWC with 50% Scoria	1	0.0225	7.543	807.03	35.88
	2	0.0225	7.489	794.66	35.33
	3	0.0225	7.566	772.16	34.33
Compressive Strength Mean = 35.18					

Table C15 28th day SCLWC (75% Scoria) compressive strength

Concrete Group	**Sample No.**	**Area (m^2)**	**Weight(kg)**	**Failure Load(KN)**	**Compressive Strength(KN/m²**
SCLWC with 75% Scoria	1	0.0225	7.343	721.93	32.1
	2	0.0225	7.305	746.67	33.2
	3	0.0225	7.249	823.14	36.6
Compressive Strength Mean = 33.3					

Table C16 28th day SCLWC (100% Scoria) compressive strength

Concrete Group	Sample No.	Area (m^2)	Weight(kg)	Failure Load(KN)	Compressive Strength(KN/m^2
SCLWC with 100% Scoria	1	0.0225	7.076	712.56	31.7
	2	0.0225	7.162	690.06	30.67
	3	0.0225	7.067	734.61	32.67
Compressive Strength Mean = 31.68					

SPLIT TENSILE STREHGTH

Table C17: 7th day SCLWC split tensile strength

Concrete Group%	Weight(kg)	Failure Load(KN)	Split tensile strength(KN/m^2)
0	3.633	62.94	2.01
25	3.509	95.92	3.06
50	3.416	94.7	3.00
75	3.447	87.36	2.72
100	3.311	77.97	2.46

Table C18: 14th day SCLWC split tensile strength

Concrete Group%	Weight(kg)	Failure Load(KN)	Split tensile strength(KN/m^2)
0	3.672	70.16	2.24
25	3.544	106.25	3.42
50	3.462	105.25	3.38
75	3.429	95.88	3.06
100	3.342	90.48	2.93

Concrete Group%	**Weight(kg)**	**Failure Load(KN)**	**Split tensile strength(KN/m^2)**
0	3.644	97.90	3.13
25	3.521	116.53	3.72
50	3.487	102.24	3.32
75	3.433	111.84	3.57
100	3.341	100.61	3.23

Table C1: 28^{th} day SCLWC split tensile strength

Appendix D

Chemical Composition

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

Issue Date: -15/12/2020

Customer Name:- Beyashi Toresa

Request No:- GLD/RQ/441/20

Report No:- GLD/RN/852/20

Sample type:- Scoria

Sample Preparation: - 200 Mesh

Date Submitted: - 07/12/2020

Number of Sample:- One (01)

Analytical Result: In percent (%) Element to be determined Major Oxides & Minor Oxides

Analytical Method: $LiBO_2$ FUSION, HF attack, GRAVIMETERIC, COLORIMETRIC and AAS

Collector's code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI
B-7534	54.40	13.92	11.88	4.36	9.12	<0.01	1.68	0.20	0.69	0.68	0.67	1.85

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

Analysts	Checked By	Approved By	Quality Control
Lidet Endeshaw	Fizita Zemene	Yohannes Getachew	Gosa Haile
Nigist Fikadu			

Appendix E

Photo Gallery


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