Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Construction Engineering and Management Stream

Comparative Study of River sand and Scoria as Fine Aggregate in Concrete Production

A thesis submitted to the School of Graduate Studies of Jimma University Institute of Technology, Faculty of Civil and Environmental Engineering in Partial fulfillment of the requirements for the Degree of Master of Science in Construction Engineering and Management

By:- Selamawit Admasu

May, 2017

Jimma, Ethiopia

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By

Selamawit Admasu

Main Adviser :- Eng. Elmer C. Agon

Co- Adviser :- Eng. Kabtamu Getachew

May, 2017

Jimma, Ethiopia

DECLARATION

I, the undersigned, declare that this thesis entitled "Comparative Study of River Sand and Scoria as Fine Aggregate in Concrete Production." is my original work, and has not been presented for any other person for an award of a degree in this university or any other universities, and all sources of material used for the thesis have been duly acknowledged. Therefore, whatever the result of my thesis final defense based on the criteria as evaluated by the examiners, will be accept in good faith.

Signed:

Selamawit Admasu ____________________ ________________

Signature Date

As Master research Advisors, we hereby certify that we have reviewed carefully the document and prepared under our guidance by Ms. Selamawit Admasu, her thesis entitled: "Comparative Study of River Sand and Scoria as Fine Aggregate in Concrete Production." Therefore, we recommend that this document would be submitted to fulfilling the MSc Thesis requirements in this University.

Eng. Elmer C. Agon ___________________ ___________________

(Main Advisor) Signature Date

Eng. Kabtamu Getachew __________________ ___________________

(Co-Advisor) Signature Date

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ABSTRACT

Because of the development of construction industry in Ethiopia, consumption of construction materials is increasing from time to time. Concrete is an important and most widely used material in the construction industry. One of ingredient material in the production of concrete which is solely used for, beside manufactured sand, a long period of time without any substitute materials is river sand. As a result, searching for alternative materials which can satisfy both the quality requirements and other aspects such as cost, accessibility, workability and environmental considerations is an important task for the engineering community. Volcanic light weight aggregates are available in Ethiopia, especially in Great Rift Valley. But the practice of using those materials in concrete production is very low due to the absence of confidence and concern on the final output of the material. Therefore the main objective of this research was to compare the properties of concrete by partially replacing river sand by scoria fine in concrete production.

The methodology followed under this research was passing through laboratory experimentation and cost comparison. The experimental laboratory procedure of the study includes; material selection, material preparation, material testing, preparing mix design, mixing, freshly and harden concrete test. There were six mix proportion of the two materials (i.e. 100%RS+0%SFA, 80%RS+20%SFA, 60%RS+40%SFA, 40%RS+60%SFA, 20%RS+80%SFA, 0%RS+100%SFA) at uniform W/C ratio of 0.62. The hard concrete test was done at the age of 7^{th} and 28^{th} days to determine the compressive strength as well as cost comparison for Hawassa town.

For the minimum compressive strength requirement of 25MPa, the 28^{th} day compressive strength test at the mix proportion of 20%RS+80%SFA failed the minimum strength requirement but up to mix proportion of 40%RS+60%SFA, scoria added concrete attain the minimum required strength. The slump test result showed when the percentage of SFA increases workability of concrete decreases this is due to the surface roughness, irregularity and absorption capacity. The cost comparison result also showed that, for $1m^3$concrete cast by SFA, 8.1% reduction in the total cost of concrete for the study area. Therefore this research can conclude that in areas where river sand is expensive and scoria deposit abundantly available, can be used for concrete production.

Key words*:-* Scoria fine aggregate, River sand, Workability, Compressive strength, Cost benefit.

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ACRONYM

ACI	American concrete institute
ASTM	American society for testing materials
EBCS	Ethiopian building code standard
FA	Fine aggregate
FM	Fineness modulus
LWA	lightweight aggregate
LWAC	Lightweight aggregate concrete
LWC	lightweight concrete
LWS	lightweight sand
LWSAC	lightweight sand added concrete
MPa	Mega Pascal
OPC	Ordinary Portland cement
RS	River sand
SA	Scoria aggregate
SAC	Scoria added concrete
SFA	Scoria fine aggregate
SNNPRS	Southern nation, nationality and people regional
SSD	Saturate surface dry
W/C	Water to cement ratio

CHAPTER ONE

INTRODUCTION

1.1 General

Construction industry for the development of a country has a vital role. Having accessible infrastructure, building, railways, power supplies facilitates economic transaction and development. Ethiopia, categorized as a developing country, now a day involves from mini to mega construction projects through local as well as international contractors. This leads to increasing consumption of construction materials.

In the world, about 90-95% of the construction material market for structural and non – structural application is made of concrete compared with other materials used for similar function (Salahaldain, 2015).

Concrete is a mixed product of cement, fine aggregate, coarse aggregate, water and admixtures, if needed, through hydration process. Due to its strength, durability and flexibility in fresh state, it is being used widely in construction sectors. According to (Taylor, 1977) Good concrete, whether plain, reinforced or pre-stressed, should be strong enough to carry super imposed loads during its anticipated life. Other essential properties include impermeability, durability, minimum amount of shrinkage, and cracking.

According to (Taylor, 1977)**,** factors contribute to the production of good quality concrete are Knowledge of the properties and fundamental characteristics of concrete making materials and the principles of design, Reliable estimates of site conditions and costs, Quality of component materials, A careful measurement of weight- batching of cement, water and aggregate, Proper transport, placement and compaction of the concrete, Early and through curing and Competent direction and supervision.

From the total volume of concrete the volume of fine aggregate and coarse aggregate takes the major part. Fine aggregate takes about 35% by volume of concrete used in construction industry and it can be classified as natural aggregates and artificial aggregates.

As per (Amnon and Hadassa, 2006), the global consumption of natural sand is very high, due to the extensive use of concrete or mortal. In general, the demand of natural sand is quite high in developing countries to satisfy the rapid infrastructure growth, in this situation developing country facing shortage in good quality natural sand.

As per (Hadson, 1997), extraction of natural sand from river beds causing many problems, loosing water retaining sand strata, deepening of the river course and causing bank slides, loosing of vegetation on the bank of rivers, exposing the intake wall of water supply schemes, disturbs the aquatic life as well as affecting agriculture due to lowering the underground water.

According to (Shewaferaw, 2006), due to various reasons good sand is not necessarily readily available and it should be transported from long distances. Transportation is a major factor in the delivered price of construction sand. Moving construction sand to the market increases the sale price of the market significantly, due to the high cost of transportation. The use of specific deposits of sand depends on the performance of these materials in standardized engineering testes. It is agreed that natural sand, which is available today, is deficient in many aspects to be used directly for concrete production.

According to (Shewaferaw, 2006), stated due to much fine particles than the recommended proportion, Contains an organic and soluble compound that affects the setting time and properties of cement as well as the presence of impurities such as clay, dust and silt coatings, increase water requirement and impair bond between cement paste and aggregate.

The rate with which construction industry is growing facilitates the consumption of RS. Even if the total amount of river sand resource is sufficient for the time being, quality of sand obtained is not similar throughout. Furthermore way of extraction leads to environmental problems. (Shewaferaw, 2006), indicates future drawback of RS digging like digging if the sand riverbed reduces the water head leads to less percolation of rainwater in ground resulting in lower ground water level, In the absence of sand, more water gets evaporated due to direct sunlight, If there is no sand in riverbeds, water will not be filtered.

1.2 Statement of Problem

In Ethiopia the construction industry mainly uses river sand and in places where river sand is not available nearby and uneconomical, manufactured sand is being used. The reason for limited application of light weight aggregates for structural concrete could be due to lack of confidence in using the material for structural purposes. In this regard, researchers should attempt to justify the use of lightweight aggregates for structural concrete and forward recommendation on construction undertakings (Abebe, 2005).

Scoria aggregate is widely available in most parts of the county and being used for a limited purpose. As per Negusse and Shiferaw investigated the use of scoria light weight aggregate as fine aggregate in our country, on their preliminary study, furnish insight into same of the observations made on the experimental investigation by taking scoria, sand and normal weight coarse aggregate, the data may not be used to all scoria concrete. They suggest farther experimental investigation on the subject.

Due to booming out of construction in the country, utilization of river sand increased. This leads to gradual increase in the cost of the material. Searching an alternative material which can satisfy both the quality and cost is needed. Therefore this research was conducted to check the potential capacity of scoria to use as a fine aggregate in concrete production together with cost comparison for the study area only.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of the research is to compare the properties of concrete by partially replacing fine aggregate with scoria fine in concrete production.

1.3.2 Specific Objective

- ❖ To assess and compare quality of SFA with RS.
- ❖ To compare workability and compressive strength of concrete made by scoria as fine aggregate to that of ordinary concrete.
- ❖ To compare the cost of concrete made of SFA and RS for Hawassa town.

- To determine the optimum mix proportion of the two materials to attain required minimum compressive strength.

1.4. Research Question

- What are the quality of SFA and RS?
- Is there any difference on workability and compressive strength of concrete made with scoria to that of concrete made of RS?
- Which one of them is more economical in concrete production?
- At what mix proportion SAC will attain the minimum required compressive strength?

1.5 Significance of the Study

Scoria is abundantly available material in a great rift valley of the country and mostly being used only for specific purpose in the construction. If there is adequately addressed document available on the scoria added concrete engineers can take as an alternative material for utilization of scoria in concrete construction sectors.

1.6 Scope and limitation of the Study

Aggregate in concrete comprise of both fine aggregate commenly known as sand and coarse aggregate refered to as gravel. Fine aggregates generally being used obtained from naturally and those which are manufactured. This thesis only covers the natural type of fine aggregates obtained from river bed and scoria deposit in Hawassa town. The study addressed the suitability of scoria as partial replacing material of RS in concrete production, without studying the mechanical and chemical properties of parent materials as well as by taking only samples from one quarry source for all the constituent materials. This research was geographically limited on Hawassa town and cost comparison was done only for the study area.

CHAPTER TWO
LITERATURE REVIEW

2.1 Background

Concrete is a mixture of Portland cement, water, and aggregates, with or without admixtures. Portland cement and water form a paste that hardens due to chemical reactions between the cement and water. The paste acts as a glue, binding the aggregates, composed of sand and gravel or crushed stone, into a solid rock-like mass. Aggregates, fine and coarse aggregate make up 60 to 75% of the total volume of concrete. (Nawy, 2008)

In concrete, the properties of these principal components, the binder and the aggregate are controlled by the requirement that:

1. When freshly mixed, the mass be placable or workable.
2. When the mass has hardened, it possesses strength and durability adequate to the purpose for which it is intended.
3. The cost of the final product is a minimum consistent with acceptable quality.

2.2 Constituents of Concrete

In order to produce good quality of concrete for a particular purpose, selection of constituent materials and combined them in such a manner as to develop the required strength is needed. The selection of materials and choice of method of construction is not easy, since many variables affect the quality of the concrete produced, and both quality and economy must be considered.

The characteristics of concrete should be evaluated in relation to the required quality for any given construction purpose. The closest practicable approach to perfection in every property of the concrete would result in poor economy under many conditions, and the most desirable structure is that in which the concrete has been designed with the correct emphasis on each of the various properties of the concrete, and not solely with a view to obtain of maximum possible strength. (Wilby, 1991).

2.2.1 Cement

Cement for concrete production is essential constitutes material. Without it, the so called concrete may not have value as now. The binding nature of the paste mainly came from the properties of cement.

As per Kosmatka, et al., cement is a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used as a component in the production of mortal in masonry, and of concrete, which is a combination of cement and an aggregate to form a strong building material (Kosmatka, etal., 2003).

There are different types of cement produced by varying chemical composition and physical composition. According to (Frederick etal., 2000) Portland cement is made by carefully blending of selected raw material to produce a finished material meet the requirements of ASTM C 150 for one of eight specific cement types depends on constituents of the four major compounds [lime (CaO), iron ($Fe_2\ O_3$), silica (SiO_2), and alumina (Al_2O_3)] and two minor compounds gypsum [($CaSO_4 . 2H_2O$) and magnesia (MgO)]

In all the Portland cements, there are four major compounds. The variation in percentage composition of compounds influences the properties of cement.

2.2.2 Aggregates

Natural aggregates are formed by the process of weathering and abrasion, or by artificially crushing a larger parent mass. Thus, many properties of the aggregate depend on the properties of the parent rock, e.g. chemical and mineral composition, petrographic classification, specific gravity, hardness, strength, physical and chemical stability, pore structure, color, etc. In addition, there are other properties of the aggregate which are absent in the parent rock: particle size and shape, surface texture and absorption. All these properties may have a considerable influence on the quality of fresh or hardened concrete (Navi and Brooks, 2010)

Aggregates are granular materials, most commonly natural gravels and sands or crushed stone, although occasionally synthetic materials such as slags or expanded clays are used. They are much stronger than the cement paste and less expensive than Portland cement, leads to the production of more economical concrete. They are also assumed to be completely inert in a cement matrix (Nawy, 2008)

Despite the various ways of classifications, three important criteria should be applied in the selection of aggregates. First, the material selected as aggregate should facilitate the workability of fresh concrete. This is because the size and gradation of the aggregate has impact on the workability of fresh concrete. Second, the strength and durability of aggregates should be taken into account during the selection process. In other words, aggregates should not contain impurities and it should resist weathering process. Lastly, the selection of aggregates should be economical. When aggregates are selected from local and easily accessible quarry, the cost is substantially reduced. It has to be, however, well graded in order to minimize paste. Aggregates provide relatively cheap filler and it is advisable to use as much aggregates as possible in a given amount of paste will bind together. This enhance to cut down unnecessary costs incurred for cement. In addition to begin relative cheap fillers, the aggregates reduce the chance in volume resulting from the setting and hardening process and from moisture change in past (Mikyas, 1987).

There are two main reasons for increasing the amount of aggregates in concrete. The first is that cement is more expensive than aggregate, so using more aggregate reduces the cost of producing concrete. The second is that most of the durability problems, e.g. shrinkage and freezing and thawing, of hardened concrete are caused by cement. Generally, concrete shrinkage increases with increase in cement content; aggregates, on the other hand, reduce shrinkage and provide more volume stability. In choosing aggregate for use in a particular concrete, attention should be given among other things to three important requirements (Denamo, 2005)

1) **Workability:** for fresh concrete mix the size and gradation of the aggregate reduced such that unnecessary labor in mixing and placing.

2) **Strength and durability** when hardened for which the aggregate should be:

I. Be stronger than the required concrete strength.

II. Contain no impurities which adversely affect strength and durability.

III. Not go in to undesirable reaction with the cement.

IV. Be resistant to weathering action.

3) **Economy of the mixture** –meaning to say that the aggregate should be:

I. Available from local and easily accessible deposit or quarry

II. Well graded in order to minimize paste hence cement requirement

Aggregates have three basic functions (Denamo, 2005).

1. To provide a relatively cheap filler for the cementing material;
2. To provide a mass of particles that are suitable for resisting the action of applied loads, abrasion, the percolation of moisture, and the action of weather; and
3. To reduce the volume changes resulting from the setting and hardening process and from moisture changes in the cement-water paste.

Properties of aggregate affect the durability and performance of concrete, so FA is an essential component of concrete and cement mortal the most commonly used FA is natural river or pit sand. Fine and coarse aggregate constitute about 75% of total volume. It is therefore, important to obtain right time and good quality aggregate at site, because the aggregate forms the main matrix of concrete or mortal (Hudson 1997).

Aggregates are generally divided into two size ranges: CA, which is the fraction material retained on No.4. (4.75-mm) sieve and FA, which is the fraction passed No.4 sieve but retained on a No.100. (0.15-mm) sieve.

2.2.2.1. Coarse Aggregate

The physical properties of coarse aggregates such as size, shape, texture, gradation, porosity, absorption, moisture content, etc. affects concrete quality.

Aggregate Size

For the production of normal strength of concrete, size of coarse aggregates are not greatly affecting factor. The larger the maximum size of the CA, the lower the water demand since surface area of particles to be wet reduced. For a given W/C ratio, the amount of cement required decreases as the maximum size of coarse aggregate increases.

Extending the grading of aggregate to a larger maximum size lowers the water requirement of the mix, so that for specific workability and cement content, the lower water/cement ration can be lowered with a consequent increase in strength. Experimental results indicated that above the 38.1mm maximum size the gain in strength due to the reduced water requirement is offset by the detrimental effect of lower bond area (so that volume changes in the paste cause larger stresses at interfaces) and of discontinuities introduced by the very large particles (Neville, 1986)**.**

ASTM grading requirements are based on nominal maximum size (Sidney, et al., 2003).The largest maximum size of aggregate practicable to handle under a given set of conditions should be used. Using the largest possible maximum size will result in:

a) Reduction of cement content

b) Reduction in water requirement

c) Reduction of drying shrinkage (Ngugi, et al., 2014).

Since variations are difficult to expect, it is often more economical to maintain uniformity in manufacturing and handling coarse aggregate than to reduce variations in gradation. The maximum size of coarse aggregate used in concrete has a bearing on the economy of concrete. Usually more water and cement is required for small-size aggregates than for large sizes, due to an increase in total aggregate surface area (Kosmatka, et al., 2003).

Aggregate Shape and Texture

Roundness measures the relative sharpness or angularity of the edges and corners of a particle. Roundness is controlled largely by the strength and abrasion resistance of the parent rock and by the amount of wear to which the particle has been subjected. In the case of crushed aggregate, the particle shape depends not only on the parent rock but also on the type of crusher and its reduction ratio. i.e the ratio of the size of material fed into the crusher to the size of the finished product. Particles with a high ratio of surface area to volume are also of particular interest for a given workability of the control mix (Shewaferaw, 2006).

Surface texture of the aggregate affects its bond to the cement paste and also influences the water demand of the mix, especially in the case of fine aggregate. The shape and surface texture of aggregate influence considerably the strength of concrete. The effects of shape and texture are particularly significant in the case of high strength concrete (Shewaferaw, 2006).

Moisture content and Absorption

To calculate the mixing water content of concrete, the absorption of the aggregates and their total moisture content must be known. Absorption represents the total water content that is filled in the particle void, in aggregate at the saturated surface dry condition, and moisture content is amount of water in aggregates either can be in a saturated surface dry, surface moisture (or free moisture), or air dry state.

The total water content of a damp or moist aggregate is equal to the sum of absorption and surface moisture content. It should be noted that if the aggregate are dry they absorb water from the mixing water and there by affect the workability and, on the other hand, if the aggregates contain surface moisture they contribute extra water to the mix and thereby increase the W/C ratio. Both these conditions are harmful for the quality of concrete. In making quality concrete, it is very essential that corrective measures should be taken both for absorption and free moisture so that the W/C ratio is kept as exactly as per the mix design (Denamo, 2005)

Porosity

Due to the presence of air bubbles, which are entrapped in a rock during its formation or on account of the decomposition of certain constituent minerals by atmospheric action, minute holes or cavities are formed in it that is commonly known as pores (Gambhir, 2002)

As mentioned at the beginning of this chapter, since aggregates constitutes about 60-75% by volume of concrete. The porosity and absorption affect the bond between aggregate and the cement paste and specific gravity of the aggregate.

2.2.2.2 Fine Aggregate

Fine aggregates, is unconsolidated and highly variable mixtures of different constituents. The construction industry utilizes sand mainly from streambeds, which are commonly derived from quartz-Feld spathic basement rocks, sandy marine sediments and alluvial deposits (Mengistu and

Fentaw, 2003). Almost in all parts of Ethiopia FA for the construction industry are being supplied from natural sources.

The sand from river due to natural process of attrition tends to process smother surface texture and better shape. It also carries moisture that is trapped in between the particles. These characters make concrete workability better. However, silt and clay carreied by RS can be harmful to the concrete. Another issue associated with RS is that of obtaining required grading with a fineness modulus of 2.4 to 3.1. It has been varified and found at various locations it has became increasingly difficult to get RS of consistant quality in terms of grading requrements and limited silt/clay content. It is because we do not have any control over the natural process (Elavenil and Vijaya, 2013).

According to (Abebe, 2005) study on the need for standardization of aggregate for concrete production in Ethiopian construction industry, the method of quarrying sand is generally very old and the producers do not attempt to clean and grade the sand right from the source. From Awash basin sand with silt content as high as 20% is usually purchased from those quarry sites. Typical method of sand quarrying operations and transporting to the nearby loading station using animal transport are shown in figure. Way of extraction and transportation of the RS is in a traditional way without an attempt to attain the required quality. He indicates it is impossible to guarantee similar quality of FA materials all time with the same source leads to difficulty in producing the same quality of concrete using the same prescribed mix proportion. Contractors are thus confronted with frequent additional cost of testing for new materials and extra time will thus be required to complete projects, which eventually add to increase cost of the project.

A) Quality Requirement of Fine Aggregate

The quality of fine aggregate used in concrete has a bearing effect on the quality of the final output. Therefore, standards have been set in order to help obtain the desired concrete quality. Some of the requirements are discussed below:

Silt Content

Sand which is a product of natural or artificial disintegration of rocks and minerals is obtained from glacial, river, lake, marine, residual and wind-blown deposits. These deposits however do not only provide sand but also contain other materials such as dust, loam and clay that are finer than sand. The presence of such materials in sand used to make concrete or mortar decreases the bond between the materials to be bound together and hence the strength of the mixture. The finer particles do not only decrease the strength but also the quality of the mixture produced resulting in fast deterioration. Therefore it is necessary that one make a test on the silt content and checks against permissible limits.

A simple test which can be made on site to give a guide to the amount of silt in natural sand is field settling test. This test is based on the fact that large heavy particle will settle rapidly in water while small light particle will settle most slowly. This test is only fit for normal sand and should not be used for crushed rock sands.

The British and American standards (BS 882, ASTM C-33) limit the clay and silt content not to be more than 3% of the total weight of the fine aggregate. Unlike these standard limits the Ethiopian standard gives more allowance by about 3% more. According to the Ethiopian standard it is recommended to wash the sand or reject it if the silt content exceeds a value of 6 % (Abebe D, 2002)

Sieve Analysis

The process of dividing a sample of aggregate into fraction of same particle size is known as sieve analysis, and its purpose is to determine the grading or size distribution of the aggregate. A sample of air-dried aggregate is graded by shaking or vibrating a nest of stacked sieves, with the largest sieves at the top, for a specified time so that the material retained on each sieve represents the fraction coarser than the sieve in question but finer than the sieve above (Neville, 1999).

The most desirable fine aggregate grading depends on the type of work, the richness of the mixture, and the maximum size of coarse aggregate. In leaner mixes or when small-size coarse aggregate are used, a grading that approaches the maximum recommended percentage passing each sieve is desirable for workability. In general, if the water-cement ratio is kept constant and the ratio of fine-to-coarse aggregate is chosen correctly, a wide range in grading can be used without measurable effect on strength. However, the best economy will sometimes be achieved by adjusting the concrete mixture to suit the gradation of the local aggregates (PCA manual)

Table 1 shows the grading requirement of BS and ASTM for fine aggregate. BS 882 divides the grading in to four zones, zone 1 is coarser and zone 4 is finer. Grading zone 2 and 3 is moderate grading zones and approach to ASTM standard.

Table 1: BS and ASTM grading requirement for fine aggregate (Neville, 1999)

Standard sieve size		Percentage by weight passing sieve				
		BS 882: 1992				ASTM Standard C 33- 78
BS	ASTM	Grading zone 1	Grading zone 3	Grading zone 3	Grading zone 4	
9.5mm	3/4in	100	100	100	100	100
4.75mm	3/16in	90-100	90-100	90-100	95-100	95-100
2.36mm	8	60-95	75-100	85-100	95-100	80-100
1.18mm	16	30-70	55-90	75-100	90-100	50-85
600 μm	30	15-34	35-59	60-79	80-100	25-60
300 μm	50	5-20	8-30	12-40	15-50	10-30
150 μm	100	0-10	0-10	0-10	0-15	2-10

Fineness Modulus

It is used as an index to the fineness or coarseness and uniformity of aggregate supplied, but it is not an indication of grading since there could be an infinite number of grading which will produce a given fineness modulus. The following limits may be taken as guidance (Denamo, 2005)

Table 2: limitation of fineness modulus as guideline for different sand category

Category of sand	Fineness Modulus
Fine sand	2.2-2.6
Medium sand	2.6-2.9
Coarse sand	2.9-3.2

Sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete (Denamo, 2005). However it is clear that one parameter, the average, cannot be representative of a distribution. Thus the same fineness modulus can represent an infinite number of totally different size distribution or grading curves. Therefore, the fineness modulus cannot be used as a description of a grading of an aggregate but it is valuable for measuring slight variations in the aggregate from the same sources that is a day to day check (Neville, 1999).

2.2.3 Water

Water is a key ingredient in the manufacture of concrete. Water used in concrete mixes has two functions: the first is to react chemical with the cement, which will finally set and harden, and the second is to lubricate all other materials and make the concrete workable (Taylor, 1977) Although it is an important ingredient of concrete, it has little to do with the quality of concrete (Sidney, etal., 2003)**.** One of the most common cause of poor quality concrete is the use of too much mixing water. Fundamentally "the strength of concrete is governed by the nature of the weight of water to the weight of cement in a mix, provided that it is plastic and workable, fully compacted, and adequately cured" (Taylor, 1977). It has been said that there is much more bad concrete made through using too much good quality water than there is using the right amount of poor quality water. The rule of thumb for water quality is "if you can drink it, you can work concrete with it." A large fraction of concrete is made using municipal water supplies. However, good quality concrete can be made with water that would not pass normal standards for drinking water (Sidney, etal., 2003)**.**

2.3. Light Weight Aggregate

2.3.1 General

Light weight aggregates distinction can be made between aggregates occurring in nature and those manufactured. The main natural lightweight aggregates are diatomite, pumice, scoria, volcanic cinders and tuff; except for diatomite, all of these are of volcanic origin.

Volcanic aggregates of basalt, Scoria, pumice and tuff were used in concrete by Roman engineering and designers. Their awareness of the differences between heavy basaltic aggregates and extremely light pumice and tuff made possible the construction of structures which were quite sophisticated. A famous example of this expertise is a dome shape structure, pantheon, in Rome. Heavy basalt was used in foundations and lower walls. In upper walls, builders mixed brick and tuff into the concrete, and towards the center of the vault they used the lightest of pumice (Richard, 1985)

The entry of the United State into world War I in 1917 and shortage of high-grade plate steel for building ships led to one of its first uses. Small ships, barges and a tanker had already been designed and built using conventional concrete, but marine engineers thought that lightweight concrete might work even better (Richard, 1985)

Now a day, for architects, engineers and contractors true structural lightweight aggregate concrete has a broad range of applications: frames and floors for tall buildings; thin shell structures including hyperbolic paraboloid roofs; long span bridges, roofs and decks; and usual sculptural design. Economics in reinforcing steel and foundations that came from overall weight reductions are some of the more compelling reasons for using this type of concrete (Richard, 1985)

2.3.2 Lightweight Aggregate Properties

Particle Shape and Surface Texture

Shape may be cubical and reasonably regular, essentially rounded, or angular and irregular. Surface textures may range from relatively smooth with small exposed pores to irregular with small to large exposed pores. Particle shape and surface texture of both fine and coarse aggregates influence proportioning of mixtures in such factors as workability, pumpability, fine to coarse aggregate ration, binder content and water requirement. These effects are analogous to those obtained with normal weight aggregates with such diverse particle shapes as exhibited by rounded gravel, crushed limestone or manufactured sand (ACI 213R-03).

Bulk Density

The bulk density of lightweight aggregate is significantly lower. For the same grading and particle shape, the bulk density of an aggregate is essentially proportional to particle relative densities. Aggregates of the same particle density, however, may have markedly different bulk densities because of different percentages of voids in the dry loose or dry rodded volumes of aggregates of different particle shapes. Rounded and angular lightweight aggregates of the same particle density may differ by 5lb/ft^3 (80Kg/m^3) or more in the dry loose condition. The situation is analogous to that of rounded gravel and crushed stone, where differences may be as much as 160kg/m^3, for the same particle density and grading, in the dry rodded condition. Table 3 Bulk density requirements of ASTMC330 and C331 for dry, loose, light weight aggregate **(**ASTM, 1999).

Table 3: The maximum density for the LWA listed in ASTM C 330 and C331

Aggregate size and group	**Maximum density (Kg/m^3)**
Fine aggregate	1120
Coarse aggregate	880
Combined coarse and fine aggregate	1040

Strength of Lightweight Aggregates

The strength of aggregate particles varies with type and source and is measurable only in a qualitative way. Same particles may be strong and hard and others weak and friable. For compressive strengths up to approximately 5000psi (35Mpa), there is no reliable correction between aggregate strength and concrete strength (ACI 213R-03).

Absorption

Lightweight aggregates, due to their cellular structure, are capable of absorbing more water than normal weight aggregates. Based on a saturated ASTM C 127 absorption test expressed at 24h, lightweight aggregate generally absorb from 5 to 25% by mass of dry aggregate, depending on the aggregate pore system. In contrast, normal weight aggregates can absorb up to 10% of moisture (ACI 213R-03).

2.3.3. Scoria Aggregate

Geology.com defines scoria is a dark – colored igneous rock with abundant round bubble- like cavities known as vesicles. It ranges in color from black or dark gray to deep reddish brown. Scoria usually has a composition similar to basalt. The black color is mostly due to its high iron content while the red color is caused by oxidation of iron in the scoria.

Fig 1: Pictures of scoria (From geology.com)

Earlier light weight aggregate were of natural origin, mostly volcanic: pumice, scoria, tuff, etc. these have been used both as fine and coarse aggregates. They function as active pozzolanic materials when used as fine aggregates. These interact with the calcium hydroxide generated from the binder during hydration and calcium silicate which strengthens the structure and modifies the pore structure, enhancing the durability properties (Satish and Lief, 2002).

(Negusse and Tadesse, 1984) indicate scoria deposit in Ethiopia, especially in the Great Rift Valley which cross the north-eastern part of the country. The use of scoria so far has been limited to highway construction as a base course, as mortal aggregate in masonry construction and for the production of hallow concrete block.

2.4 Light Weight Aggregate Added Concrete

Properties of the lightweight aggregates such as particle shape and surface texture, specific gravity, unit weight, particle size, strength, moister content and absorption all affects properties of fresh and hardened lightweight concrete. (Saryas Qadir Sabir)

As per (Zhutovsky et al., 2002), the main benefit of water- saturated material is its capacity in providing a well- dispersed source of water within the concrete mass near cement particles. Partial replacement of normal weight sand with saturated LWS can provide a reduction in concrete settlement and plastic shrinkage. If not adequately pre wetted, the unsaturated pores lead to greater water demand during construction and result in inadequate water for hydration. Because of the absorption and desorption properties of the aggregate.

The compressive strength of lightweight aggregate concrete is usually related to the cement content at a given slump, rather than to the W/C ratio. In some cases, compressive strength can be increased by replacing part of the fine lightweight aggregate with good quality natural sand. (Saryas Qadir Sabir)

The compressive strength of LWA is usually related to cement content at a given slump rather than W/C ratio. Water reduction or plasticizing admixtures are frequently used with lightweight concrete mixture to increase workability and facilitates placing and finishing. In most cases, compressive strength can be increased with the replacement of light weight fine aggregate with a good quality of normal weight sand. (Fahrizal et al., 2008)

Geology.com indicates concrete made with scoria typically weighs about 100 pounds per cubic foot. This is a weight saving compared to concrete made with typical sand and gravel that weighs about 150 pounds per cubic foot. This saving in weight allows building to be constructed with less structural steel. The air trapped in the scoria makes the LWC a better insulator. Buildings constructed with this lightweight concrete can have lower heating and cooling costs.

As per (Aho and Uungwa, 2015) test on Engineering property of scoria concrete as a construction material. The output indicates 20.42N/mm^2 and average density of 1920kg/m^3 scoria concrete at 28 day compared to conventional concrete with 23.85N/mm^2 and 2602kg/mm^3 average density. As there conclusion scoria concrete is suitable to use as a construction material and recommend farther study on use of more ration, altering of workability parameters, introduction of workability and tests on shrinkage properties.

As per (Ozvana, et al., 2012) investigation on Compressive strength of scoria added Portland cement concretes, the compressive strength of the concrete mixtures with scoria added up to 30% exceeded the strength of the conventional mixture at 3,7,28 and 91 days, whereas the compressive strength of the 40 and 50% scoria added concrete mixture decreased at 3,7,28 and 91 days.

Blended cement and LWC using scoria: mix design, strength, durability and heat insulation characteristics studied by (Khandaker, 2006). The research use SA as a CA and Sand, SA and Sand respectively as FA for the mix proportion. The output indicates the use SA as FA in place of RS reduces the compressive strength from 32MPa to 24MPa.

(Lau, et al., 2014) studied on Properties of concrete using LWA concrete. The investigation proves a potential use of ungraded scoria as an aggregate to produce concrete by replacing normal 15% of Portland cement with fly ash, the compressive strength of LWSAC has improved by almost 35% compared to LWSAC with Portland cement only. Beside the result demonstrates that light weight scoria concrete has a much lower workability compared to a normal mix.

As per (Negusse and Shiferaw, 1984) investigation on scoria sand replacement in structural concrete, there was about five different trial mixes by varying percentage of scoria and silica sand. The mix proportioning was done ratio by weight without determining the properties of material like unit weight, moisture content. Based on their result there is a variation in compressive strength as the ration of the scoria to sand content is changed.

Concrete made with 20% LWS replacement had slightly higher or similar in situ compressive strength at 28, 56, and 91 days than similar concrete prepared without any LWS (Dalia, 2013).

Compressive strength values at various ages for mixtures made either without LWS are presented in Fig 2.3. for a given moist-curing period, mixtures made with 30%LWS replacement had slightly higher compressive strength than similar concrete prepared without any LWS. In particular, the 30-0, 0.40-6M mixture made with 30%LWS and 6 days of moist-curing exhibited higher compressive strength of 56Mpa at 91 days compared to values of 44 to 51Mpa for the other mixture made with 0.4w/c. it is interesting to note that strength increase of concrete containing 30%LWS increasing with time (Dalia, 2013).

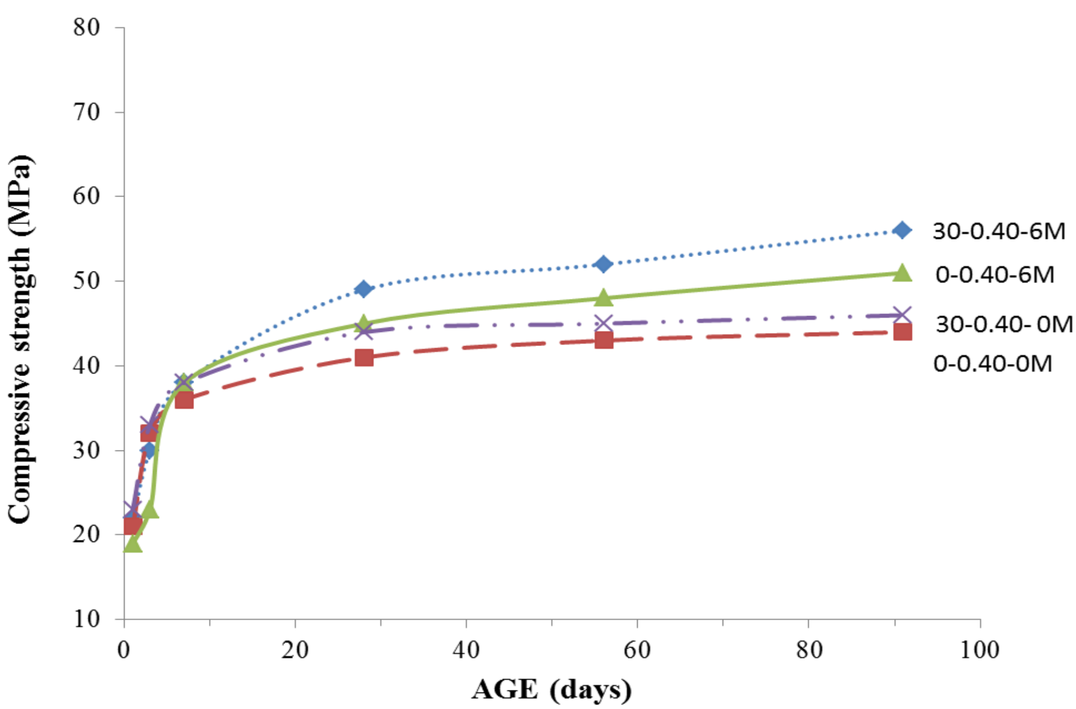

Fig 2: Effect of LWS replacement on compressive strength (Dalia, 2013)

The various types of lightweight aggregates available will not always produce similar compressive strength for concrete of given cement content and slump. Compressive strength of structural concrete is specified according to design requirements of a structure. Normally, strengths specified will range from 3000 to 5000psi (21 to 35MPa) and less frequently up to 7000psi (48MPa) or higher. Some lightweight aggregates are capable of producing very high strength concrete (ACI 213R-03).

2.4.1 Advantages and Disadvantages

There are defined technical and economical advantages and disadvantages in using LWAC same of the main advantages and disadvantages reported in the literature are summarized below.

Advantages

- For self curing concrete, by using saturated lightweight aggregates in order to supply an internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration (Sanjay, 2014).
- Reduction in the rate of shrinkage or a reduction in the overall shrinkage due to continued hydration (Henkensiefken et al. 2008).
- It have good thermal insulation and fire resistance characteristics (Khandaker, 2006).
- Reduce dead load of structures which gives economical for reinforcement steel and size of concrete structures.
- Due to reduced load, reduce transportation cost, for precast structures.

Disadvantages

- Reduce workability in Fresh state of concrete.
- Facilitate rate of shrinkage, if LWA is not at SSD or Pre wet state, by absorbing mixing water.

As per (Navil and Brook, 2010), compared some properties of lightweight aggregate concrete with normal weight concrete as followes.

a. For the same strength, the modulus of elasticity is lower by 25 to 50 percent; hence, deflection are greater.

b. Resistance to freezing and thawing is greater because of the greater porosity of the lightweight aggregate, provided the aggregate is not saturated before mixing.
c. Fire resistance is greater because lightweight aggregate have a lesser tendency to spall; the concrete also suffers a lower loss of stere with a rise in tempreture.
d. Lightweight concrete is easier to cut or to have fitments attached.
e. For the same compresive strength, the shear strength is lower by 15 to 25 percent and the bond strength is lower by 20 to 50 percent. These difference have to be taken into account in the design of reinforced concrete beams.
f. The tensile strain capacity is about 50 percent greater than in normal weight concrete. Hence the ability to withstand restraint to movement, e.g. due to internal temprature gradiations, is greater for lightweight concrete.
g. For the same strength, creep of lightweight aggregate concrete is about the same as that of normal weight concrete.
h. The water in the aggregate may be released for internal curing.

2.5. Normal Strength Concrete

The compressive strength of concrete is one of the most important and useful properties of concrete. The primary purpose for design concrete is to resist compressive strength in structural members, in general is the characteristic material value for classification of concrete.

Strength of concrete is the commonly considered its most valuable property, although in many practical cases other characteristic ,such as durability and impermeability , may in fact be more. However, strength usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hardened cement paste (Neville, 1999).

Concrete is often discussed as being of normal strength concrete or high strength. Normal strength concrete typically has a compressive strength of between 20 to 40MPa. Normal strength concrete is used in most construction applications and usually has good workability as long as concrete ingredients are used in proper proportions and an adequate aggregate gradation is used (Nawy, 2008).

The importance of using the right quality of aggregate cannot be overemphasized. The fine and coarse aggregate generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy. The most commonly used aggregates (sand, gravel, crushed stone, and air- cooled blast- furnace slag) produce freshly mixed normal weight concrete with a density (unit weight) of 2200 to 2400kg/m^3. Other lightweight materials such as pumice, scoria, perlite, vermiculite and dolomite are used to produce insulating light weight concrete ranging in density from about 250 to 1450kg/m^3.The apparent bulk density of aggregate commonly used in normal-weight concrete ranges from about 1200 to 1750Kg/m^3. The void content between particles affects paste requirements in mix design. Most natural aggregates have relative densities between 2.4 and 2.9 with corresponding particle densities of 2400 and 2900kg/m^3 (Design and Control of Concrete Mixtures)

2.5.1 Workability of Concrete

As per defined Neville & Brooks (2010), Workability of concrete is the amount of useful internal work necessary to produce full compaction. The useful internal work is a physical property of concrete alone and is the work or energy required to overcome the internal friction between the individual particles in the concrete.

Slump Test

The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. The inexpensive test, which measures consistency, is used on job sites to determine rapidly whether a concrete batch should be accepted or rejected. The test method is widely standardized throughout the world, including in ASTM C143 in the United States.

The apparatus consists of a mold in the shape of a frustum of a cone with a base diameter of 200±1mm, a top diameter of 100±1mm, and a height of 300±1mm. The mold is filled with concrete in three layers of equal volume. Each layer is compacted with 25 strokes of a tamping rod. The slump cone mold is lifted vertically upward and the change in height of the concrete is measured (Neville & Brooks, 2010).

Four types of slumps are commonly encountered, as shown in Table 4. The only type of slump permissible under ASTM C143 is frequently referred to as the "true" slump, where the concrete remains intact and retains a symmetric shape. A zero slump and a collapsed slump are both outside the range of workability that can be measured with the slump test. Specifically, ASTM C143 advises carefully in interpreting test results less than 12.5mm and greater than 225mm. If part of the concrete shears from the mass, the test must be repeated with a different sample of concrete. A concrete that exhibits a shear slump in a second test is not sufficiently cohesive and should be rejected (Wilby, 1991).

Table 4: Degree of Workability and Slump (Source: Neville and Brooks, 2010)

Degree of Workability	Slump	Application
Very low	0-25	Vibrated concrete in roads or other large sections.
Low	25-50	Mass concrete foundations without vibration. Simple reinforced section with vibration
Medium	50-100	Normal reinforced work without vibration and heavily reinforced sections with vibration
High	100-180	Sections with congested reinforcement. Not normally suitable for vibration

2.6. Overview of Material Cost

In the construction technology, resource planning and management is one of the most important parameter for competitiveness and profitability. The management of construction materials is the task of resource management and it is also important element in project planning and controlling. The cost of materials in construction projects accounts for more than 40% of the project cost. Therefore, a small saving in material cost has a significant role in the industry. A research conducted in Ethiopia had shown that 57% of the total budget allocation for construction is material cost (Denamo A, 2005)

As per (Arora & Bindra, 2000), building materials account for 50-80% of the total value of construction cost. Thus, it is very important to ensure that construction materials are available at affordable price. In most developing countries, however, the costs of construction materials are very high, and their availability is scarce.

Despite the various ways of classification, three important criteria should be applied in the selection of aggregates. First, the material selected as aggregate should facilitate the workability of fresh concrete. This is because the size and gradation of the aggregate has impact on the workability of fresh concrete. Second, the strength and durability of aggregates should be taken into account during the selection process. Lastly the selection of aggregate should be economical. When aggregates are selected from local and easily accessible quarry, the cost is substantially reduced. It has to be, however, well graded in order to minimize paste. Aggregates relatively provide cheap filler and it is advisable to use as much aggregates as possible in a given amount of paste will bind together. This enable to cut down unnecessary cost incurred for cement (Mikyas, 1987).

Construction aggregate prices are expected to increase in the future due to the rising cost of fuel used in the production and transportation processes. The rise in fuel cost is expected to affect the delivery prices of construction sand and gravel. These price increases are expected to be more noticeable in and near cities because as nearby resources are used up, more aggregates will have to be transported from distant resources (Shewaferaw, 2006).

From those literature reviews, scoria can be used as a construction material especially with cementing material. The work of Negusse T. and Shiferaw T. set a pin point on scoria to use as a FA in our country without studying the properties of materials for the mix, depending on their research compressive strength decreases in increasing percentage of scoria sample taken from Kality about 15km from Addis Ababa. But under their research W/C ratio increases when percentage of scoria increases.

In this research the aim is to identify gaps regarding site location, quality check of scoria fine for the mix design, percentage proportion of the two materials, mix proportion, compressive strength at uniform W/C ratio as well as cost comparison for the study area.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Study Area

The study area of this research was in Hawassa town. It is the capital city of SNNPRS region and located about 273 km south of Addis Ababa. The geographical extent of the city is 435202E-450980E and 763811N- 784344N. The quarry site found at an altitude of 1735m above sea level. Available construction materials for the research were taken around the town. The experimental investigation was carried out in construction material laboratory of Hawassa University. The map of Hawassa town is shown in fig. below.

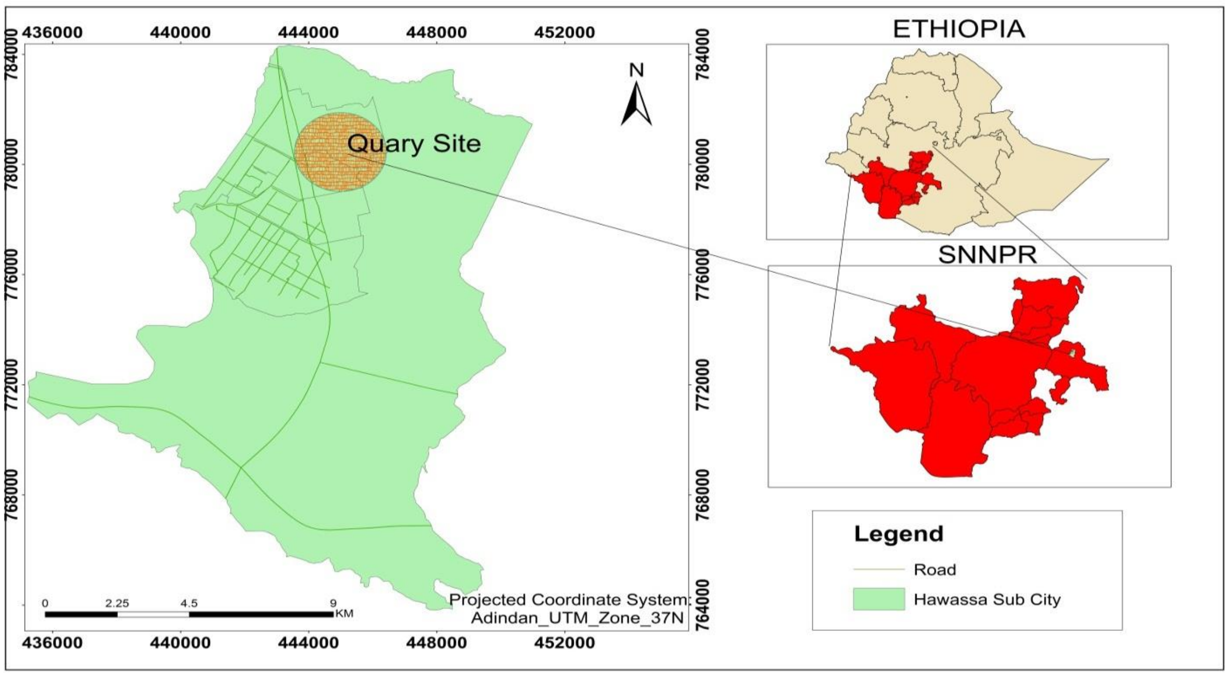

Fig 3: Geographical map of Hawassa Town

3.2 Research Design

The research design used in this research was comparative based on the laboratory out puts and cost comparison. It compared cost benefit of normal concrete and SAC for one meter cube concrete production. Research design for experimental laboratory work was shown below in figure.

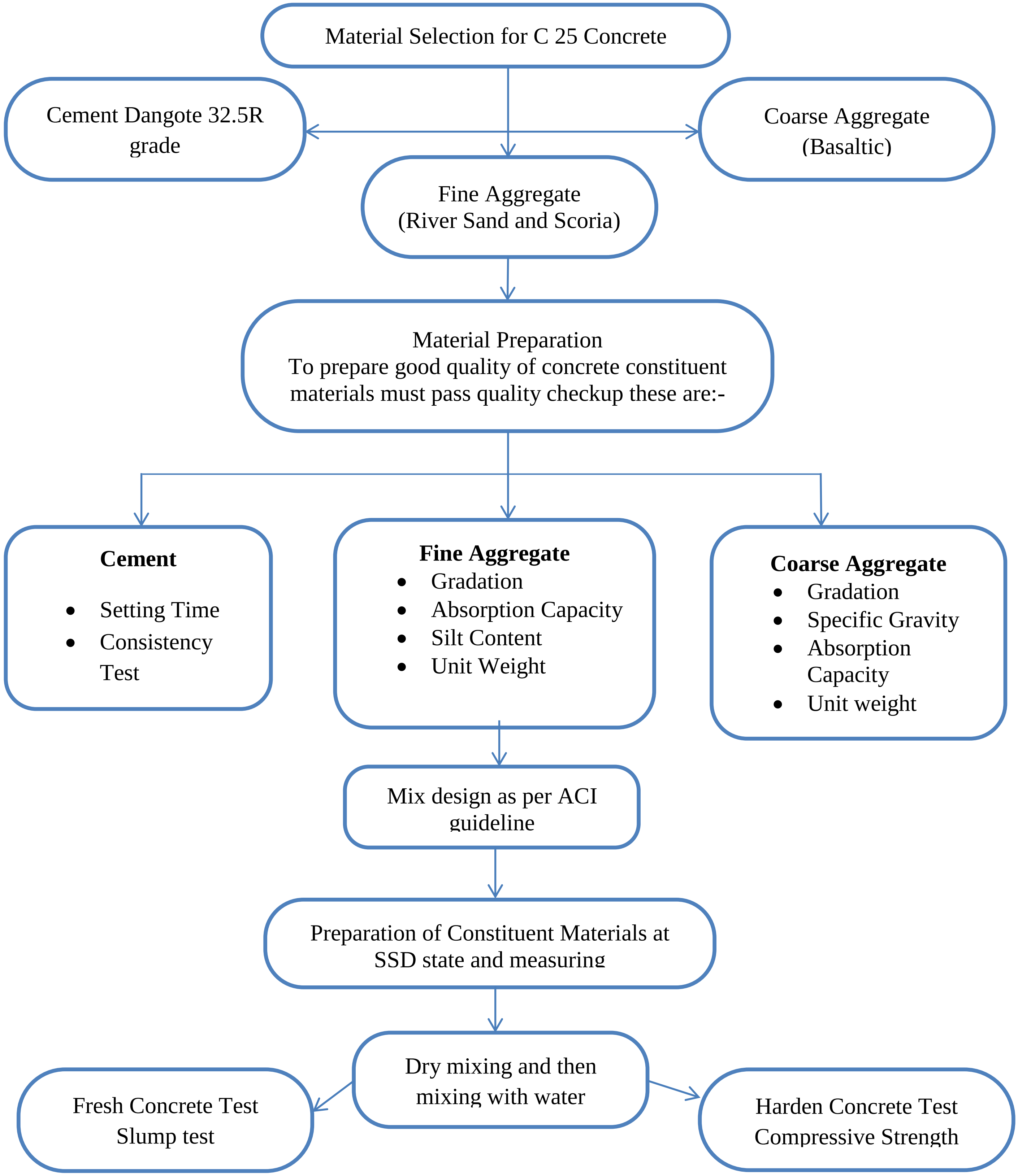

Fig 4: Research design for laboratory work

3.3 Population of the Research

The research targeted populations were concretes produced by Antate river sand and scoria aggregate, obtained from quarry deposited with in Hawassa town.

3.4 Sampling Techniques

In the laboratory, quartering method of samples by using sample splitter box was used. A total of 36 cube cast with $15x15x15cm^3$ dimensions was taken. Each mix had six cube casts to test compressive strength at 7 and 28 days. The results of the samples were taken the mean of three similar mix proportion outputs. The mix proportion of SFA and RS was as shown below.

Table 5: Mix proportion % of River sand and Scoria fine

Mixing Proportion in percentile (%)		
Trial mix	**River Sand**	**Scoria fine aggregate**
1	100	0
2	80	20
3	60	40
4	40	60
5	20	80
6	0	100

3.5 Study Variables

3.5.1 Dependent Variable

The dependent variables of the study were workability and Compressive strength of normal concrete and SAC.

3.5.2 Independent variables

The independent variables of the study were Properties of materials, and cost of materials.

3.6 Materials selected for the laboratory work

- Cement:- the type of cement used for concrete production was locally produced Dangote ordinary Portland cement with grade 32.5R.
- River sand:- the sand used for the experiment was Antate sand which is extracted from Antate river.
- Scoria:- Scoria quarry deposit with in Hawassa town was used for the study.
- Coarse aggregate:- Monopole quarry crushed aggregate was used which is most widely supplying quarry site for the town.
- Water:- Hawassa university potable water supply was used.

3.7 Material preparation and testing

To attain good quality of concrete the constituent materials quality and properties of the materials is the governing factor for the required strength. The properties of materials needed for concrete production were tested.

3.7.1 Cement

The locally produced Dangote cement, Ordinary Portland cement with grade 32.5R, for the production of concrete was used. It was planned to test the variation of concrete properties by using different cement type but find out that even if there is, it is not due to the properties of the fine aggregates. Rather due to the property of cement so this research limits the study population only by one type of cement. The properties of cement were taken from the specification of the manufacturer and same properties were tested.

3.7.2 Coarse aggregate

Coarse aggregate used for this research was collected from Monopole quarry site which is located in Hawassa town. The properties of CA affect the concrete property so testing material properties before mix design is needed.

A maximum aggregate size of 25mm was used for the mix design. The properties of CA, sieve analysis, unit weight, specific gravity, and absorption capacity, were tasted according to ASTM standard guideline.

In order to reduce effect of water contribute to the mix or absorption of water from mixing water, SSD of CA was attained by immersing in to water for about 24hr and leaved to air until it reach SSD state.

The gradation or particle size distribution was done by sieve analysis test in which the particles are divided into various size by standard sieve. The analysis was made in accordance with ASTM C 33.

Table 6: Sieve analysis of coarse aggregate

Sieve Size	Weight of Sieve (Kg)	Weight of Sieve and Retained (K	Weight Retained (Kg)	Persentage Retaine	Cumulative Coarser (%)	Cumulative Passing (%)
37.5	1.45	1.45	0	0	0	100
19	1.32	5.63	4.31	43.1	43.1	56.9
13.2	1.27	3.91	2.64	26.4	69.5	30.5
9.5	1.23	2.64	1.41	14.1	83.6	16.4
4.75	1.18	2.34	1.16	11.6	95.2	4.8
		Total	9.52	95.2	291.4	208.6

3.7.3 Fine Aggregate

a. River sand

Natural river sand for the production of concrete was used Antate river sand. Extraction of RS in the area is similar to same other river sand production. The sand extracted in an old and traditional way from the streambeds by using labors and dumped to dump trucks and transported to the site.

b. Scoria

Scoria aggregates used for the study was bought from scoria deposit in near Hawassa university. The quarry site had both bolds and finer parts so the needed samples for the study taken from the finer parts.

Both FA used for the study, RS and SFA, undertakes laboratory tests. Sieve analysis, silt content, absorption capacity and unit weight of the materials was tasted before any trial mix and compared with standards.

Sieve analysis

The particle size distribution of FA was tasted according to ASTM C 136 standard of testing materials. The sample was prepared by taking 2000g of river sand and 2000g of scoria aggregate, placed in a square opening sieve and shake for about 14minutes for each samples.

The grading of RS was in between the maximum and minimum limits of the standard with a FM of 2.6 which is within the limit. But scoria aggregates had much coarser materials with a FM of 4.3. In order to attain scoria aggregate grading as the river sand grading, the sample continually blended until it reaches as a percentage of materials retained on each sieve as river sand and FM of 2.6. The evaluation of fine aggregate gradation was done according to ASTM C 33 and BS 882.

Blending of SFA was done accordingly as follows:-

- Samples placed on sieve.
- Samples sieved by using sieve shaker.
- Samples retained on each serious of sieve placed separately.
- Retained mass of samples from each sieve mixed as per the percentage retained for RS to attain the same FM.

Silt content

The presence of more silt in FA results reduction of the bondage between CA and paste, leads to less compressive strength. Under this research field silt content test was undertaken to check the quality of sand. The river sand sample washed thoroughly until it reaches with in the recommended range which is less than 6% by volume of sample.

Unit weight

Unit weight determination of an aggregate measures the volume of an aggregate in a concrete together with its voids. It is measured by filling a known volume container by the sample and weigh. The ratio of weight to volume gives loose unit weight of aggregate. Oven dry sample was taken to reduce the effect of moisture content in aggregates. For the compacted unit weight, a cylindrical metal measure filled with the sample in to three layers. Each layer was compacted by using tamping rod 25 times.

Specific gravity

The specific gravity of an aggregate is mass of aggregate in air divided by mass of equal volume of water. Determining the specific gravity for aggregates are described in ASTM C 128 and ASTM C 127 respectively for coarse and fine aggregates. It can be used both saturated surface dry (SSD) or oven dry state to calculate specific gravity of aggregates. The variation between the two results is due to water with in the internal pores and without water in the pores of aggregates. The specification indicates that bulk specific gravity of normal weight aggregate at SSD state between 2.4 and 2.9.

Absorption capacity

The internal structure of an aggregate particle is made up of solid matters and voids. The void can be filled by moistures or absorbed water added for the mix design. Determining the absorption capacity and moisture content of an aggregate is needed to adjust the total water content for the mix design. Absorption capacity of fine and coarse aggregate was done according to ASTM C 128 and ASTM C 127 respectively.

3.8 Concrete mix design and Proportion

Concrete mix design was done according to ACI 211 guidelines. In the research C-25 grade concrete by a maximum aggregate size of 25mm was designed to produce. Uniform W/C ratio of 0.62 was used for all mixes with designed slump in the range of 20-100mm. All aggregates were taken at SSD state to avoid the W/C ratio variation as the percentage of materials proportioning varies.

Table 7 shows the quantity of materials for one metric cubic cast of C-25 concrete. RS to SFA replacement by volume was done as per the percentage described.

Table 7: Quantity of material for $1m^3$ mix of concrete

Sample name	Cement (kg/m^3)	C.A (kg/m^3)	Total F.A (kg/m^3)	Water (lit)	W/C ratio	% of Sand	% of Scoria
100% RS	315	1103	717	195	0.62	100%	0%
80% RS	315	1103	717	195	0.62	80%	20%
60% RS	315	1103	717	195	0.62	60%	40%
40% RS	315	1103	717	195	0.62	40%	60%
20% RS	315	1103	717	195	0.62	20%	80%
0% RS	315	1103	717	195	0.62	0%	100%

3.9 Concrete Mixing Process

Concrete mixing process was conducted by hand with the help of workers. Concrete casting molds and all needed mixing tools was cleaned from all dusts and molds was coated with releasing agent to smooth the surface and to prevent sticking of mixed concrete.

The constituent materials, cement, river sand and coarse aggregate, was measured by weight and RS and SFA replacement by volume was done. The ingredients first dry mixed and then with added water until uniformly mixed.

3.10 Concrete Tests

3.10.1 Fresh concrete test

Workability test for fresh concrete mix was conducted for each mix according to ASTM C-143 guideline. The cone was properly cleaned, filled with one third of the height and rolled 25 times by tamping rod. The next two layers were rolled as above and leveled. The cone lifted carefully and the height difference between the cone and concrete measured. That was the slump.

After the required slump obtained, the concrete placed to the mold and compacted manually by hand using tamping rod in to three layers. The concrete mold was kept for 24 hours and then the casted concrete cubes were removed from the mold and placed inside water for curing until the require date.

3.10.2 Harden concrete test

The concrete specimens were casted to test at ages of 7^{th} and 28^{th} days. Three specimens were made for each mix in order to take the mean of the three specimens for compressive strength test. The samples were curried in water bath for 6 and 27 days and left on dry surface for a day. Air dried samples were weighted and putted in to compressive strength testing machine.

3.11 Cost Analysis

The total cost of concrete influenced by many factors, material cost, equipment cost and man power cost are the major ones. Under this research concrete production cost for $1m^3$ concrete was considered by taking only cost of material.

3.12 Analyzing and Discussion

All the data that collected were organized and relevant answer were forwarded in order to ensure a meaning full presentation and also analysis of data. Compare and contrast on the properties of materials, workability of conventional concrete and scoria added concrete, compressive strength in harden concrete as well as cost of materials were assessed. Result and discussion were done based on the result.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 General

It was stated above that the main objectives of the laboratory test specimens were to assess and compare quality of SFA with RS, To compare workability and compressive strength of concrete made with scoria as fine aggregate to that of ordinary concrete, To compare the cost of concrete made of SFA and RS for the study area as well as to determine the optimum mix proportion of the two materials to attain required minimum compressive strength.

In the following section the test results presented and evaluated in light of the requirements of concrete strength and workability.

4.2 Cement used for the experiment

Ordinary Portland cement (OPC) produced by Dangote Cement Factory, Grade 32.5R, was used throughout the experiment. Laboratory tests results outputs on the physical properties of cement and taken from the manufacturer shown below.

Table 8: Test result of cement

Description	**Result**
Cement grade	32.5R
Specific gravity	3.15
Normal consistency	29.15%
Setting time	
Initial setting	63min
Final setting	338min

4.2 Physical Properties of Coarse Aggregate

Same of the physical properties of coarse aggregate were tested to check quality of the material as per ASTM standard of testing materials. Normal weight basaltic coarse aggregate with maximum aggregate size of 25mm was used for experimental investigation. Summarized test results are shown below in table 4.2.

Table 9: Physical properties of coarse aggregate

Item no	Description	Test result
1	Maximum aggregate size	25mm
2	Unit weight – Compacted	1588.11kg/m3
	Loose	1332.6kg/m3
3	Absorption capacity	0.75%
4	Specific gravity – Apparent	2.65
	- Oven dry base	2.6
	-Saturated surface dry	2.62

4.3 Physical Properties of Fine Aggregate

Sieve analysis

The gradation curve of river sand ranged with in the upper and lower limits as per ASTM C 33 specification. But SFA was much coarser and out of recommended range for fine aggregate. Based on BS 882, sieve analysis of RS showed under category of zone 2 which is under moderate grading zone. But for the SFA, sieve analysis test result showed out of recommended range for fine aggregate.

To reduce effect of different FM and gradation on the property of concrete SFA was designed to have, after progressive blending, mass retained on each sieve as similar to mass retained for each sieve size as river sand. The gradation curve of SFA before and after blending together with upper and lower limits of ASTM C33 standard are shown below in figures. Sieve analysis result of RS and SFA before blending showed below in table 4.3 together with ASTM and BS recommended grading requirements.

Table 10: Sieve analysis based on BS and ASTM grading for FA before blending

Standard sieve size		Percentage by weight passing sieve						
		RS	Scoria	BS 882: 1992				ASTM Standard C 33- 78
BS	ASTM	Cum.% passing	Cum.% Passing	Grading zone 1	Grading zone 2	Grading zone 3	Grading zone 4	
9.5mm	3/4in	100	100	100	100	100	100	100
4.75mm	3/16in	98	68	90-100	90-100	90-100	95-100	95-100
2.36mm	8	96	48	60-95	75-100	85-100	95-100	80-100
1.18mm	16	82.75	29	30-70	55-90	75-100	90-100	50-85
600 μm	30	48	16	15-34	35-59	60-79	80-100	25-60
300 μm	50	13.5	5	5-20	8-30	12-40	15-50	10-30
150 μm	100	3.25	2	0-10	0-10	0-10	0-15	2-10

The FM of FA stated as per ASTM C 33 was between the range 2.3 and 3.1. In this research the FM of RS was 2.6, which is within the range. But before blending SFA was 4.3, which shows the material was coarser than the recommended limit. According to (Denamo,2005) the fineness modulus between the range of 2.6-2.9 categorized under medium sand and for the fine sand the range goes between 2.2-2.6. So the RS used on the study can be categorized under medium or fine sand. For the SFA, FM was 4.3 which was out of the recommended range for fine aggregate. To avoid the effect of different value of FM of the two materials on concrete property, FM of SFA was set at 2.6 by progressive blending of retained mass samples on each sieve as mass retained for RS. Summarized sieve analysis for the material shown below.

Table 11: Sieve analysis of RS

Sieve Size	Weight of Sieve	Weight of Sieve and Retained	Weight Retained	Persentage Retained	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	-	0	0	0	0	100
4.75	0.42	0.46	0.04	2	2	98
2.36	0.46	0.5	0.04	2	4	96
1.18	0.46	0.72	0.27	13.25	17	82.75
600	0.41	1.11	0.70	34.75	52	48
300	0.37	1.06	0.69	34.5	87	13.5
150	0.27	0.48	0.21	10.25	97	3.25
pan	0.55	0.62	0.06	3.25	-	-
Total	2.93	4.93	2.00	100	**259**	441.5

Table 12: Sieve analysis of SFA

Sieve Size	Weight of Sieve (Kg)	Weight of Sieve and Retained (kg)	Weight Retained (kg)	Persentage Retained	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	-	0	0	0	0	100
4.75	0.41	1.06	0.65	33	33	68
2.36	0.455	0.85	0.395	20	52	48
1.18	0.45	0.82	0.37	19	71	29
600	0.405	0.68	0.28	14	85	16
300	0.365	0.575	0.21	11	95	5
150	0.27	0.34	0.07	3	98	2
pan	0.545	0.58	0.03	2	-	-
Total	2.9	4.90	2.00	100	**433**	266.75

$$\text{Fineness Modulus} = \frac{\Sigma\text{ (cum. \% coarser)}}{100}$$

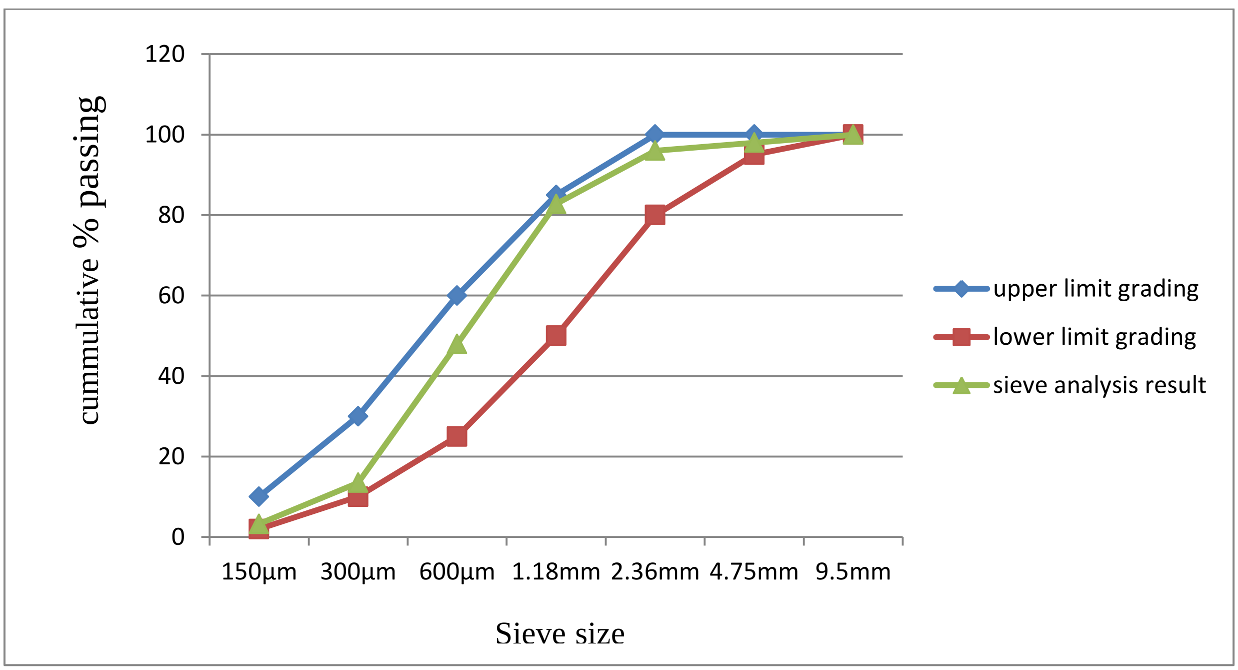

Fig 5: Gradation curve of RS

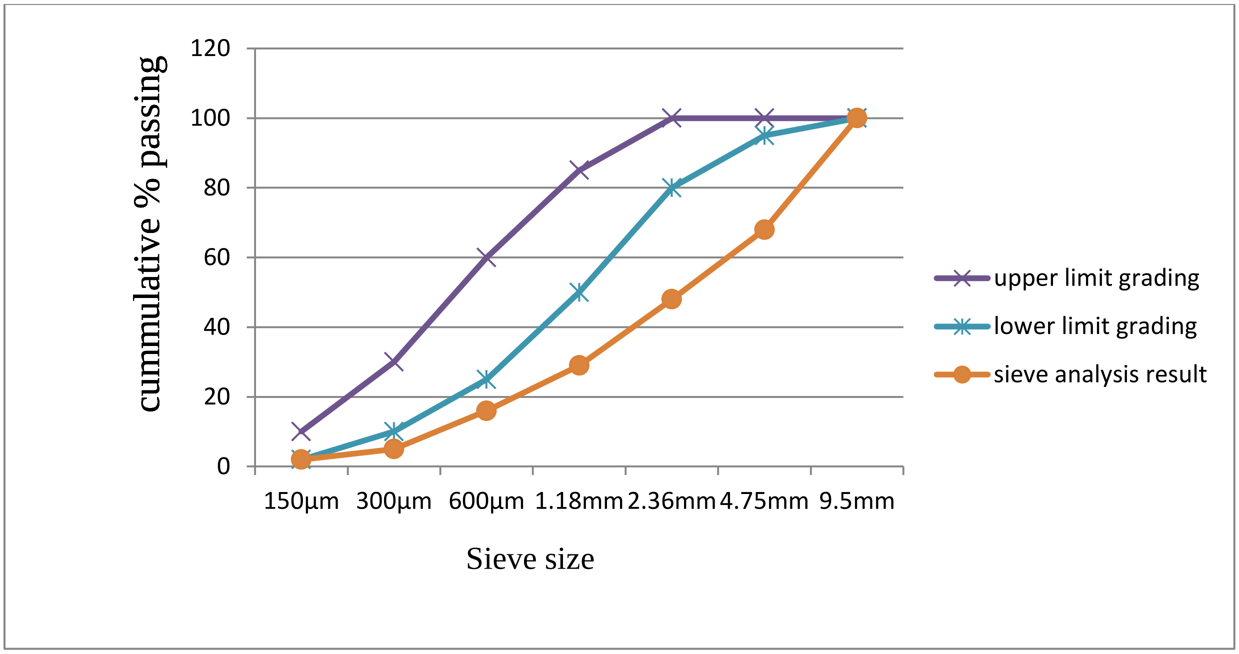

Fig 6: Gradation curve of SFA before blending

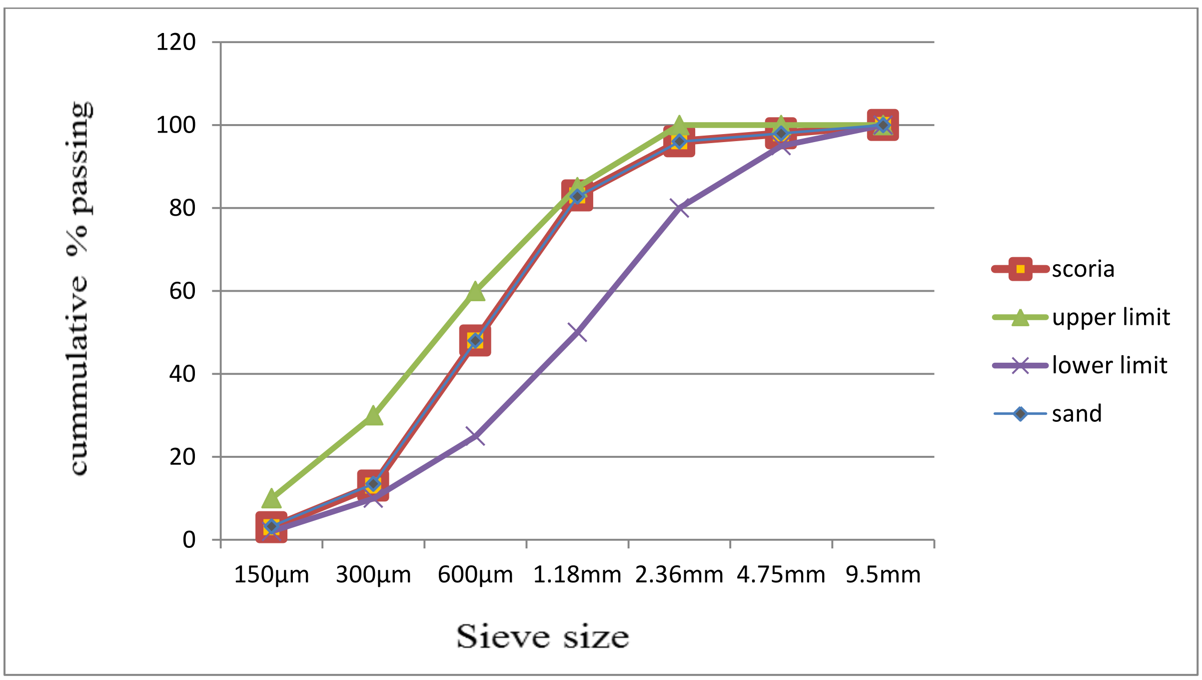

Fig 7: Gradation curve of SFA after blending

Unit weight

To determine the unit weight of fine aggregates, oven dry samples were taken and compaction by hand was done in order to determine compacted unit weight of materials. According to ASTM C 331 the maximum dry loose unit weight of lightweight aggregate 1120Kg/m^3. From the test result obtained dry loose unit weight of scoria fine aggregate was 1103.74Kg/m^3 which were with in recommended range for lightweight fine aggregates. According to ACI E-710 dry rooded bulk density of aggregates for normal weight concrete ranges 1200 to 1760Kg/m^3. For both coarse and fine aggregates the unit weights were within the recommended range.

Table 13: Unit weight of RS and SFA

	Compacted unit weight			
Fine aggreg	**wt. of sample + mold (kg)**	**wt. of mold(kg)**	**wt. of sample (kg)**	**Unit weight (kg /m3)**
River sand	15.31	8.16	7.15	1574.89
Scoria	14.18	8.16	6.02	1325.99
	loose unit weight			
River sand	14.715	8.16	6.555	1443.83
Scoria	13.171	8.16	5.011	1103.74

Both compacted and loose unit weight of SFA have lower unit weight than RS. Compacted unit weight and loose unit weight of RS was 18.77 % and 30.81% respectively shows greater value than SFA. The result behind this was due to voids between the particles and pore structure of lightweight aggregate.

Silt content

Antate river sand was subjected to more silt content than the recommended limit. By using field test method, it contains 13.64% by volume of the sample. According to the British and American standards (BS 882, ASTM C-33), maximum percentage of fines less than 150µm sieve should not be more than 3% by mass of the fine aggregate and also in Ethiopia, in EBCS standard, maximum recommended silt content of sand needs to be less than 6%. Sand with higher silt content results less compressive strength of concrete due to lower bondage between the cement paste and coarse aggregates. To attain with in recommended standard limit, river sand was washed and obtained silt content of 2.04% but for the SFA there is no noticeable silt content.

Absorption capacity

The absorption capacity represents the maximum amount of water the aggregate can absorb. By using ASTM C 128 absorption testing method, the absorption capacity test result of RS was 1.29% and 12.16% for SFA. According to ACI 213R-03, lightweight aggregates can absorb up to 25% by mass of dry aggregate and for a normal weight aggregate, according to ACI E-710, can absorb up to 8%by mass of dry aggregates. Absorption capacity of SFA was relatively have much higher value than RS. This property of SFA was due to internal pore structure of the material and void within and between the particles. From literature reviews, high absorption capacity of lightweight aggregates is important for internal curing by uniformly hydrating the cement paste.

Table 14: Summary of Physical Properties of Fine aggregates

Description		**River sand**	**Scoria aggregate**
Silt content	Before washing	13.64%	0%
	After washing	2.04%	-
Absorption capacity		1.29%	12.16%
Unit weight	Compacted (kg/m3)	1574.89	1325.99
	Loose (kg/m3)	1443.83	1103.74
Fineness modulus	Before blending	2.6	4.3
	After blending	2.6	2.6

4.4 Fresh Concrete Results

To compare the effect of SFA by partially replacing to RS in concrete production, all the parameters that affect the properties of concrete was set to be uniform for all mixes. Slump test was carried out to check the workability at a w/c ration 0.62 on fresh concrete.

From observed laboratory results absorption capacity of SFA is higher than RS. In order to reduce the variation of W/C ratio, due to added water for moisture adjustment, with in the mixes constituent materials of concrete was set to be in a SSD state.

Using a W/C ratio of 0.62, variation of slump between normal concrete and SAC was observed. The results are shown below in table.

Table 15: Measured slump of Trial mixes

No	Mix code	W/C	Slump(mm)
1	100%RS	0.62	73
2	80%RS	0.62	62
3	60%RS	0.62	51
4	40%RS	0.62	46
5	20%RS	0.62	37
6	0%RS	0.62	28

Generally the observed test results conducted from the experiment, SAC, like other concretes, has to comply with several criteria in its fresh states. It must have sufficient workability to allow it to be mixed, transported, placed and compacted so as to attain required strength and durability.

The test result shows, when the percentage of SFA increases, workability of concrete reduces. Up to a percentage mix proportion of 60%RS to 40%SFA, the test result showed a medium slump, ranged 50-100, but for the mix proportion more than 40%SFA low slump, ranged 25-50 as per (Naville and Brooks, 2010). This happen due to the irregular shape of SFA, it leads an increased surface area of particles. When the surface area of a particle increases, amount of water required to moister the surface of a particle increases causes reduction of workability together with roughness of the particles. But at a given W/C ratio attain required design workability of concrete.

4.5 Harden Concrete Results

Harden concrete property, compressive strength test, is used to determine the rate of compressive strength development of harden concrete. The compressive strength of the concrete specimens was determined by testing concrete cubes of size 150mm. The cubes were compressed in a compressive testing machine at a rate of 1.5kN/sec until the samples fails at the age of 7th and 28th. All specimen weighted and compressive strength test result recorded in MPa. The mean of three sample test results, for each mix, reported below in tables.

Table 16: Summary of compressive strength of concrete at 7th day

No	Mix code	Weight (gm)	Failure load(kN)	Compressive Strength(MPa)
1	0%RS	8164.33	421.64	18.74
2	20%RS	8095	365.11	16.23
3	40%RS	7991.67	419.03	18.62
4	60%RS	8331.67	493.29	21.92
5	80%RS	7952.33	508.95	22.62
6	100%RS	8258.67	558.89	24.84

As a test result show, the compressive strength of normal concrete at a W/C ratio of 0.62 and maximum aggregate size of 25mm shows 24.84MPa. But for scoria added concrete, when percentage of SFA varies, there is a reduction of compressive strength. At the age of 7th day, maximum compressive strength of SAC attain at 80%RS and 20% SFA mix proportion by volume which was 22.62MPa. The minimum compressive strength attained at 20%RS and 80% SFA mix proportion by volume, which was 16.23MPa.

Table 17: Summary of compressive strength of concrete at 28th day

No	Mix code	Weight (gm)	Failure load(KN)	Compressive Strength(MPa)
1	0%RS	8217	623.02	27.69
2	20%RS	8126	520.68	23.14
3	40%RS	8146.67	604.77	26.88
4	60%RS	8216.67	614.45	27.31
5	80%RS	8305	670.08	29.78
6	100%RS	8260	745.05	33.11

At the age of 28th day, compressive strength of the control mix at slump of 73mm was 33.11Mpa. At the 7th day compressive strength, maximum value of SAC attains at 80%RS and 20%SFA which was 29.78MPa. For the minimum strength at 20%RS and 80%SFA mix proportion by volume, the test result shows a value of 23.14MPa. For all SAC mix proportion, the compressive strength at 28th day pass the minimum design compressive strength except at mix proportion of 20%RS to 80% SFA. This can show that scoria can be used as fine aggregate in concrete production. Summarized compressive strength test results at 7th and 28th days shown below in figure.

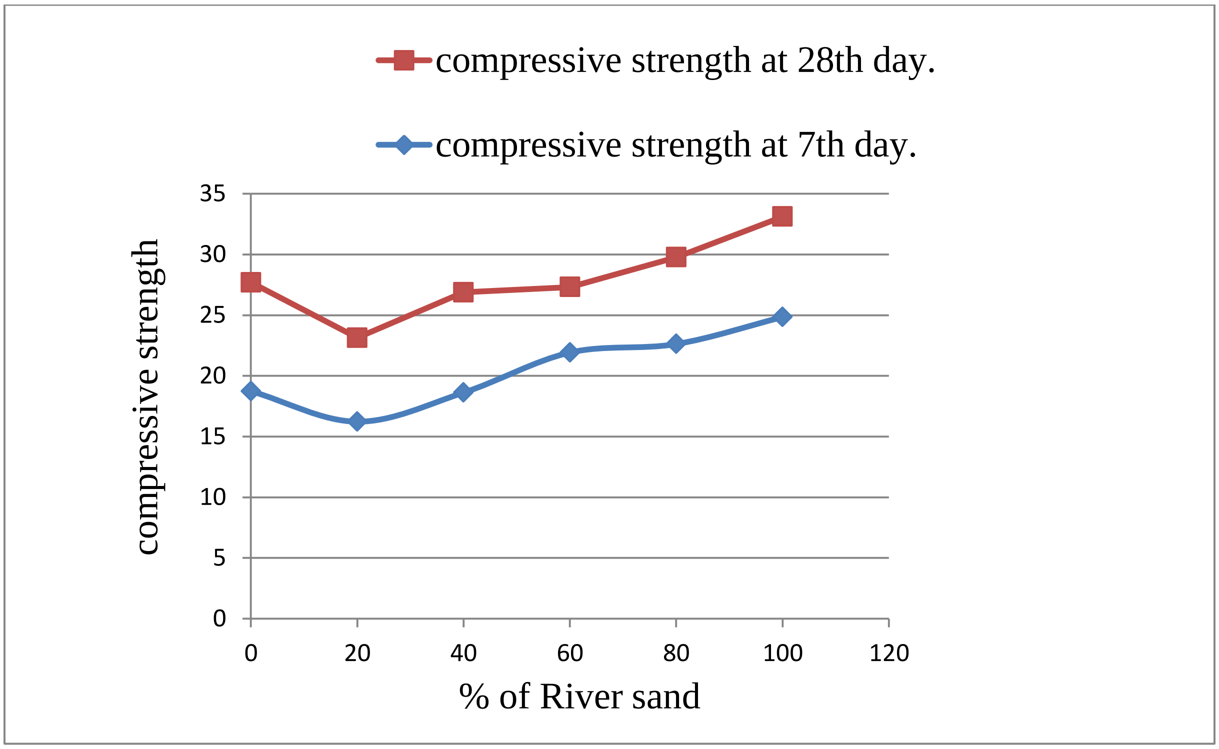

Fig 8: 7th and 28th day compressive strength graph

4.6 Cost Comparison of Materials

To say concrete with good quality, good quality of constituent materials together with cost needs to be considered. For cost comparisons, one sources of RS and one source of SFA was taken. Most natural sand supplied to Hawassa town obtained from Alaba, Dore Bafena, Antate and Blate sources. Material cost comparison, for the production of $1m^3$ of concrete, was considered by taking only cost of materials delivered to the site.

Table 18: Cost of Concrete for 100% RS

Material cost for 1m^3 of C-25 concrete					
Type of material	unit	Quantity	Rate(birr)	%age combination	Total cost
Sand	m^3	0.456	281.00	100%	128.14
Scoria	m^3	0	80.00	0%	0.00
Cement	Qt	3.15	250.00	-	787.50
Coarse aggregate	m^3	0.695	450.00	-	312.75
				Total Cost/birr	**1228.39**

Table 19: Cost of Concrete for 80% RS and 20%SFA

Material cost for 1m^3 of C-25 concrete					
Type of material	unit	Quantity	Rate(birr)	%age combination	Total cost
Sand	m^3	0.365	281.00	80%	102.57
Scoria	m^3	0.091	80.00	20%	7.28
Cement	Qt	3.15	250.00	-	787.50
Coarse aggregate	m^3	0.695	450.00	-	312.75
				Total Cost/birr	**1210.10**

From cost analysis by taking only cost of materials for the production of 1m^3 C-25 concrete, relative to conventional concrete, at 80% RS and 20%SFA mix proportion showed a cost reduction of 18.29birr/m^3, a percentage cost difference of 1.51%.

Table 20: Cost of Concrete for 60% RS and 40%SFA

Material cost for 1m^3 of C-25 concrete					
Type of material	unit	Quantity	Rate(birr)	%age combination	Total cost
Sand	m^3	0.279	281.00	60%	78.40
Scoria	m^3	0.177	80.00	40%	14.16
Cement	Qt	3.15	250.00	-	787.50
Coarse aggregate	m^3	0.695	450.00	-	312.75
				Total cost/birr	**1192.81**

From cost analysis by taking only cost of materials for the production of 1m^3 C-25 concrete, relative to conventional concrete, at 60% RS and 40%SFA mix proportion showed a cost reduction of 35.58birr/m^3, a percentage cost difference of 2.98%.

Table 21: Cost of Concrete for 40% RS and 60%SFA

Material cost for 1m^3 of C-25 concrete					
Type of material	unit	Quantity	Rate(birr)	%age combination	Total cost
Sand	m^3	0.182	281.00	40%	51.14
Scoria	m^3	0.274	80.00	60%	21.92
Cement	Qt	3.15	250.00	-	787.50
Coarse aggregate	m^3	0.695	450.00	-	312.75
				Total Cost/birr	**1173.31**

From cost analysis by taking only cost of materials for the production of 1m^3 C-25 concrete, relative to conventional concrete, at 40% RS and 60%SFA mix proportion showed a cost reduction of 55.08birr/m^3, a percentage cost difference of 4.69%.

Table 22: Cost of Concrete for 20% RS and 80%SFA

Material cost for 1m^3 of C-25 concrete					
Type of material	unit	Quantity	Rate(birr)	%age combination	Total cost
Sand	m^3	0.091	281.00	20%	25.57
Scoria	m^3	0.365	80.00	80%	29.20
Cement	Qt	3.15	250.00	-	787.50
Coarse aggregate	m^3	0.695	450.00	-	312.75
				Total Cost/birr	**1155.02**

From cost analysis by taking only cost of materials for the production of 1m^3 C-25 concrete, relative to conventional concrete, at 20% RS and 80%SFA mix proportion showed a cost reduction of 73.37birr/m^3, a percentage cost difference of 6.35%.

Table 23: Cost of Concrete for 0% RS and 100%SFA

Material cost for 1m^3 of C-25 concrete					
Type of material	unit	Quantity	Rate(birr)	%age combination	Total cost
Sand	m^3	0	281.00	0%	0.00
Scoria	m^3	0.456	80.00	100%	36.48
Cement	Qt	3.15	250.00	-	787.50
Coarse aggregate	m^3	0.695	450.00	-	312.75
				Total Cost/birr	**1136.73**

From cost analysis by taking only cost of materials for the production of 1m^3 C-25 concrete, relative to conventional concrete, at 0% RS and 100%SFA mix proportion showed a cost reduction of 91.66birr/m^3, a percentage cost difference of 8.1%. Summarized graphical cost analysis showed below on figure 4.7.

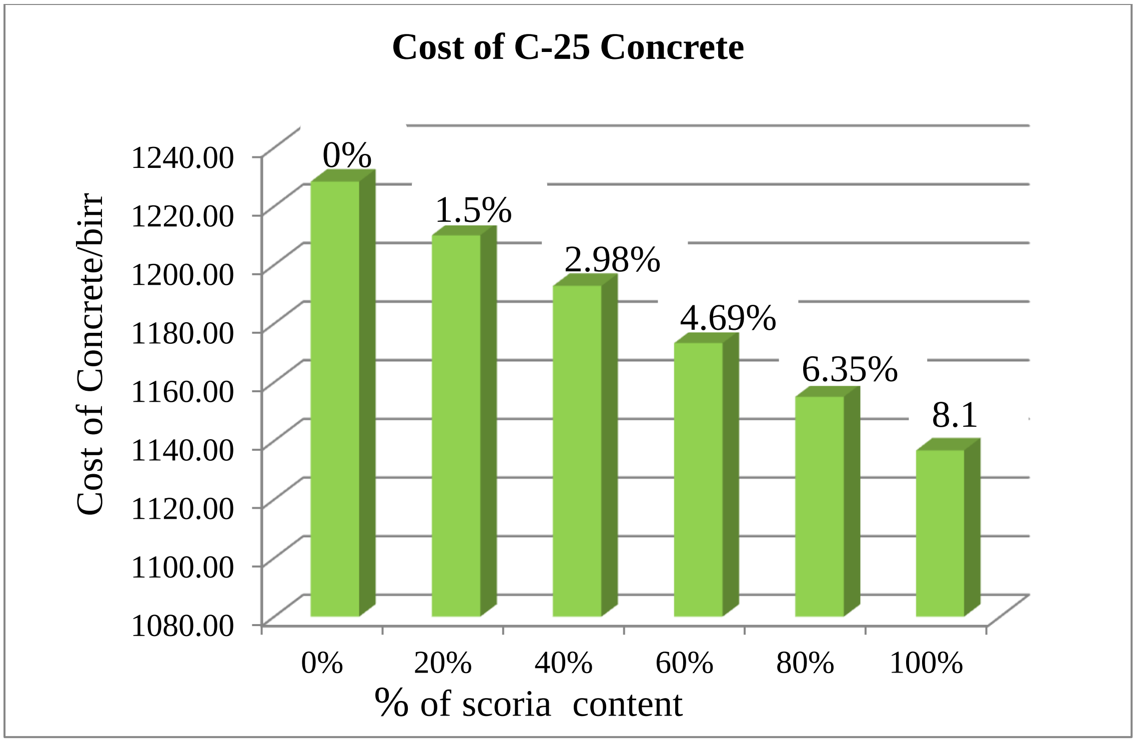

Fig 9: Cost analysis result of RS and SFA for $1m^3$ concrete production

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

Based on the conducted laboratory result using Dangote cement, normal weight basaltic coarse aggregate with maximum aggregate size of 25mm, scoria and river sand as fine aggregate, with uniform W/C ration of 0.62, mix design was prepared for compressive strength of 25MPa. Then compressive strength test of scoria added concrete with respect to control mix was compared together with cost analysis. Finally conclusion and recommendation were given based on the results.

5.1. Conclusion

- SFA showed higher absorption capacity and less value of loose and compacted unit weight than recommended range for normal RS.
- As the percentage of SFA increases the measured slump test value decreases at uniform W/C ration of 0.62. This research concluded that SFA decreases the workability of fresh concrete.
- This experiment agreed with Nigusse and Shiferaw experimental investigation. The hardened property of SFA added concrete showed a gradual reduction of compressive strength as percentage of SFA increases both at the age of 7^{th} and 28^{th} days.
- A mean compressive strength of 27.69MPa was obtained at 100%SFA relative to 33.11Mpa for the control mix at the same proportion of W/C ratio. This shows SFA could be used as fine aggregate for production of normal concrete.
- At a mix proportion of 20%RS to 80%SFA, compressive strength test result at 28^{th} day fall the minimum design compressive strength.
- Under cost analysis by taking cost of materials only, SFA for $1m^3$ concrete production at 100% SFA showed 8.1% cost reduction relative to concrete made at 100%RS for Hawassa town. The cost variation between the two materials may not be the same for other parts of the country.

5.3 Recommendation

- In concrete mix design, the presence of moisture content and absorption capacity of aggregates has influence on W/C ratio. Scoria as fine aggregate has higher absorption capacity than normal fine aggregates. So in using the material for concrete production the absorption capacity and reduction on the workability of concrete needs consideration.

- This research was done to investigate the potential capacity of scoria to river sand under W/C ratio of 0.62. So, farther studies are required on the area at a lower W/C ratio together with admixtures to obtain the best benefit of the material for concrete production.

- This research covered only potential capacity of scoria to C-25 concrete production, so farther researches are required on the material for production of high grade concrete as well as the durability of concrete.

- Concerned authorities have to give detail information the potential availability of the material in the country together with environmental concerns.

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ANNEXES

1. Properties of materials

1.1 Fine Aggregate

A) Sieve analysis

	River Sand					
Sieve Size	Weight of Sieve	Weight of Sieve and Retained	Weight Retained	Persentage Retained	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	-	0	0	0	0	100
4.75	0.42	0.46	0.04	2	2	98
2.36	0.46	0.5	0.04	2	4	96
1.18	0.46	0.72	0.27	13.25	17	82.75
600	0.41	1.11	0.70	34.75	52	48
300	0.37	1.06	0.69	34.5	87	13.5
150	0.27	0.48	0.21	10.25	97	3.25
pan	0.55	0.62	0.06	3.25	-	-
Total	2.93	4.93	2.00	100		
				F.M	2.6	

	Scoria					
Sieve Size	Weight of Sieve (Kg)	Weight of Sieve and Retained (kg)	Weight Retained (kg)	Persentage Retained	Cumulative Coarser (%)	Cumulative Passing (%)
9.5	-	0	0	0	0	100
4.75	0.41	1.06	0.65	33	33	68
2.36	0.455	0.85	0.395	20	52	48
1.18	0.45	0.82	0.37	19	71	29
600	0.405	0.68	0.28	14	85	16
300	0.365	0.575	0.21	11	95	5
150	0.27	0.34	0.07	3	98	2
pan	0.545	0.58	0.03	2	-	-
Total	2.9	4.90	2.00	100		266.75
				F.M	4.3	

B. Silt content determination (field method)

Silt content (%) = $\frac{A}{B} * 100$

Where :-

A = volume of silt deposit

B = volume of clean sand

River Sand	Volume of sample	Volume of clean fine aggregate(B)	Volume of silt deposit(A)	Silt content (%)
Before washing	50ml	44	6	13.64
After washing	50ml	49	1	2.04
Scoria	50ml	50	0	0

C. Unit weight

Compacted unit weight

Internal diameter = 14cm

Internal height = 29.5cm

Volume of apparatus = $\frac{\pi d^2 h}{4}$ = 0.00454m^3

Unit weight = $\frac{m}{v}$

	Compacted unit weight			
Fine aggreg	**wt. of sample + mold (kg)**	**wt. of mold(kg)**	**wt. of sample (kg)**	**Unit weight (kg /m3)**
River sand	15.31	8.16	7.15	1574.89
Scoria	14.18	8.16	6.02	1325.99
	loose unit weight			
River sand	14.715	8.16	6.555	1443.83
Scoria	13.171	8.16	5.011	1103.74

D. Moisture Content

W (%) = $\frac{A-B}{B} * 100$

Where :

W = moisture content (%)

A = weight of original sample

B = weight of oven dry

	wt. of orginal sample (A)	wt. of pan (kg)	wt. of ovendry sample + pan (kg)	wt. of ovendry sample (kg) (B)
River sand	0.5	0.285	0.78	0.49
Scoria	0.5	0.775	1.25	0.48

W (river sand) = $\frac{0.5-0.49}{0.49} * 100$

$= 2.04\ \%$

W (scoria) = $\frac{0.5-0.48}{0.48} * 100$

$= 4.17\ \%$

1.2 . Coarse Aggregate

A) Unit weight

	Compacted unit weight			
	wt. of sample + mold (kg)	wt. of mold(kg)	wt. of sample (kg)	Unit weight (kg /m3)
Coarse aggregate	15.37	8.16	7.21	1588.11
	loose unit weight			
Coarse aggregate	14.21	8.16	6.05	1332.60

B) Specific gravity and Absorption capacity

S. no	Description	Sample wt. in (gm)
1	Wa = weight of basket with sample in water	2109.03
2	Wb = weight of basket in water	861
3	Mw = weight in water of the saturated agg.(wa - wb)	1248.03
4	Mssd = weight in air of the saturated surface dry agg.	2020
5	Md = weight in air of oven dried agg.	2005

Apparent specific gravity = $\frac{Md}{Md-Mw}$

$$= \frac{2005}{2005-1248.03}$$

= 2.65

Bulk specific gravity (oven dry basis) = $\frac{Md}{Mssd-Mw}$

$$= \frac{2005}{2020-1248.03}$$

= 2.60

Bulk specific gravity (saturated sur. dry Basis)

$$= \frac{Mssd}{Mssd-Mw}$$

$$= \frac{2020}{2020-1248.03}$$

= 2.62

% Water absorption = $\frac{Mssd-Md}{Md} * 100$

$$= \frac{2020-2005}{2005} * 100$$

= 0.75%

2. Mix Design

1. Slump = 20 – 100mm
2. Maximum agg. Size = 25mm
3. Water content = 195kg

   Air content = 1.5%
4. W/C ratio = 0.62

   Cement content = 314.52kg
5. Coarse agg./m3 = 0.69

   = 1588.11kg/m3 * 0.69

   = 1095.8 kg/m3

   Surface saturated density of coarse agg. = 1095.8*1.75%

   = 1104.013 kg/m3

6. Fine aggregate determination

$$Um = 10Ga\,(100 - A) + Cm\,\left(1 - \frac{Ga}{Gc}\right) - Wm\,(Ga - 1)$$

Ga = 2.62 Gc = 3.15

$$= 10*2.62\,(100 - 1) + 3.15\,\left(1 - \frac{2.62}{3.15}\right) - 195\,(2.62 - 1)$$

= 2330.82 kg/m

Density of fresh concrete from table = 2380kg/m3

Fine agg. = 2331 – 315 – 1103 – 195

= 718kg/m3

Material / m3	For one trial mix = 0.0223m3 (by taking 10% wastage)
Cement = 315kg/m3	= 7.025kg
Sand = 718 kg/m3	= 16.01 kg
Coarse agg. = 1103kg/m3	= 24.6 kg
Water = 195kg/m3	= 4.35kg

3. Compressive Strength Test Results

Sample no	Testing age	Sample weight		Total load(KN)		Comp. Strength(Mpa)	
1,0	28	8201		617.632		27.450	
2,0	28	8215	8217	613.722	623.02	27.277	27.69
3,0	28	8235		637.707		28.343	
1,20	28	8350		553.28		24.590	
2,20	28	8132	8126	478.505	520.68	21.267	23.14
3,20	28	7896		530.258		23.567	
1,40	28	8150		594.94		26.442	
2,40	28	8235	8146.67	622.481	604.77	27.666	26.88
3,40	28	8055		596.903		26.529	
1,60	28	8352		629.098		27.960	
2,60	28	7958	8216.67	588.344	614.45	26.149	27.31
3,60	28	8340		625.908		27.818	
1,80	28	8345		672.133		29.873	
2,80	28	8215	8305	662.504	670.08	29.445	29.78
3,80	28	8355		675.598		30.027	
1,100	28	8315		738.459		32.820	
2,100	28	8305	8260	737.293	745.05	32.769	33.11
3,100	28	8160		759.398		33.751	

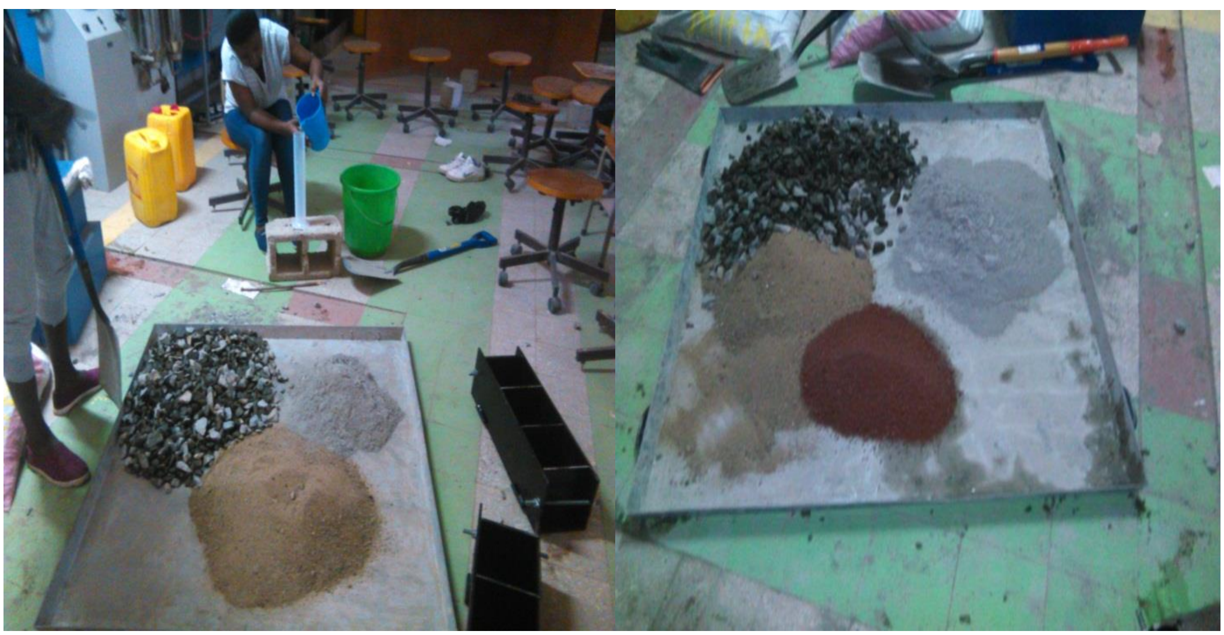
Compressive Strength Test Results at 7th day

sample no	Testing age	Sample weight		Total load(KN)		Comp. Strength(Mpa)	
1,0	7	8073		404.292		17.969	
2,0	7	8081	8164.33	438.78	421.64	19.501	18.74
3,0	7	8339		421.86		18.749	
1,20	7	7964		376.017		16.712	
2,20	7	8033	8095.00	377.372	365.11	16.772	16.23
3,20	7	8288		341.943		15.197	
1,40	7	8016		430.1811		19.11916	
2,40	7	7928	7991.67	409.2588	419.03	18.18928	18.62
3,40	7	8031		417.6414		18.56184	
1,60	7	8315		497.2419		22.09964	
2,60	7	8430	8331.67	467.5311	493.29	20.77916	21.92
3,60	7	8250		515.0889		22.89284	
1,80	7	7848		516.813		22.969	
2,80	7	8159	7952.33	532.361	508.95	23.66	22.62
3,80	7	7850		477.679		21.23	
1,100	7	8365		559.2519		24.85564	
2,100	7	8051	8258.67	563.1768	558.89	25.03008	24.84
3,100	7	8360		554.2506		24.63336	

Figures

Compacted unit weight determination of SFA and RS

Preparation of coarse aggregate to SSD state



Prepared ingredients of concrete for mixing

Slump test of trial mix

Compaction of concrete by hand for slump test and cube cast

Cube cast of concrete during curing

Fig 4 1: Sample prepared for test in compressive strength test machine