



ADISS COLLAGE

DEPARTMENT OF CONSTRUCTION TECNOLOGY AND MANAGEMENT

**EXPERIMENTAL INVESTIGATION ON PARTIAL REPLACEMENT OF FINE
AGGREGATE WITH WASTE BRICK AND LATERITE SAND IN CONCRETE
PRODUCTION**

By

Meron Tsehaye

Advisor: BAHIRU BEWUKET (PhD)

Adiss Abeba, Ethiopia, 2021

Experimental Investigation on Partial Replacement of River Sand with Waste Brick and
Laterite Soil in Concrete Production.

Meron Tsehaye Ayeligne

A thesis submitted to the school of Graduate Study, Adiss Collage, in partial fulfillment
of the requirements for the degree

Of

Masters in the Construction Technology and Management

Advisor: Bahiru Bewket. (Ph.D.)

Adiss Abeba, Ethiopia

August 2021

DECLARATION

I hereby declare that this thesis entitled “**EXPERIMENTAL INVESTIGATION ON PARTIAL REPLACEMENT OF FINE AGGREGATE WITH WASTE BRICK AND LATERITE SAND IN CONCRETE PRODUCTION**” was composed by myself, with the guidance of my advisor, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted, in whole or in part, for any other degree or professional qualification.

Name of the student: MERON TSEHAYE

Signature:

Date: 6/8/2021

APPROVAL SHEET

ADISS COLLAGE

DEPARTMENT OF CONSTRUCTION TECNOLOGY AND MANAGEMENT

THESIS PAPER

Student:

Meron Tsehaye

Name

Signature

Date

The following graduate faculty members certify that this student has successfully presented the necessary written thesis paper and oral presentation of this thesis paper for partial fulfillment of the thesis-option requirements for the Degree of Master of Science in Construction Technology and Management.

APPROVED BY BOARD OF EXAMINERS

Advisor:

Dr. Bahiru Bewket

Name

Signature

Date

External Examiner

Name

Signature

Date

Internal Examiner

Name

Signature

Date

ACKNOWLEDGMENT

This thesis paper has become a reality due to the generous help and support of many individuals. I have deepest gratitude and appreciation for Dr. Bahiru for giving me an opportunity to work with him and all his limitless efforts in guiding me through my work and for providing me useful advice. I couldn't have asked for a better mentor and guide for my MSc program and I really appreciate all the support, guidance and motivation that he has provided me through my academic career.

I also want to thank my friends and ERA lab assistants for their support and encouragement through the whole procedure in my work. Lastly, I would like to thank my beloved family and colleagues for their motivation, support, and kindness in this paper.

ABSTRACT

Concrete is the most widely used construction material in the world because of the economic and widespread availability of ingredients, its versatility, adaptability, and durability. Due to these developing countries, like Ethiopia, are facing a shortage of good quality and quantity of river sand that satisfies the demand for rapid infrastructure growth. This increase in demand create disturbance in the proportion between availability and need for material. Hence an alternative material is required to manage the situation. The main objective of this study was to investigate the workability, durability, strength, and cost of partially replacing sand for normal strength concrete with waste brick and laterite soil. Towards this experimental investigation were conducted to study the chemical and physical property of concrete containing waste brick and laterite soil. And there are 13 different sets of mixes including the control mix used for investigations. This mixes having constant water-cement ratio of 0.49 and slump range between 75-100 mm for concrete having a compressive strength of 25 MPa without admixture was used for this research. And the workability of each fresh concrete mix was checked immediately following the mixing. The compressive strengths of 117 concrete cubes of sizes 150mm x 150mm x 150mm sample are evaluated at 3days, 7days, and 28days. The chemical analysis test result shows that waste brick is mainly composed of Silicon Oxide (SiO_2), Aluminum Oxide (Al_2O_3), and Iron Oxide (Fe_2O_3). Whereas, laterite soil is composed of Silicon Oxide (SiO_2), Iron Oxide (Fe_2O_3), Aluminum Oxide (Al_2O_3), Magnesium Oxide (MgO), and Calcium Oxide (CaO). Concrete containing waste brick and laterite soil as natural sand replacement shows a better compressive strength and less percentage of water absorption which is an indication of better durability than the conventional concrete. But workability decreased with an increase in percentage replacement of waste brick and laterite soil. Concrete containing 45% waste brick and 22% laterite soil is the optimum replacement rate with having 4.43% water absorption capacity and it can save up to 4.58% of the total cost of concrete.

Keywords: Compressive strength, Concrete, Fine aggregate, Laterite soil, Waste brick.

TABLE OF CONTENTS

DECLARATION.....	i
APPROVAL SHEET.....	ii
ACKNOWLEDGMENT	iii
ABSTRACT	iv
TABLE OF CONTENTS	v
LIST OF TABLE.....	viii
LIST OF FIGURE	ix
ABBREVIATION/ACRONYMS	x
CHAPTER ONE.....	1
1. INTRODUCTION	1
1.1. Background`	1
1.2 Statement of Problem.....	2
1.3. Research Objectives.....	3
1.3.1. General objectives	3
1.3.2. Specific objectives.....	3
1.4. Research Questions.....	4
1.5. Significance of the Study	4
1.6. Scope of the Study	4
1.7. Limitation of the Study	5
1.8. Organization of the thesis	5
CHAPTER TWO.....	6
2. LITERATURE REVIEW	6
2.1. Introduction.....	6
2.2. Concrete Making Material	6
2.2.1. Cement	6
2.2.2. Water	7
2.2.3. Aggregates.....	8
2.3. Production of Fine Aggregate.....	9
2.3.1. Manufactured/ crushed fine aggregate	9
2.3.2. Natural river sand.....	9
2.3.3. Characteristics of fine aggregate	10

2.4. Properties of Concrete.....	13
2.4.1. Fresh Concrete.....	13
2.5.2. Hardened Concrete.....	16
2.6. Environmental and Technical Effect of Fine Aggregate	17
2.6.1. Environmental Effect of Fine Aggregate	17
2.6.2. A Technical Effect of Fine Aggregate	19
2.7. Waste Brick.....	19
2.7.1 Processes of fired clay bricks production.....	20
2.7.2. Chemical and Physical Properties of Brick.....	23
2.8. Laterite sand/soil.....	25
2.8.1. Origin and Formation of Laterite soil	27
2.8.2. Engineering /Physical and Chemical Properties of Laterite Soils.....	27
2.9. Previous Studies on Waste Brick and Laterite Sand.....	28
2.10. Gap Identification	30
CHAPTER THREE	31
3. MATERIALS AND METHODS	31
3.1. General.....	31
3.2. Formulation of the Combination Method	31
3.3. Methodology.....	32
3.4 Material Preparation and Tests	35
3.5. Slump and Compressive Strength Test.....	36
3.6. Chemical Test	36
3.7. Testing for Water Absorption of Concretes.....	36
3.8. Mix Design.....	36
3.9. Preparation of Specimens and Mixing Procedure of Concrete.....	37
3.10. Economic Feasibility	38
3.11. Statistical Analysis.....	38
3.11.1. Factorial ANOVA	38
3.11.2. Hypothesis Testing in Factorial ANOVA	38
3.12. Modeling.....	39
3.13. Data Analysis of Test Results	39
CHAPTER FOUR	41

4. RESULTS AND DISCUSSION.....	41
4.1. Introduction.....	41
4.2. Material Property	41
4.2.1. Cement	41
4.2.2. Aggregate	42
4.2.3. Water	44
4.2.4. Replacing Material	45
4.3. Chemical Composition.....	47
4.4. Concrete Test	49
4.4.1. Fresh Concrete Properties	49
4.4.2. Hardened Concrete Properties.....	50
4.5. Modeling.....	55
4.6. Statistical Analysis.....	59
4.6.1. Significant Factors Affecting the Compressive Strength of Concrete	60
4.6.2. Post-hoc Test	61
4.7. Economic Analysis	66
4.8. Optimization of Replacement of Sand with Waste Brick and Laterite Soil	73
4.9. Summary of the Finding	75
CHAPTER FIVE	77
5. CONCLUSION AND RECOMMENDATION	77
5.1. Conclusion	77
5.2. Recommendation	77
5.3. Further Study Suggestions	78
REFERENCES	79
APPENDE X A: MATERIALS TEST RESULTS.....	84
APPENDE X B: MIX DESIGN	102
APPENDE X C: COMPRESIVE STRENGTH RESULT	111
APPENDE X D: STATISTICAL ANALYSIS RESULT	114
APPENDE X E; SAMPLE GALLERY TAKEN DURING RESEARCH.....	129
APPENDE X F; CHEMICAL ANALYSIS TEST RESULT	137

LIST OF TABLE

Table 2. 1:Chemical composition (%) of natural sand	10
Table 2. 2:BS and ASTM grading requirements of fine aggregate	11
Table 2. 3;Ingredients/oxides of good clay brick	24
Table 2. 4;Average values of the engineering properties of brick pavers	25
Table 2. 5;Physical properties and chemical composition for laterite.....	28
Table 3. 1;Test Specimen	31
Table 3. 2;Test of Aggregate and Test Methods	35
Table 4. 1;Summarized test result for Dangote Cement (OPC)	41
Table 4. 2;Physical properties of river sand	42
Table 4. 3;Physical properties of coarse aggregate	44
Table 4. 4;Physical properties of waste brick.....	45
Table 4. 5;Physical properties of laterite soil	46
Table 4. 6;Complete silicate analysis of waste brick, laterite soil, river sand.....	48
Table 4. 7;Properties of fresh concrete.....	49
Table 4. 8;Summary of mean compressive strength result of different concretes mixes	51
Table 4. 9;Water absorption of the concretes	54
Table 4. 10;Estimated regression coefficient for compressive strength for equal of laterite soil and waste brick.....	56
Table 4. 11;Compressive strength graph for laterites soil to waste brick 1:1 ratio	57
Table 4. 12;Estimated regression coefficients for compressive strength for waste brick twice laterite soil	58
Table 4. 13;Main effect and interaction effects of SPPS test results.....	60
Table 4. 14;Tukey HSD post-hoc analysis of waste brick	61
Table 4. 15;Tukay HSD post-hoc analysis of laterite sand	63
Table 4. 16;Tukey HSD post-hoc analysis of Age	66
Table 4. 17;Unit cost of ingredient in Birr/kg	67
Table 4. 18;Total cost of ingredient material of concrete production in birr/m ³ based on the unit cost of Table 4.17	68
Table 4. 19;Percentage increase /decrease in strength, workability and cost.....	74

LIST OF FIGURE

Figure 2. 1:Typical sand quarrying practices along the Awash Basin and transporting of quarried sand.
 10

Figure 2. 2:Slump, true, shear, and collapse..... 15

Figure 2. 3;World-Wide distribution of laterites soil 26

Figure 3.1: Methodology flow chart..... 34

Figure 4. 1;Gradation curve for river sand 43

Figure 4. 2 Gradation curve for coarse aggregate 44

Figure 4. 3;Gradation curve for waste brick..... 46

Figure 4. 4;Gradation curve for laterites sand 47

Figure 4. 5;Slump test..... 50

Figure 4. 6;Compressive strength of concretes 53

Figure 4. 7;Water absorption of concrete mixes at 28-day age 55

Figure 4. 8;Compressive strength graph for soil to waste brick 2:1 ratio 57

Figure 4. 9;Compressive strength graph for laterite soil to waste brick 1:1 ratio 58

Figure 4. 10;Compressive strength graph for laterite soil to waste brick 1:2 ratio 59

Figure 4. 11;Cost comparison indifferent mix with conventional concrete 73

Figure 4. 12;Percentage increase/decrease in strength, workability and cost mixes% 75

ABBREVIATION/ACRONYMS

ACI	American Concrete Institute
ASTM	American Society for Testing Materials
BS	British standard
DoE	Department of the environment
ERA	Ethiopian Road Authority
FM	Fineness Modulus
HCB	Hollow Concrete Block
OPC	Ordinary Portland Cement
PPC	Portland Pozzolana Cement
W/C	Water to Cement ratio
IS	Indian Standard
RS	River sand
EBCS	Ethiopian Building Code Standard
LoI	Loss of Ignition

CHAPTER ONE

1. INTRODUCTION

1.1. Background`

Almost all commercial activities undertaken in buildings and on highways, airports, rails, and marine systems require concrete. Concrete is the most widely used man-made construction material in the world. Global production of concrete is about 12 billion tons per year, but that number is expected to rise to over 18 billion tons by 2025, thus making it one of the largest users of natural resources in the world. (Jonathan, 2019)

According to (Denamo, 2005) the increasing consumption of concrete by the construction industry has led to the rapid depletion of natural sand and good quality sand is not readily available in most areas of Ethiopia. It must be transported a long distance or contractors use whatever sand is available, which might not meet the necessary standards. Therefore, it is necessary to find a locally abundant supply of natural material, industrial and construction wastes, or demolish work as a substitute. On the other hand, a significant amount of waste is generated with an increase in production, and this waste negatively affects the environment (Tunc, 2019). Sustainable construction was introduced due to the concern for the future of our planet because the construction industry is found to be a huge consumer of natural resources and producer of waste (Cachim, 2009).

Brick is one of the most widely used conventional construction materials throughout the world (Alaa & Ali, 2013). The waste materials of clay bricks usually come in different ways. It may be the mistakes made at the time of production, using inappropriate materials, during transportation, or most common source or large amount is from demolished material. Sometimes, removing this material may need additional costs for cart away (sintayehu & Moges, 2019). This waste may be utilized as a replacement for sand in concrete production.

Laterite soil is tropical soil that is present in parts of Africa, Asia, and America, vary in color but is generally bright highly weathered. Its neglect as an engineering material is linked to uncertainty in its strength and other structural characteristics such as creep, shrinkage, and long-term durability in addition to that the potential benefits derivable from the application of laterite in concrete are improved

residual concrete structure, reduced construction costs, improved resistance to cracking and spalling; superior post yielding and post-cracking behavior (Awolusi et al., 2017). However, these locally available materials have not been tested and approved for use widely in the Ethiopian construction industry.

The main natural and sources of sand are riverbeds and these natural resources are depleting very fast. Transportation, increasing construction activates, land-use conflicts, and environmental problems associated with rapid urban expansion are major factors contributing to these shortages. Also, depletion of the resources leads to the production and supply of poor quality sand that will in turn cause structural defects in concrete production application (Ashwin et.al, 2017). The major sand supply for the construction works in and around Gelan Metahra and Langano. However, 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.

Nowadays there is a scarcity of sand and it becomes a very difficult process to get sand easily in an economical way (Joshua el at., 2016). Overcoming this problem is very essential by finding materials. Hence, the general objective of this project is to evaluate the use of waste brick and laterite sand in partial replacement of riverbed sand in an experimental setup.

1.2 Statement of Problem

Developing countries, like Ethiopia, are facing a shortage of good quality natural sand that satisfies the demand of rapid infrastructure growth (Denamo, 2005). Particularly in Gelan, natural sand deposits are being used up extensively and start causing serious threat the environment as well as the society. Rapid extraction of sand from river beds causes so many environmental problems. The environmental issues caused by fetching river sand are losing water retaining soil strata, deepening the river beds and causing bank slides, loss of vegetation on the bank of rivers, disturbing the aquatic life, and troubling the agriculture due to lowering the water table in the well, etc. (Ajeet & Pankaj, 2016). At present, the construction industry in Ethiopia is facing a serious shortage of sand due to overexploitation and government banning of river sand mining (Denamo, 2005). Waste management has become an unavoidable social concern in modern societies (Lin & Chang, 2013), (Pasetto & Baldo, 2015,). In particular, the building sector provides up to 25% of the total solid waste disposal (United Nations Environment Program, 2009). According to different researchers Liu et al. (2014) and Robayo (2017)

stated that bricks, tiles, and concrete are the materials that contribute the most to construction and demolition waste (CDW) and from this wastes brick residues reach 50% of the total construction and demolition waste and the concrete ones reach around 12%, making these cases special concerns. This kind of waste typically accounts for between 15 and 30% of urban waste (Asmara, 2015).

Laterite is a naturally occurring hard soil widely spread in the tropics and subtropics and approximately 30% of the world's present population still lives in laterite (Biju et al., 2016). This soil is a widely available material in Ethiopia as revealed by the Ethiopian Roads Authority design manual (ERA, 2001). But laterite has used limited construction material as a "fill" for foundation and as a base course for highway construction in Ethiopia (Abebaw, 2005). At present, the construction industry in Ethiopia is facing a serious shortage of sand (Denamo, 2005). Having understood these problems, this study will determine the extent to which waste brick and laterite soil can be substituted for sand and the effect it has on strength, workability, and cost to produce normal strength concrete.

1.3. Research Objectives

1.3.1. General objectives

The general objective of this research is to evaluate the potential of waste brick and laterite soil properties as a sand (natural fine aggregate material) replacement for the production of concrete.

1.3.2. Specific objectives

The specific objectives of this research are:

- ✓ To investigate the chemical composition of waste brick and laterite soil.
- ✓ To analyze workability and compressive strength property of concrete containing different mixes of waste brick and laterite soil.
- ✓ To estimate the cost of waste brick and laterite soil containing concrete about ordinary concrete.

1.4. Research Questions

This research will be conducted to answer the following research questions:

- What is the chemical composition of waste brick and laterite soil?
- What are the workability, durability, and compressive strength property of concrete containing different mixes of waste brick and laterite soil?
- What is the cost of concrete containing waste brick and laterite soil relative to conventional concrete?
- What is the natural sand replacement rate at which waste brick and laterite soil can be effectively substituted for concrete production?

1.5. Significance of the Study

The rapid growth in urbanization in Ethiopia resulted in an increase in the concrete construction industry. Gelan city in particular is expanding significantly in the last decade with an increase in buildings in private citizens. This increase in construction activities resulted in a decrease in availability and quality of sand, an increase in price, and environmental impact. Hence, this study is significant because it investigates the feasibility of using alternative materials (waste brick and laterite sand) as a partial replacement of fine aggregates in concrete without altering the properties of conventional concrete. If successful, it would reduce the negative consequences of using riverbed sand in concrete production, and it also can contribute towards environmental problems and solid waste management.

In addition to that, it is of great significance to engineers and building construction experts, as well as the academia and body of knowledge. This research project also will serve as a reference point to other future researchers and students in related fields of study.

1.6. Scope of the Study

The overall scope of this study was to investigate the workability, strength, and cost of partially replacing sand with waste brick and laterite sand for normal strength concrete. The fresh concrete property of concrete containing waste brick and laterite sand would be examined by slump test to determine workability and hardened concrete property would be examined by compressive strength test to determine compressive strength.

1.7. Limitation of the Study

Due to time, cost, and resource constraints, this research has the following specific scopes:

- ✓ Although the research methodology is applicable anywhere, the materials used (river bed sand, laterite sand, and waste brick) for this study were from within and around Gelan, Ethiopia, and different locations weren't investigated.
- ✓ Even though cement types like PPC and OPC was available, this research were conducted using a cement type of Ordinary Portland cement (OPC 42.5R).
- ✓ Concrete having a compressive strength of 25 MPa (C-25) were used to conduct this research and the property of harden concrete was studied by compressive strength only
- ✓ Tensile and other grades of the concert are not studied.
- ✓ Slump test was the only test done to study the property of fresh concrete.
- ✓ The durability of concrete properties wasn't studied.

1.8. Organization of the thesis

The thesis is organized into five chapters and further break down into different sections and subsections. A general introduction is provided along with the problem statement, scope, and limitation, research objective, and significance in the first chapter. In chapter two, a comprehensive review of concrete, aggregate, brick waste, and laterite soil is presented. Chapter three is entirely describe the methods and materials followed to conduct this research. It explains the properties of materials used for the production of concrete, mix proportions selected, specimen preparation, testing procedures, and method of data analysis used in the attempt to find out in a systematic and scientific study. Chapter four covers the obtained data from the experimental program and discussions of the tests carried out during the study. And chapter five contains conclusions based on the obtained results to develop a practical and reliable method for concrete production using an alternative material. Moreover, some recommendations are suggested for future researchers in this field. This is followed by a list of references. The Appendixes contain the results of the individual tests, other relevant data, and representative photos taken during the research work.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

This chapter provides an overview of studies and literature that investigate concrete constituents, fine aggregate, requirements of river sand for concrete production, environmental and technical defect of river sand, mix design selection, properties of concrete both in the fresh and hardened state, river sand replacement material and finally gap identification we will discuss.

2.2. Concrete Making Material

Concrete, the oldest and the most widely used construction material in the construction of civil engineering structures. It consists of two components: aggregates and paste. The paste, comprised of Portland cement and water, binds the aggregates (usually sand and gravel or crushed stone) into a rocklike mass as the paste hardens because of the chemical reaction of the cement and water. Supplementary cementations materials and chemical admixtures may also be included in the paste (kosmatka et al., 2003). Aggregates, both fine and coarse, take about 65-85% by volume of concrete and are important ingredients in concrete production; their properties affect the properties of concretes the most. Concrete is made to possess different properties by adjusting the proportions and varying the properties of the concrete making materials (Abebe, 2002). Potable water is preferably used since other sources may contain impurities that may bring undesirable effects on the properties of fresh and hardened concrete (kucche et al., 2015).

2.2.1. Cement

Cement is the essential component of concrete which, when hydrated, binds the aggregates together to form the hard, strong, and monolithic whole that is so useful. Well over 95% of the cement used in concrete throughout the world is Portland cement in its various forms. The properties of concrete depend on the quantities and qualities of its constituents. Because cement is the most active component of concrete and usually has the greatest unit cost, its selection and proper use are important in obtaining most economically the balance of properties desired for a particular concrete mixture (Peter & John, 2010).

In engineering, purpose cement are materials which form a paste which sets and harden using hydration reactions, and which after hardening retain its strength and stability even underwater and can be molded or deformed but later it sets and hardens to a rigid mass (Anteneh, 2017).

2.2.1.1. Types of Cement

There are different type of cement can be varied depending on the composition and characteristics of the cement. As a result, the followings are the most common types of cement are Ordinary Portland cement (OPC), Rapid Hardening Portland cement, Sulphate Resisting Portland Cement, Low heat Portland cement, Portland Pozzolana Cement (PPC). But, Ordinary Portland cement and Portland Pozzolana Cements are produced in Ethiopia (Aregaw, 2010).

According to ASTM C595-08, Portland Pozzolana cement is also known as blended hydraulic cement. It is manufactured by blending 10-30% by weight of pozzolanic material with Portland cement: either by simple mixing or by inter-grinding with cement Clinker.

Based on ASTM C85, Specification for Portland cement uses type designations I through V for Portland cement. Type I Portland cement is applicable for any purpose so it is called common or general-purpose cement. But Type II Portland cement provides moderate sulfate resistance and gives off less heat during hydration. This type of cement costs about the same as type I. But tricalcium aluminate contains should not be greater than 8%. Whereas Type III Portland cement is used when high early strength is desired and this type of cement is similar to type I, but ground finer with having specific surface area 50–80% higher. On the other hand Type IV Portland cement is a wall known for its low heat of hydration and this type of cement is with having a maximum of (C3A) is seven percent and the maximum of (C3S) is thirty-five percent. Because of this heat given off by the hydration reaction to develop at a slower rate. Lastly, Type V Portland cement which is used when sulfate resistance is important. And this cement has a small amount of (C3A) composition which accounts for its high sulfate resistance.

2.2.2. Water

Water is one of the ingredients of concrete material in which its quality is important because impurities in it may interfere with the setting of cement, may adversely affect the strength of concrete or cause staining of its surface, and may also lead to corrosion of the reinforcement. In addition to that, health

issues related to the safe handling of such water must be considered. Water serves two purposes in making concrete. First of all, it triggers the hydration of cement, and secondly, it makes the mixed fluid and workable. Almost any water that is drinkable may be used to make concrete (kucch et al., 2015).

The principal considerations on the quality of mixing water are related to performance in fresh as well as harden states. The suitability of water can be identified from past service records or tested to performance limits such as setting times and compressive strength and durability tests. Limits are specified for mixing water with their constituents such as total alkalis, chloride sulfate, etc. Biological treatment and pathogen reductions are also ensuring safety in the handling of reclaimed water and saline water. The quality and quantity of water which we use or concrete production affects the free water/cement ratio that is the most important for control of consistency, strength, and durability of concrete (kucch et al., 2015).

2.2.3. Aggregates

2.2.3.1. General

Aggregates were first considered to simply be filler for concrete to reduce the amount of cement required. However, it is now known that the type of aggregate used for concrete can have considerable effects on the plastic and hardened state properties of concrete. So their properties are crucial to the properties of concrete (Anteneh, 2017).

2.2.3.2. Physical Property of Aggregate

Aggregate constitutes more than three-fourths of the volume of concrete and it affects the property of this mixture. So, if the physical property of aggregate is described it manages the property of concrete as a whole. The physical properties like specific gravity, porosity, thermal behavior, and chemical properties of an aggregate are attributed to the parent material (Abebaw, 2005).

The properties of fresh concrete are more than hardened concrete are affected by the shape, size, and texture of aggregate. Therefore, it is necessary to understand the physical properties of aggregate and its modes of production to produce the required quality of concrete at a minimum price (Abebaw, 2005).

2.3. Production of Fine Aggregate

Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed. Whereas manufactured aggregate is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. But the construction industry utilizes sand mainly from natural sand. (Abebaw, 2005)

2.3.1. Manufactured/ crushed fine aggregate

Manufactured sand is aggregate materials having dimensions less than 5.0mm that are quarry dust or the crushed granite stone that is sieved and made to suit particle size of natural sand to be used as fine aggregate for construction use. However, the engineering properties of Manufacture sand are governed by the source of its raw material, thus their properties can be changed from region to region. The extensive use of manufactured aggregates has been concentrated on regions or projects where the availability of natural aggregates has been limited. And manufactured sand has been used for products and engineering application of premixed concrete with partially and completely replacing the river sand in concrete (Yajurved et al., 2015).

2.3.2. Natural river sand

An individual particle in this range size between gravel and silt is termed a sand grain. And the ideal shape fine aggregate in concrete is natural sand because the natural sand particles are well-rounded and are usually nearly spherical. So, these spherical particles decrease the percentage of voids within the concrete mixture and no additional paste is required to fill these voids. Natural sand does not require more water to enhance the workability of the mixture so the amount of bleed water in the concrete will not be increased. And this sand most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz (Ashenafi, 2018). According to Denamo (2005), in Ethiopia construction industry usually uses river sand and it is the most common one which is made from quartzo-feldspathic basement rock, sandy marine sediments, and alluvial deposits



Figure 2. 1: Typical sand quarrying practices along the Awash Basin and transporting of quarried sand. According to Abebe (2005), natural sand is mainly made of SiO_2 , Al_2O_3 , Fe_2O_3 , CaO , MgO , and Na_2O . And also it is made of minor oxides like K_2O , H_2O , TiO_2 , MnO , and LoI .

Table 2. 1: Chemical composition (%) of natural sand

SiO_2 ,	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	H_2O	TiO_2	MnO	LoI
49	16.1	13.74	8.2	5.4	3.3	0.9	0.8	2.4	0.2	0.7

2.3.3. Characteristics of fine aggregate

The aggregate will have a great influence on the properties concretes and the characteristics of aggregate have different parts of particle size, shape, and texture, specific gravity and bulk density, absorption, and Moisture Content, etc. As a result of this, the properties of the aggregate have a significant effect on concrete properties in both the fresh and hardened concrete state. So, it is important to examine whether those aggregates fit for which is planned to be used and tests on-site and laboratory should have to be made. Some of the characteristics listed below:

2.3.3.1. Specific gravity

According to ASTM C 127-84, specific gravity is defined as the ratio of mass (or weight in air) of a unit volume of material to the mass of the same volume of water at the stated temperature. Aggregates contain pores in their structure. Therefore, the specific gravity depends on whether the pores are included in the measurement or not (Kosmatka et al., 2003).

2.3.3.2. Sieve analysis

Sieve analysis is the process of dividing a sample of aggregate into fractions of the same particle size and its purpose is to determine the grading or size distribution of the aggregate (Kosmatka et al, 2003).

The grading determines the paste requirement for a workable concrete since the amount of void requires needs to be filled by the same amount of cement paste in a concrete mixture. To obtain a grading curve for aggregate, sieve analysis will be conduct. According to ES C.D3.201, BS882, and ASTM the grading requirement of fine aggregate, is summarized as shown in Table 2.2.

Table 2. 2: BS and ASTM grading requirements of fine aggregate

Sieve size	Percentage of passing %				ASTM Standards (C33-78)
	BS882:1973				
	Grading zone 1	Grading zone 2	Grading zone 3	Grading zone 4	
9.5 mm	100	100	100	100	100
4.75 mm	90-100	90-100	95-100	95-100	95-100
1.18 mm	60-95	75-100	85-100	95-100	80-100
600 μm	30-70	55-90	75-100	90-100	50-85
600 μm	15-34	35-59	60-79	80-100	25-60
300 μm	5-20	8-30	12-40	15-50	5-30
150 μm	0-10	0-10	0-10	0-15	0-10

2.3.3.3. Fineness modulus

Based on the sieve analysis results, a numerical index called the fineness modulus (FM) is often computed. According to ASTM125, the fineness Modulus is the sum of the total percentages coarser than each of a specified series of sieves, divided by 100. The specified sieves used for FM are 9.5 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600 μ m, 300 μ m, and 150 μ m (No. 4, 8, 16, 30, 50, and 100). Note that the lower limit of the specified series of sieves is the 150 μ m (No. 100) sieve.

The coarser the aggregate size, the higher the FM. For fine aggregate used in concrete, the FM generally ranges from 2.3 to 3.1 as called for in ASTM C 33 (ACI Committee). It is used as an index to the fineness, coarseness, and uniformity of aggregates. These properties of the aggregate significantly affect the property of the concrete, but it is not an indication of grading since there could be an infinite number of grading the will produce a given fineness modulus (Anteneh, 2017).

2.3.3.4. Bulk density

Bulk density is the mass of a unit volume of bulk aggregate material, in which the volume includes the volume of individual particles and the volume of the voids among the particles, and it is expressed in a unit Kg/m³. However, the degree of tamping or time vibration will change the amount of void space. The bulk density depends on how densely the aggregate is packed and consequently, on the size distribution and shape of the particles. Thus, for the best purposes, the degree of compaction has to be specified (ASTM 29).

2.3.3.5. Fine materials

Among factors that affect the quality of concrete are sand fines which are materials that pass through the 75 μ m sieve. These fines are considered as an impurity in the sand in the BS882:1992. The presence of sand fines in concrete is likely to affect the workability, strength, and long-term performance of concrete (Anteneh, 2017). To this effect, the percentage limits of fines are recommended by various building standards in other to check their effects on the strength of concrete. Some of these are the British Standards (BS), and the American Standard for Testing and Materials (ASTM) C117 - 95 which recommends 4% and 10% of fines in sand respectively.

A simple test that can be made on-site to give a guide to the amount of silt in the natural sand is the 'field settling' test. This test should not be used for crushed rock sands. 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, 2002).

2.3.3.6. Moisture Content

Aggregates exposed to rain collect considerable amounts of moisture on the surface of the particles, and, except at the surface of the stockpile keeps this moisture for a long period. The moisture content must be allowed for in the calculation of batch quantities and the total water requirements of the mix (Ashenafi, 2018).

The aggregates in concrete are assumed to be inert materials. But most of the aggregates do not meet this assumption by either absorbing water (dry aggregates) or by releasing it (wet aggregates) to the mix. As a result of this property of aggregates the design water to cement ratio of the mix changes (Ashenafi, 2018). Therefore, it is important into determine both the absorption capacity and the moisture content of the aggregate. The moisture content of fine aggregates was determined by oven drying a sample of fine aggregate (500gm) in an oven at a temperature of 110°C for 24hrs and dividing the weight difference by the oven-dry weight.

2.4. Properties of Concrete

2.4.1. Fresh Concrete

Fresh concrete is defined as concrete at the state when its components are fully mixed but its strength has not yet developed. It directly influences the handling, placing, and compaction of fresh concrete as well as hardened concrete (Anteneh, 2017).

2.4.1.1. Workability

Workability is the property of freshly mixed concrete. And the ease of placing, such as its cohesiveness, mobility, compatibility, consolidating, finishing, freshly mixed concrete, and the degree to which it resists segregation is called workability (Kosmatk et al., 2003).

Furthermore, the desired workability in any particular case would depend on the means of compaction available: likewise, workability suitable for mass concrete is not necessarily sufficient for thin inaccessible or heavily reinforced sections (Nevil, 2011). There are different measurements of workability such as slump test (ASTM C143), compaction factor test (BS 1881), Vebe test (BS 1881). Factors affecting workability are water content, aggregate mix proportion, maximum aggregate size, aggregate physical properties, admixture, temperature, and time.

For a given fixed w/c ratio, an increase in the aggregate/cement ratio will decrease the fluidity. Also, a higher fine aggregate/coarse ratio leads to a higher cohesiveness. For a given w/c ratio, as the maximum size of the aggregate increase, the fluidity increases. This is generally due to the overall reduction in surface area of the aggregate. And also the shape and texture of aggregate particles can affect workability. As a general rule, the more nearly spherical and smoother the particles, the more workable the concrete. As the temperature increases the workability decrease, besides, workability decreases in time. These effects are related to the progress in the chemical reaction (Charles, 2019).

I. Slump

A slump test is the most commonly used method of measuring the workability of fresh concrete both in the field and in the laboratory. Which was conducted based on ASTM standard ASTM C143. The decrease in the height of the center of the slumped concrete is called slump and is measured to the nearest 5 mm to reduce the influence on the slump of the variation on the surface friction (Nevil, 2011). Three different kinds of possible slumps exist; true slump, shear slump, and collapse slump as shown in Figure2-2.

✓ **True slump:** It has slumping of evenly all around, this type of slump indicates a well-proportioned concrete.

✓ **Shear slump:** One-half of the cone slides down an inclined plane, and the test should be repeated.

✓ **Collapse Slump:** Difficult to measure, results from very wet mixes. Usually, when shear collapse or collapse slump occurred, the test is considered invalid (Nevil, 2011).

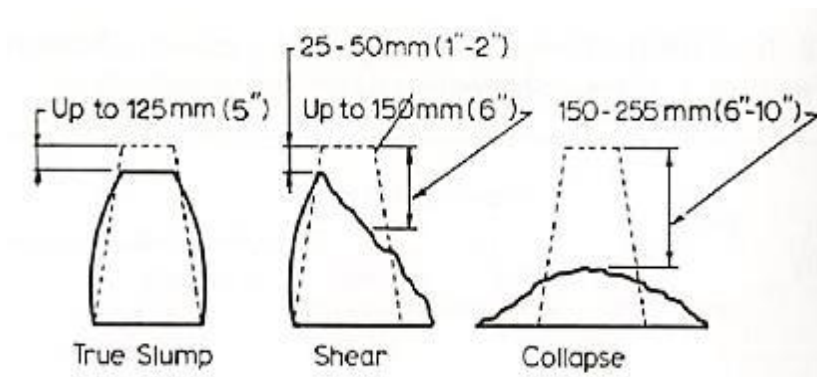


Figure 2. 2: Slump, true, shear, and collapse

2.4.1.2. Consistency

Consistency is a term used to describe the ease with which concrete will flow or the degree of wetness of the concrete and can be defined by such terms as dry, plastic, fluid, or wet. The concrete of plastic consistency can be shaped into a ball, while that of semi-fluid consistency spreads out slowly and without segregation of aggregate. The concrete of fluid consistency spreads out fast and results in segregation of aggregates, and hence unacceptable (Ashenafi, 2018).

2.4.1.3. Segregation

Segregation is the separation of concrete ingredients from the concrete mix maybe this separation is coarse aggregates or cement paste from the mass of concrete, this is the result of:

- ✓ Improper pumping of the concrete mix
- ✓ Dropping of concrete from height place.
- ✓ Placing of the concrete underwater.
- ✓ Placing concrete in congested reinforced members (Ashenafi, 2018).

2.4.1.4. Bleeding

Bleeding is the separation of water from the concrete mix. This is due to aggregate settle down and water rise. As a result of this concrete will be weak, porous, and loses its homogeneity (Ashenafi, 2018).

2.4.1.5. Stiffening and Setting

Mixing of cement, aggregates, and water completely plastic for the time before sets and in time it will harden. But it is required to remain plastic for the time to be taken to transport, place, and consolidate it. Heat and temperature speed up the setting and Stiffening of concrete and the reverse slows it down and can even completely stop the processes (Ashenafi, 2018).

2.5.2. Hardened Concrete

The main properties of hardened concrete are strength and durability even though curing, density, permeability, and water tightness highly affect the hardened property of concrete.

2.5.2.1. Strength

Strength is defined as the ability of a material to resist stress without failure. The 28-days compressive strength of concrete is determined by a standard uniaxial compression test that is universally accepted as a general index of concrete strength (Charles, 2019). The strength of concrete is measured using compressive strength testing machine by crushing both cube and cylinder specimens. Factors affecting concrete strength are water-cement ratio (W/C), age, curing condition, the property of aggregate, and admixtures.

The density of hardened concrete is governed by the water/cement ratio. With higher w/c, the paste is more porous and hence the strength is lower. In addition, the strength continues to increase with decreasing w/c ratio only if the concrete can be fully compacted (Charles, 2019).

If concrete is properly cured, the strength increases with time due to the increased degree of hydration. As a rule of thumb, for type, I cement, the 7 days and strength can range from 60-80% of the 28 days strength, with a higher percentage for a lower w/c ratio. After 28 days, the strength can continue to go up. For the same w/c ratio, mixes with larger aggregates give lower strength. This is due to the presence of a weak zone at the aggregate/paste interface, where cracking will first occur (Charles, 2019).

I. Compressive strength test

Compressive strength may be defined as the measured maximum resistance of a concrete specimen to axial loading. It is generally expressed in mega pascal (MPa) or at an age of 28 days (Kosmatka et al., 2003). There are three types of compression test specimens are used: cubes, cylinders, and prisms. Cubes are the most commonly used in the United Kingdom and other countries, which have a standard similar to that of BS, like Ethiopia. A standard cube (150mm×150mm×150mm) is used for a test as per BS 1881-116 standard and concrete cubes cast and tested by a compressive strength testing machine.

2.5.2.2. Durability

Durability is the long-term strength of the concrete and ability to resist weathering action, chemical attack, abrasion, and any other deterioration and hence to retain its original shape, dimension, quality, and serviceability (Nevil, 2011). Water absorption is directly related to concrete's resistance to water penetration; water can carry many deleterious agents from the surrounding environment, so water penetration plays an important role in various deterioration mechanisms. Water absorption permits the transport of chloride, oxygen, and carbon dioxide, which cause corrosion of reinforcing steel in concrete. Therefore, the water absorption of concrete should be determined properly to predict the durability of concrete (Safiuddin et al., 2011).

Water absorption can be determined based on the increase in the mass of concrete specimens when saturated. The specimens become saturated because of the penetration of water into their open pores. The saturated condition can be achieved by applying ASTM saturation techniques. ASTM C642 presents cold water and boiling water saturation techniques to measure the water absorption of concrete (Safiuddin et al., 2011). Water absorption of most good concretes is below 10% by mass (Neville, 2008).

2.6. Environmental and Technical Effect of Fine Aggregate

2.6.1. Environmental Effect of Fine Aggregate

The sand was used as an aggregate material for different civil constructions from ancient times until now. This resource has been used intensively. And also the cost increases and the resource become depleted. So this valuable natural resource must be used carefully and sensibly (Marius, 2017).

Sand mining is a global activity in both developed and developing countries exploiting sand from different sources has multiple benefits (poverty reduction, economic growth new habitats for plants and animals, new water reservoirs are created, etc.) and a series of negative impacts on the environment. The environmental effects of natural river sand mining can be broadly classified into six categories (Marius, 2017).

A. Effect on Air

The extraction of sand will increase the level of air pollution this air pollution will make human life at risk.

B. Effect on Flora and Fauna

Sand mining will destroy vegetation, physical disturbance of the habitat, and habitat loss. Because of this alteration on the fish population, increasing level of weed infestation, degradation of aquatic biota, alter the number of animal species, and reduction of farmlands and grazing lands.

C. Effect on Water

It increases water turbidity, water pollution, sinking, deformation of riverbeds and banks, affects hydrological function increase soil and coastal erosion, and water quality deterioration. This has its consequence like decrease plant photosynthetic activity, changes in nutrient parameters, disturbing feeding activity for different aquatic animal species, reduce light penetration and oxygen levels that can affect aquatic animals activities and composition of phytoplankton, affect spawning and hatching, affect aquatic animals respiration (cause respiratory distress), increase infections and death risk for aquatic animals, redistribution of fine particles in the water, seawater intrusion, affect infrastructure projects, increase water salinity, alteration of water sources, increase water treatment, cost change in water flows, flood regulation and marine currents, etc.

D. Effect on Soil

The mining of sand leads to a decrease in soil quality and soil erosion. Because of this increase in dark areas (fertile land became infertile due to lowering groundwater levels), changes in soil geochemistry

(increase the concentration of lead, arsenic, mercury, etc.), and watercourses, wetlands, and lakes pollution.

E. Effect on Land

The large-scale extraction of streambed materials, mining, and dredging increases the effect on landscape disturbance, mine-induced seismicity, and structures stability. These impacts may cause a dramatic change in the landscape, deforestation, loss of bathing beaches, decrease sand reserve for natural beach storm response, and damage to the public and private property.

2.6.2. A Technical Effect of Fine Aggregate

The natural fine aggregate affects concrete production technically. Some of the technical effects that affect concrete mixtures are shown below (Anteneh, 2017).

- ✓ The amount of containing fine particles affects the mix ratio and strength of concrete.
- ✓ Containing organic and soluble compounds affect the setting time and properties of cement.
- ✓ Containing impurities and clay particles that affect the amount of water and bonding between cement and aggregate.
- ✓ The presence of organic materials affects the durability of the concrete; therefore, it shortens the life of the concrete product.

2.7. Waste Brick

Brick is one of the oldest manufactured building materials in the world. As early as 14,000 BC, hand-molded and sun-dried clay bricks were found in the lower layers of Nile deposits in Egypt (Aeslina & Noor, 2012).

The term brick refers to small units of building material, often made from fired clay and secured with mortar, a bonding agent comprising of cement, sand, and water. Long a popular material, brick retains heat, with-stands corrosion, and resists fire. Moreover, with minimal upkeep, brick buildings generally last a long time. And brick is a type of block used to make walls, pavements, and other elements in masonry construction. Traditionally, the term brick referred to a unit composed of fired clay, but it is now used to denote rectangular units made of clay-bearing soil, sand, and lime, or concrete materials. Bricks can be joined together using mortar, adhesives, or interlocking them.

According to Hariharan and Jebarj (2018), the production of bricks depends on numerous classes, types, materials, and sizes which vary with region and period, and are produced in bulk quantities. Basically, there are two types of bricks these are fired and non-fired bricks.

A brick remains highly competitive technically and economically, with other systems of structure and field. The main raw material for bricks is clay besides clayey soils, soft slate, and shale, which are usually obtained from open pits with the attendance of disruption of drainage, vegetation, and wildlife habitat (Hendry and Khalaf, 2001). Clays used for brick making vary broadly in their composition and are dependent on the locality from which the soil originates. Different proportions of clays are composed mainly of silica, alumina, lime, iron, manganese, sulphur, and phosphates (Aeslina & Noor, 2012) .

The most common building material used for decades are bricks for the construction of houses and different structures. A replacement need occurred as natural sand is a limited natural resource and brick debris can be crushed in a crusher and used as fine or coarse aggregate. Brick is a commonly used construction material and can be found in different types. Spent fire bricks are the bricks that are disposed of after use. This spent fire brick waste should be disposed of properly without creating environmental and different problems in the area. Commonly these brick wastes are dumped by land filling. Bricks are also used as land filling material. Brick waste used as fine or coarse aggregate is easily available, cheap, and enhances strength in mortar and concrete. It also affects the different properties in the fresh state and hardened state of the concrete and mortar (Anayat & Shamshad, 2019).

2.7.1 Processes of fired clay bricks production

Bricks mainly are composed of clay, a group of surface minerals that arise from the weathering of igneous rocks. Natural clay minerals, including kaolin and shale, make up the main body of brick. Small amounts of manganese, barium, and other additives are blended with the clay to produce different shades, and barium carbonate is used to improve brick's chemical resistance to the elements. Many other additives have been used in brick, including byproducts from papermaking, ammonium compounds, wetting agents, flocculents (which cause particles to form loose clusters), and deflocculents (which disperse such clusters). Some clay requires the addition of sand or grog (Hall, 1990), (Richards, 1990).

The colour and surface texture of brick can be getting through a wide variety of coating materials and methods are used. The most common method of coating is mechanically mixed with some type of colourant. Not commonly but a flux or frit (a glass containing colourants) also is added to produce surface textures. Because the flux lowers the melting temperature of the sand so it can bond to the brick surface. On the other hand, other materials including graded fired and unfired brick, nepheline syenite, and graded aggregate can be used as well. By itself, clay is not useless making bricks of plain clay and drying them in the sun makes a sturdy building "stone." Having some sand in the mix helps keep these bricks from cracking (Hall, 1990). (Richards, 1990).

The current technologies have been developed greatly in every aspect but the current clay bricks basic production isn't far from the old production. The new development of clay bricks production is mainly associated with replacing intensive human labour. And firing temperature optimization by using energy-saving kilns and proper firing temperature management in the kiln improves the product quality and optimizes production cost (Altayework, 2013).

Brick production has six steps: 1) mining and storage of raw materials, 2) preparing raw materials, 3) forming the bricks, 4) drying, 5) firing and cooling and 6) De-hacking (Brick Industry Association, 2016).

2.7.1.1. Mining and storage of raw materials

The profitability of brick production is mainly dependent on brick factories' location closeness to the raw material supplies because this increases their production costs. The production cost of brick includes (U.S. Environmental protection agency, 2003)

- ✓ Equipment cost and installation
- ✓ Energy costs which are the costs for the firing of bricks
- ✓ Labour costs include wage and incentives
- ✓ Materials cost like inputs such as clay minerals, parts, and additives.

Planning is necessary for brick factories because the raw material location will increase production costs. As a result of this most brick factories are built near the raw material sources. Moreover,

continuous brick production regardless of weather conditions is ensured by storing sufficient quantities of raw materials required for many days of operation.

2.7.1.2. Preparation

Drying with air, blending, mixing, and crushing the raw materials are included in the preparation stage. To make the ingredient well-graded it is necessary to crush the raw materials to reduce the oversized particles of the raw materials. The fineness of the clay affects the external appearance of the finished clay, compressive strength, and water absorption of brick

2.7.1.3. Forming.

Forming of brick has three principal processes this are stiff-mud, soft-mud, and dry-press and this forming will begin by tempering, is forming processes, produces a homogeneous, plastic clay mass and this is achieved by adding water to the clay until it becomes plastic which makes it to be shaped to the desired sizes.

A. Soft-Mud Process

For clays having a high index of plasticity needs a soft mud process rather than the other process. So the amount of mixing water for clay soils is between 20 to 30%.

B. Stiff-Mud Process

Are a brick making process and the amount of water used for mixing the clay soils is in the range of 10 to 15% in which a stiff mixture of water and clay is extruded in a continuous column through a die and individual bricks are cut by wires or automatic cutter from the column.

C. Dry-Press Process

This process is chiefly suited to clays of very low plasticity. Clay is mixed with a minimum amount of water (up to 10 percent), then pressed into moulds under pressure. But in addition to these forming processes, it requires to use of the amount of water for mixing based on the plasticity index of the raw materials.

2.7.1.4 Drying.

Before the burning of bricks, it is necessary to be dry in an open area having sufficient air to reduce the large percentage of moisture content in green brick, but the drying area may be in dryer chambers or they can be dried in the open shed where there is sufficient place for drying.

2.7.1.5 Firing and cooling

A. Firing

Definition of firing Standard terminology of structural clay products of ASTM C 43-98a express firing as follows (ASTM standards,1999): -

Firing is the process of heating material to elevated temperatures. The temperatures are usually more than 930°C . The extent of firing is a key step in the manufacturing of dry brick because it controls their properties. The materials experience irreversible structural changes reaching the proper brick structure and inter-particulate bond that is responsible for the final properties of the product. And the process of firing is accompanied by shrinkage and colour change.

B. Cooling

The fired brick will be cooled for the final stage of firing in the kiln.

2.7.1.6. De-hacking

This process is making the cooled brick to be sorted, graded, and packaged to be placed in storage for delivery. The clay bricks production processes in the surveyed brick factories are similar to the above processes. But the factories use old machines and methods of production.

2.7.2. Chemical and Physical Properties of Brick

2.7.2.1. Chemical Properties of Brick

Brick is composed of silica (SiO_2), Alumina (Al_2O_3), and water (H_2O) plus an appreciable concentration of oxides of iron, alkali, and alkaline earth, and contains groups of crystalline substances known as clay minerals such as quartz, feldspar, and mica (Kae et al., 2010).

Table 2. 3; Ingredients/oxides of good clay brick

No.	Ingredients/oxides	Proportions (%)	Remark
1	Silica (SiO ₂)	50–60%	
2	Alumina (Al ₂ O ₃)	20-30%	
3	Lime(CaO)	10%	
4	Magnesia(MgO)	<1%	The sum of these ingredients is less than 20%
5	Ferric Oxide(Fe ₂ O ₃)	<7%	
6	Alkalis (NaOH,KOH,....)	10%	
7	Carbon dioxide(CO ₂)		Very small percentage
8	Sulphur trioxide (SO ₃)		
9	Water (H ₂ O)		

The Iron contains in the clay soil will determine the redness colour of most bricks. Other elements including sodium, calcium, and potassium help the silica melt more easily—that is, they act as a flux. All of these are natural parts of many clay deposits (The McGrawHill Companies, 2004).

2.7.2.2. Physical Properties of Waste Brick

Brick is durable and has developed with time. It remains highly competitive technically and economically, with other systems of structure and field (Hendry and Khalaf, 2001).

Table 2. 4; Average values of the engineering properties of brick pavers

Dry density (kg m-3)	Minimum Compressive strength,	Water absorption (%)	Specific gravity
747.7	8.6	21- No limit	2.33

2.8. Laterite sand/soil

According to Abdul et al. (2014), laterite is a soil formed by the effects of place, environment, and this soil is a highly weathered natural material formed by the concentration of hydrated oxides of iron and aluminum, because of this the soil is rich in iron and aluminum in addition to the main mineralogical composition of the rock further oxidized to form an insoluble precipitate of fine particles. Further concentration, dehydration, and subsequent cementation form hard concretionary nodules or the coalescence of particles into a hard vesicular mass of honeycomb structure where cavities may contain the host soil.

Mohammed (2018) stated that laterite soils have some degree of cohesion and a reasonable angle of internal friction. It has been discovered to be an alternative base material due to its consequent strength development in compaction at appropriate moisture contents. And the major property of laterite is its cohesiveness or plasticity i.e. the ability of a soil to accept and retain moisture without deforming or crumbling. This kind of soil is relatively cheaper and easier to get and to explore as a raw material in road construction and building engineering thought in its natural state.

Laterite from the engineering perspective is all the reddish residuals and non-residual tropically weathered soils which generally form a chain of materials ranging from decomposed rock through clays to sesquioxide rich crusts, generally known as curasse or currapace. But necessarily it doesn't mean all laterites are red. So the continuous varying proportions of iron can identify them and aluminium oxides present in the soil as clay materials and show more resistance to weathering than non-lateritic soils (Mohammed, 2018) .

The special characteristics of laterites, by which they differ from other soils, are:

- ✚ Soft occurrences tend to harden on exposure to air, which is why blocks have traditionally been cut in situ, allowed to harden, and then used for masonry wall construction.
- ✚ The darker the laterite, the harder, heavier, and more resistant to moisture it is.
- ✚ Some laterites are found to have a pozzolanic reaction when mixed with lime (which can be explained by the high clay content), producing hard and durable building materials (Joshua et al., 2016).

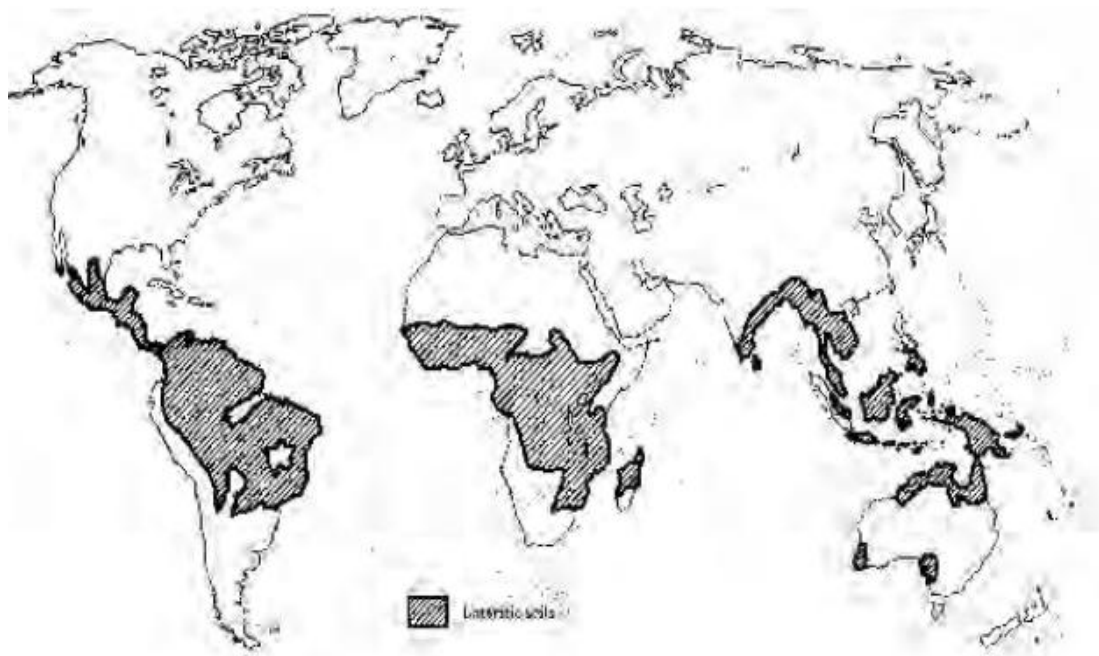


Figure 2. 3; World-Wide distribution of laterites soil

2.8.1. Origin and Formation of Laterite soil

Laterite soils are formed in hot, wet tropical regions with annual rainfall between 750mm to 3000mm, having a largely dry season. Based on the above discussion, the three major processes responsible for the formation of laterites can be summarized as follows (Abebaw, 2005).

2.8.1.1. Decomposition, Latinization, and Desiccation

Physico-chemical breakdown of primary minerals and the release of constituent elements (SiO_2 , Al_2O_3 , Fe_2O_3 , CaO , MgO , K_2O , Na_2O , etc), which appear in simple ionic forms. Leaching under appropriate conditions, of combined silica and bases and the relative accumulation or enrichment of Oxides and Hydroxides of Sesquioxides (Fe_2O_3 , Al_2O_3 , and TiO_2). The soil conditions under which the various elements are rendered soluble and removed through leaching or combination with other substances depend mainly on the pH of the ground water and the drainage conditions.

Desiccation or dehydration involves partial or complete dehydration (sometimes involving hardening) of the Sesquioxide rich materials and secondary minerals. The dehydration of colloidal hydrated Iron oxide involves loss of water and the concentration and crystallization of the amorphous Iron colloids into dense crystals, in the sequence; Limonite, Goethite with Hematite to Hematite (Hamilton, 1964). Dehydration may be caused by climatic changes, the upheaval of the land, or may also be induced by human activities, for example by clearing of forests.

2.8.2. Engineering /Physical and Chemical Properties of Laterite Soils

Laterite is a residual material and chemically it is a soil having the ratios of silica to sesquioxide represented by the molecular silica-alumina ratio: $\text{SiO}_2/(\text{Fe}_2\text{O}_3+\text{Al}_2\text{O}_3)$, in the range of 1.33 – 2.0, for classification of laterite soils, where ratios less than 1.33 are considered indicative of true laterites, those between 1.33 and 2 indicate laterite soils and those greater than 2 are non-laterite tropically weathered soils (Mohammed, 2018).

- Lateritic clays < 0.002 mm
- Lateritic silts = 0.002 ~ 0.06 mm
- Lateritic sands = 0.06 ~ 2 mm
- Lateritic gravels = 2 ~ 60 mm

➤ And cuirasses > 60 mm (Abebaw, 2005).

Table 2. 5; Physical properties and chemical composition for laterite

Engineering & Physical Properties (Laterite)	value	Chemical composition	Value (%)
Specific gravity	2.15-2.63	SiO ₂	21.55
Bulk dry density (kg/ m ³)	1330	Al ₂ O ₃	24.30
		Fe ₂ O ₃	29.4
		Na ₂ O	0.07
		K ₂ O	0.11
		P ₂ O ₅	16.71
		SO ₃	3.98
		CO ₂	3.65

2.9. Previous Studies on Waste Brick and Laterite Sand

Usha and Martina (2016); aimed to investigate the suitability of using crushed brick in concrete. Crushed brick originated from demolished masonry was crushed in the laboratory and added partial sand replacement. Three replacement levels, 15%, 20%, and 25%, were compared with the control. The tests on concrete showed that the mechanical properties (compressive, flexural, and splitting tensile strengths) of concrete containing crushed brick were well comparable to those of the concrete without ground brick. The main focus of the research is to present additional information in the field of

recycling clay masonry rubbles to explore the possible uses of these recyclable materials in structural applications.

Saidi et al. (2015) also study investigate the use of the refractory brick wastes (with high specific) obtained from local cement industry (furnaces) in mortar by partial substitution of natural sand at different content (0,10, 20, 30, and 50 wt.%). They have studied the thermal behavior of these mortars at different cycles (20, 600, 700, 900, 1,010, and 1,100°C for 8 h). The mechanical tests obtained by these authors have shown that the resistance increases with an increase in the replacement level (20%) of refractory brick waste (RBW) by sand substitution. According to their study, a non-significant reduction in density was remarked for the specimens with 20% of RBW with the temperature increase.

Naceri et al. (2009); showed that the quantity of pozzalanic admixture (waste brick) of cement manufacturing is the principal parameter that influences the variation of the physic-chemical properties of the cement tested. This paper presents a preliminary study on the assessment of the pozzolanic activity of waste bricks powder as well as its potential use in concrete as a partial replacement of cement. A series of tests were conducted to study the pozzolanic activity and the compressive strength tests were to monitor the strength development of the concrete at different ages containing from 5 to 50 percent bricks powder as cement replacement.

Biju et al. (2014): In this investigation, a study was conducted to determine the suitability of partial replacement of sand with laterite soil and manufactured sand in M20 grade concrete. Concrete mixes containing 0%, 10%, 20%, 30%, and 40% sand replacement levels were cast, with super plasticizer. Split tensile strength, compressive strength test, and flexural strength test were conducted. Results show a maximum of 20% replacement levels of sand by laterite attained workable concrete with satisfactory strength.

Afolayan et al, (2019); A study investigating the structural characteristics of concrete containing lateritic aggregate as partial coarse aggregate replacement. The coarse aggregate was replaced by 10, 20, 30, 40, and 50% with lateritic aggregate. All the specimens were cured and compressive strength tests were carried out at the age of 7, 14, 21, and 28 days respectively. The result revealed that replacement of lateritic aggregate up to 30% was able to produce lateritic concrete exhibiting the target strength which is 30 N/mm².

2.10. Gap Identification

Previous researchers conducted a variety of studies on waste brick and laterite soil as substitutions for cement, coarse aggregate, and fine aggregate, but no research has been done by combining both waste brick and laterite sand. Laterite soil and waste brick are known to reduce workability, because of their porosity. Since laterite soils improve resistance to spalling, superior post-yielding, and post-cracking behavior. According to Chen et al. (2019) waste brick meanwhile has water demand it helps as an internal curing agent. So by combining the two the reliance on conventional coarse and fine aggregate can be reduced. In addition to that, both waste brick and laterite sand will reduce the self weight of the concrete.

Laterite soil is highly abundant in Ethiopia, however, there is a lack of confidence in laterite soil for structural purposes. So, it is mostly used in road construction and for earthwork, and on the other hand, in a brick factory, demolish works and construction sites produce a huge amount of brick wastes. This study will determine the extent to which waste brick and laterite sand can be substituted for other fine aggregates and the effect it has on strength, durability, workability, and cost.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. General

The research was conducted at the Akakipoli technic college construction material laboratory and the Ethiopian Road Authority (ERA). This research aimed to investigate the workability, durability, strength, and cost of partially replacing sand with waste brick and laterite soil for normal strength concrete. Compressive strength having 25 Mpa was used for concrete production. The materials used in the investigation were described to their source and physical properties for waste brick and laterite soil, and chemical analysis was conducted at the Ethiopian Geological Survey Laboratory. The proportions of cement, water, and coarse aggregate in the control mix were held constant in all the test mixes while the amount of waste brick, laterite soil, and river sand was variable.

A total of 117 (150mm×150mm×150mm) concrete cubes will be poured and tested based on the EBS2:1995 standard. waste brick: laterite soil ratio of 2:1, 1:1, and 1:2 will be used, and then the combined level of both waste brick, laterite soil increase from 33 to 50 to 67 to 100% to substitute natural sand. This setup yields 13 different sets of a mix including the control concrete. Each concrete cubes will be prepared by applying a compressive strength of 25 Mpa (C-25). The cement content for all mixes will be 394 kg/m³. The workability of each fresh concrete mix will be checked immediately following the mixing. Table.3.6. shows the mix proportioning. Compressive strength tests will be carried out at three ages of concrete (3 days, 7 days, and 28 days). Water absorption will be carried out at the ages of concrete 28 days to check the durability of the concrete. No admixture will be used for this research.

3.2. Formulation of the Combination Method

There are 13 different sets of mixes including the control mix used for the investigations with a constant water-cement ratio of 0.49 and slump range between 75-100 mm. Waste brick: Laterite soil ratio of 2:1, 1:1, and 1:2 used, and then the combined level of Waste brick: Laterite soil increase from 33, 50, 67 to 100%. Table3.1 shows the proportioning and test specimens. According to EBS2:1995 to determine compressive strength minimum of 3 cubes should be taken.

Table 3. 1; Test Specimen

	w/c	Sand (%)	Waste brick (%)	Laterite soil (%)	Number of cubes			Total
					3 day	7 day	28 day	
Mix 1	Constant	100	0	0	3	3	3	9
Mix 2		67	11	22	3	3	3	9
Mix 3		67	16.5	16.5	3	3	3	9
Mix 4		67	22	11	3	3	3	9
Mix 5		50	17	33	3	3	3	9
Mix 6		50	25	25	3	3	3	9
Mix 7		50	33	17	3	3	3	9
Mix 8		33	22	45	3	3	3	9
Mix 9		33	33.5	33.5	3	3	3	9
Mix 10		33	45	22	3	3	3	9
Mix 11		0	33	67	3	3	3	9
Mix 12		0	50	50	3	3	3	9
Mix 13		0	67	33	3	3	3	9
Total								117

3.3. Methodology

Stage 1: A Literature review

A comprehensive review of the published and unpublished work from secondary sources of data in the areas of specific interest to the topic was used to understand the previous efforts and the laboratory testing procedures.

Stage 2: Experimental Setup

1. Material properties of concrete ingredients like cement tests, absorption capacity, moisture content, specific gravity, gradation, and silt content were conducted.

2. Mineralogical composition of waste brick and laterite soil was conducted.
3. Different mixes targeting at characteristics compressive strength of 25 MPa were also made.

Each grade of concrete will be prepared with thirteen different mix proportions: the first with 100% river sand used as a control mix, the second with 67% river sand, 11% waste brick, and 22% laterite soil, the third with 67% river sand, 16.5% waste brick and 16.5 % laterite soil and the rest with the partial replacement of river sand with 17%, 22%, 25%, 33%, 33.5%, 45%, 50% and 67% of waste brick and laterite soil.

The rest ingredients are constant.

For the compressive strength test, nine 150*150*150mm cubes were cast for the 3rd, 7th, and 28th days.

4. The durability of the concretes was studied through water absorption.
5. based on the result and discussion conclusions and recommendations were drawn.

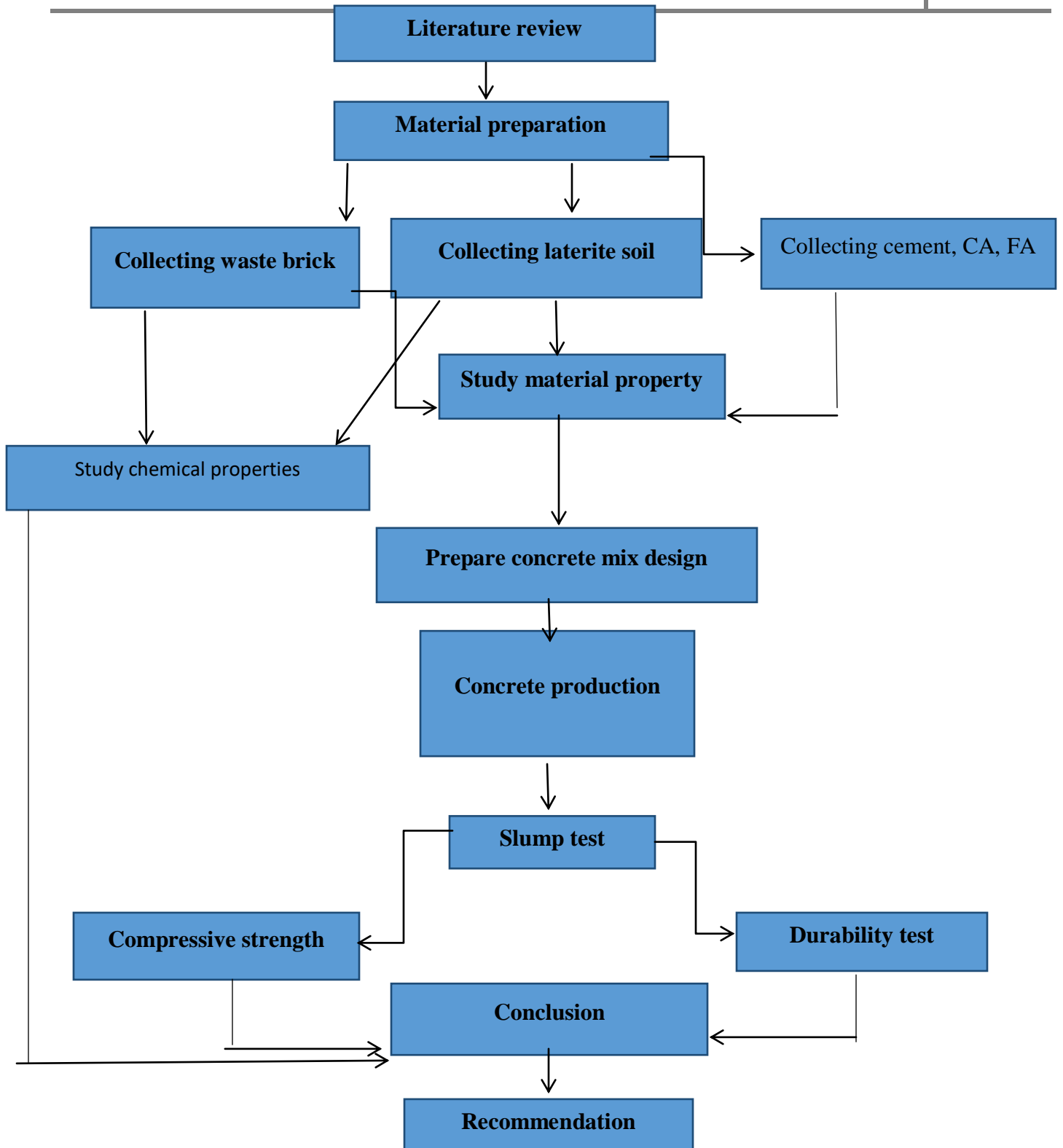


Figure 3.1: Methodology flow chart

3.4 Material Preparation and Tests

- ✓ **Cement:** Ordinary Portland cement (OPC) 42.5 R grade made by Dangote cement factory, which is available in the local market, is used. This cement is equivalent to ASTM type I (CEM I) and a test was conducted for the cement.
- ✓ **Coarse Aggregate:** Well-graded crushed basaltic stone free from deleterious materials collected from quarry sites around TikurAbay, Gelan city, which meet the requirements of ASTM standards.
- ✓ **Sand:** River sand from metahera and langano were used for investigation, which fulfills the ASTM code of requirements.
- ✓ **Waste brick:** The waste brick was extracted from quarry sites around Gelancity, gendakora. After all, the jaw crusher at TikurAbay has crushed the waste brick scrap to use it as fine aggregate.
- ✓ **Laterite sand-** The laterite sand was extracted around tulusdimtu.
- ✓ **Water:** Potable water in the laboratory was used for the concrete mix and no test was conducted on the water.

Table 3. 2; Test of Aggregate and Test Methods

Types of Test	Test Methods	
	Coarse Aggregate	Fine Aggregate
Moisture Content	ASTM C 566	ASTM C 566
Gradation	ASTM C 136	ASTM C 136
Unit Weight	ASTM C 29	ASTM C 29
Specific Gravity & Absorption	ASTM C 127	ASTM C 128
Silt Content	-	Ethiopian standard

3.5. Slump and Compressive Strength Test

A slump test was conducted for each mix as per EBCS2:1995 to measure and determine the workability of the mix. The compressive strength of the standard cube was done on the 3rd, 7th, and 28th days after casting. Controls comprehensive strength test machines were used for the test. During the test, the slump, the mass of individual cubes, the applied load, and other results on each cube will be measured and recorded in standard formats. The mass of cubes will be used to determine the density of cubes and the applied load help to compute the compressive strength of cubes.

3.6. Chemical Test

The chemical analyses were conducted on waste brick and laterite soil to determine their mineralogical composition using complete silicate analysis of a sample at the Ethiopian Geological Survey Laboratory because it is essential before using it for concrete production.

3.7. Testing for Water Absorption of Concretes

Triplicate 100 × 50 mm cylinder specimens were used to determine the water absorption of concrete at 28 days based on ASTM saturation techniques. At first, the specimens place in oven-dried at 105± 5°C for 24hr. Then the specimens were cooled to the room temperature of 23 ±2°C and weighed to obtain the oven-dry mass. The next step is to determine the saturation of the specimens needed to determine the saturated surface-dry mass of the specimens by immersion for 48hr in cold water. The cold water ASTM standard procedures show as follows.

$$W_a = [(M_s - M_d)/M_d] \times 100\% \dots\dots\dots (3.1)$$

Where, W_a water absorption (%), M_d oven-dry mass of the specimen in air, and M_s saturated surface-dry mass of the specimen in air.

3.8. Mix Design

Mix design is the process of defining the quantity and proportioning of concrete ingredients to be able to satisfy the concrete required grade. So based on ACI 211.1-91 the concrete mix design procedure will be followed for all 13 concrete mixes having a water-cement ratio of 0.49, a slump range between 75-100 mm, and compressive strength of 25 Mpa (C-25).

The partial replacement of sand with waste brick and laterite sand was done with a percentage mass of sand. Mix 1 (100% sand, 0% waste brick, and 0% laterite soil) were used as a reference or control mix to prepare other mixes of waste brick and laterite sand. Trial mixes were prepared for 9 (150mm×150mm×150mm) cubes and 20% wastage, which become $0.0365m^3$ for each series of concrete mixes. The proportioning of all materials for each mix is shown in Table B-1 on Mix Proportions and the mix design computation and procedure presented in APPENDIX B: MIX DESIGN

3.9. Preparation of Specimens and Mixing Procedure of Concrete

The ingredients, such as; cement, fine aggregate (river sand, waste brick, and laterite soil), coarse aggregate, and water measure by weight balance. After mixing the ingredients in the mixer the mixed concrete check for workability by filling the standard slump cone with three layers by rodding each layer 25 times. Then, after the slump is checked, the mixed concrete is placed in the mould and well compacted in three layers. After compacted the top surface is finished using a trowel. The concrete moulds are kept for 24 hours and then cast concrete is removed from the cubes mould. All concrete specimens cure for three days and expose to room temperature in the laboratory until the day of testing.

The compressive strength test is done through ASTM C39/C39M provides the Standard test method for compressive strength of cylindrical concrete specimens having a cube of 15cm X 15cm x 15cm sizes. These specimens were tested at the age of 3rd, 7th, and 28th days of concrete. The load should be applied gradually until the Specimens fails.

The other concrete test is the water absorption test and for this test, the fresh concrete was cast in single-use plastic moulds to prepare the required number of 100 mm(diameter) × 200 mm (height) cylindrical specimens. The ASTM C642 standard practice followed for making the concrete specimens. After casting the sample the sample was left out for 24hr and transferred to the curing tank for 28day until testing days. The cured cylinders needed to be cut into three small cylinders having 100 mm (diameter) × 50 mm (height) from parent 100 × 200 mm dry hard cylinder concrete. During the cutting operation, thin sections from both ends needed to be discarded to eliminate the end effects.

3.10. Economic Feasibility

In this section, the economic feasibility of waste brick and laterite soil is determined. For the economic evaluation of concrete mixes, the current market price of ingredients of concrete is portrayed. And the cost of concrete mixes per cubic meter is determined by multiplying the number of ingredients per cubic meter by their current market prices.

3.11. Statistical Analysis

This section focuses on the statistical analysis applied to the conducted laboratory test results. SPSS V 20 is used to analyse factorial two-way ANOVA based on the dependent variable (compressive strength) and three independent variables (percentage of waste brick, percentage of laterite, and age of concrete). The statistical approach is used to determine if there is a correlation between compressive strength percentage of waste brick, percentage of laterite, and age of concrete.

3.11.1. Factorial ANOVA

Beins & McCarthy (2012) stated that in a single experiment, if there are multiple independent variables and a single dependent variable, the method implemented to test the effect of those independent variables on the dependent variable is called Two-Way Factorial ANOVA. When multiple variables are used, each variable will have different levels. Therefore, it's customary to analyze the combination of different levels on each variable.

3.11.2. Hypothesis Testing in Factorial ANOVA

Testing of a hypothesis is significant to determine there is enough statistical evidence in favor of a certain belief, or hypothesis is Accepted or rejected. Commonly, there are two types of hypotheses, the null hypothesis and the alternative hypothesis (Kothari, 2004).

The null hypothesis, denoted by “H₀” is a hypothesis that is used to disprove or reject a statement, while an alternative hypothesis “H_a” is used to explain the cause of a phenomenon or anticipated relationship of the variables or treatments.

The alternative and null hypotheses for two variables can be expressed using the following two statistical notations (Beins & McCarthy, 2012):

Null Hypothesis is H0: $\mu_01 = \mu_02$ where μ_01 and μ_02 are null hypothesis variables and

Alternative Hypothesis Ha: $\mu_a1 \neq \mu_a2$ μ_a1 and μ_a2 are alternative hypothesis variables

In a Factorial ANOVA, due to the presence of more than two variables, there were multiple null and alternative hypotheses depending on the number of levels. The effects of those multiple independent variables can be categorized as main effects and interaction effects. The main effect is the impact of a single independent variable on a dependent variable; whereas, an interaction effect is the simultaneous impact of multiple independent variables on a dependent variable.

3.12. Modeling

Modeling involves setting up mathematical formulations of physical or other systems. Many factors of different effects occur in nature simultaneously dependently or independently. When they interplay they could inter-affect one another differently at equal and different partially combined rates variationally, to generate varied natural constants in the form of coefficients and/or constant. Modeling is done through linear regression in SPSS v20.

So for linear regression, the formula is

$$Y = \alpha + \beta X_1 + \beta X_2 + \dots + \beta X_n \quad (3.2)$$

Where X_1, X_2, \dots, X_n are the independent variables (Kumari and Yadav, 2018).

3.13. Data Analysis of Test Results

The data analysis was made of a different part. The first part is the complete silicate analysis part of the study was discussed. Secondly, the test results of waste brick and laterite sand are analyzed by referring to different standards. Water absorption, bulk density, specific gravity, and gradation of waste brick and laterite soil are tested and analyzed. The third is the analysis of the test results of concrete, which is produced based on the conventional mix. Workability (slump) of fresh concrete, durability, and compressive strength of the hardened concrete having of a waste brick and laterite sand analysis is made based on the control mix. As an analysis tool for compressive strength test on harden concrete, factorial two way ANOVA with SPSS version 20 is used to determine the mix with a higher degree of significance and 0.05 confidence level is used for the statistical analysis, and Tukey post-hoc analysis is

used to determine the mix with a higher degree of significances. The fourth step is the cost comparison analysis. Finally, the sand replacement rates at which waste brick and laterite sand can be effectively substituted into concrete production from the series of mixes were determined.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Introduction

In this chapter, the test results such as the chemical property of waste brick and laterite sand, the mechanical property (Compressive strength and workability) of concrete containing waste brick and laterite sand, cost comparison of concrete containing waste brick and laterite sand with the conventional concrete and the rate of effective substitution of sand with waste brick and laterite sand are presented, analyzed and discussed.

4.2. Material Property

4.2.1. Cement

Ordinary Portland cement (OPC) having a grade of 42.5R which is produced by Dangote Cement PLC was used throughout the experiment. The reason to select only one cement type is due to availability and time limitations to perform experiments. OPC was used for the preparation of all mixes of concrete. Ordinary Portland cement (OPC) was conducted on the cement to confirm the Ethiopian standard.

Table 4. 1; Summarized test result for Dangote Cement (OPC)

Item no	Description		Test result
1	Cement consistency test	w/c ratio (%)	30%
		Water (gram)	150
		Penetration (mm)	11
2	Setting Time	Initial setting time (min)	60min
		Final setting time (mm)	510(8hr.30min)

Ethiopian standard recommends cement consistency is between 26% about 33%. So the cement fulfilled that standard. And also Ethiopian standard recommends the initial setting time for Portland cement is not less than 45 minutes and the final setting time does not exceed 10 hours. From this experiment, we

get the exact penetration value of 22mm at 60 minutes and the final setting of 8hrs 30min. Hence the initial and final set time is acceptable.

4.2.2. Aggregate

4.2.2.1. Properties of river sand

To take control of the mix for C-25 normal river sand which is extracted from metahra and langano was used. All fine aggregates retained on 9.5mm sieve size were no longer relevant, and all the passing fine aggregates were used for experimentation.

To design and make a concrete mix, several tests were carried out on river sand. The test performed includes: sieve analysis, bulk and dry density, moisture content, absorption capacity, unit weight, etc. All aggregates tests were done to conform to ASTM and Ethiopian standards requirements. The physical properties of river sand obtained from the tests are summarized in Table 4.2 below.

Table 4. 2; Physical properties of river sand

Item no	Description	Test result	
1	Fines modules	2.75	
2	Silt content	3.45%	
3	Moisture content	2.88%	
4	Dry unit weight	1814.78 kg/m ³	
5	Absorption capacity	3.88%	
6	Specific gravity	Bulk	2.64
		Bulk (SSD)	2.74
		Apparent	2.94

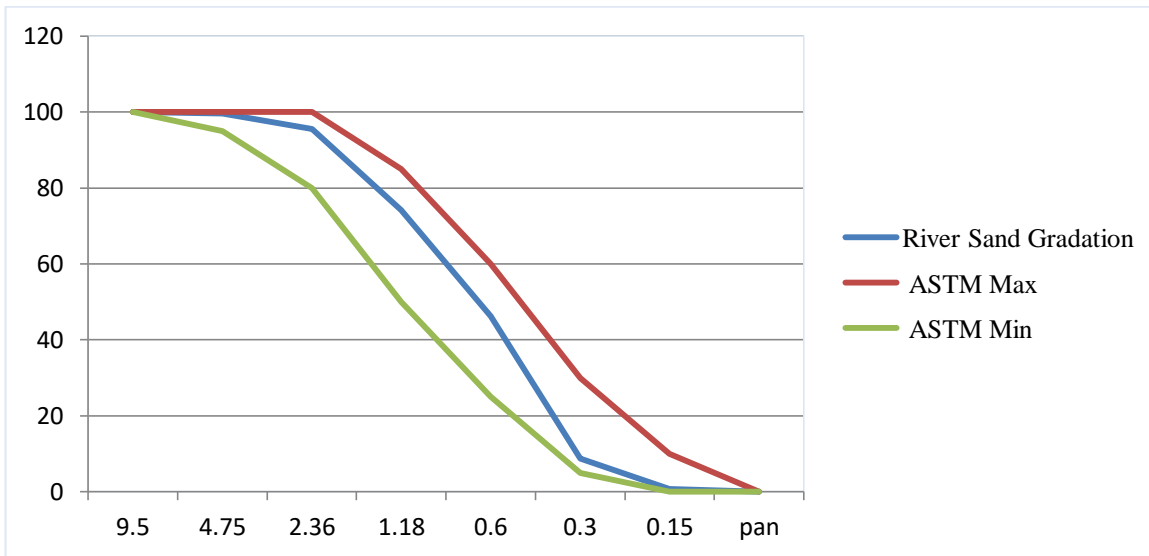


Figure 4. 1; Gradation curve for river sand

4.2.2.2. Properties of Coarse Aggregate

The coarse aggregate used for this research was crushed basaltic rock, which was brought from Gelan city around TikurAbay crushing plants. The aggregate coming from the construction site was washed thoroughly and dried in the air inside the laboratory room to remove dust. The size of coarse aggregate used for the experimental investigation was a mixture of 25mm, 19mm, 12.5mm, 9.5mm, and 4.5mm diameter aggregate sizes. In this study, a maximum size of 25mm diameter aggregate was used in all the concrete mix designs. The physical properties of coarse aggregate test results are shown in Table 4.3 below

Table 4. 3; Physical properties of coarse aggregate

Item no	Description	Test result	
1	Nominal maximum aggregate size	25mm	
2	Moisture content	0.25%	
3	Dry unit weight	1747.03 kg/m ³	
4	Absorption capacity	0.55%	
5	Specific gravity	Bulk	2.9
		Bulk (SSD)	2.92
		Apparent	2.95

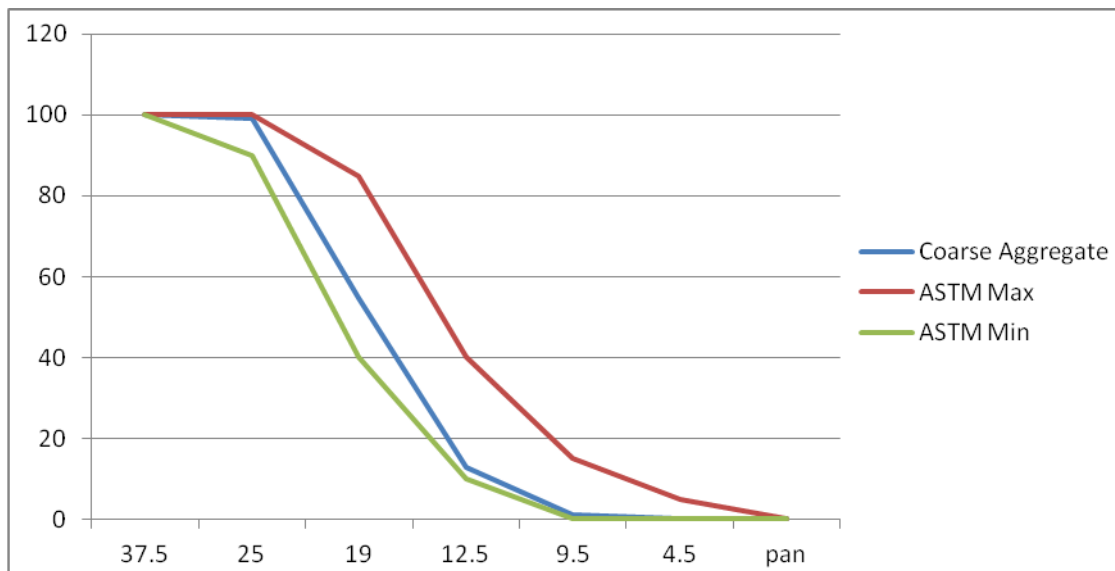


Figure 4. 2 Gradation curve for coarse aggregate

4.2.3. Water

Potable water in the laboratory was used for the concrete mix and for curing, no tests were conducted on the water.

4.2.4. Replacing Material

4.2.4.1 Waste brick

The waste brick content used in this study is a partial replacement of fine aggregate. Waste brick was tested well before crushing and this crushed waste brick was sieved through a 4.75mm sieve size retained on 75-micron sieve size was selected before using it in the concrete mix. The waste brick was taken from demolishing works.

The physical tests conducted for waste brick were gradation, moisture content, unit weight (bulk density), specific gravity & absorption, and silt content as presented in Table 4.4.

Table 4. 4; Physical properties of waste brick

Item no.	Description	Test result	
1	Fines modules	2.9	
2	Silt content	5.26%	
3	Moisture content	0.41%	
4	Dry unit weight	1055.7kg/m ³	
5	Absorption capacity	15.2%	
6	Specific gravity	Bulk	1.9
		Bulk (SSD)	2.2
		Apparent	3.08

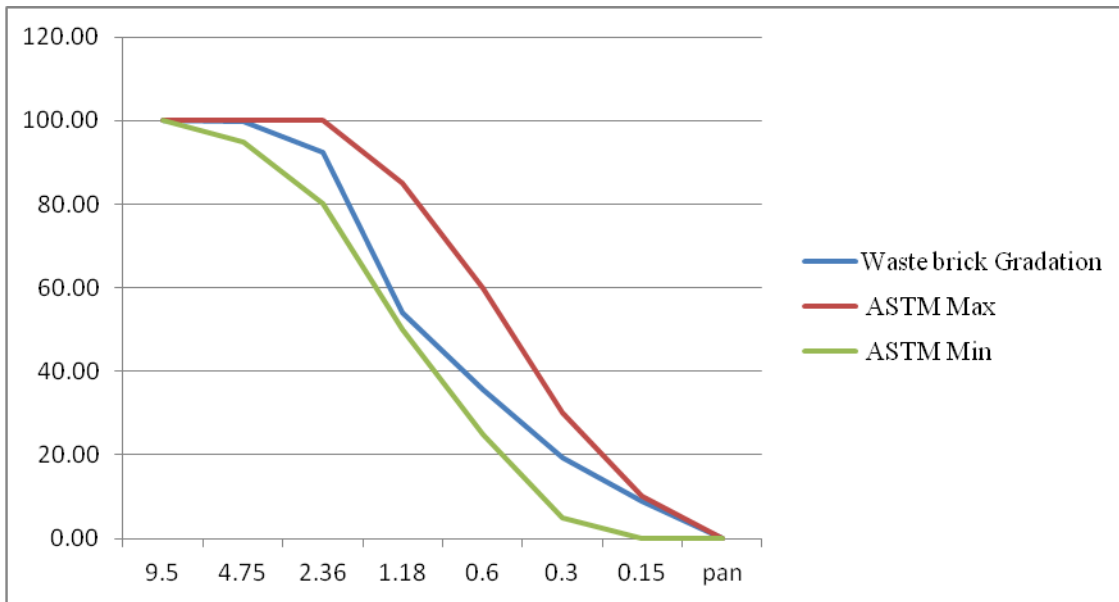


Figure 4. 3; Gradation curve for waste brick

4.2.4.2 Laterite soil

Laterite sand from Gelan city around Tulu Dimtu was used for replacement for fine aggregates which contributes to the concrete mix. Laterite sand which passes through 4.75mm and is retained on 75-micron sieve size was selected. Physical tests were conducted for laterite sand like gradation, moisture content, unit weight (bulk density), specific gravity & absorption, and silt content based on ASTM and Ethiopian standards as presented in Table 4.

Table 4. 5; Physical properties of laterite soil

Item no	Description	Test result	
1	Fine modules	3.06	
2	Silt content	3.45	
3	Moisture content	14.68	
4	Dry unit weight	1303.62 kg/m ³	
5	Absorption capacity	16.62	
6	Specific gravity	Bulk	1.93
		Bulk (SSD)	2.25

		Apparent	2.83
--	--	----------	------

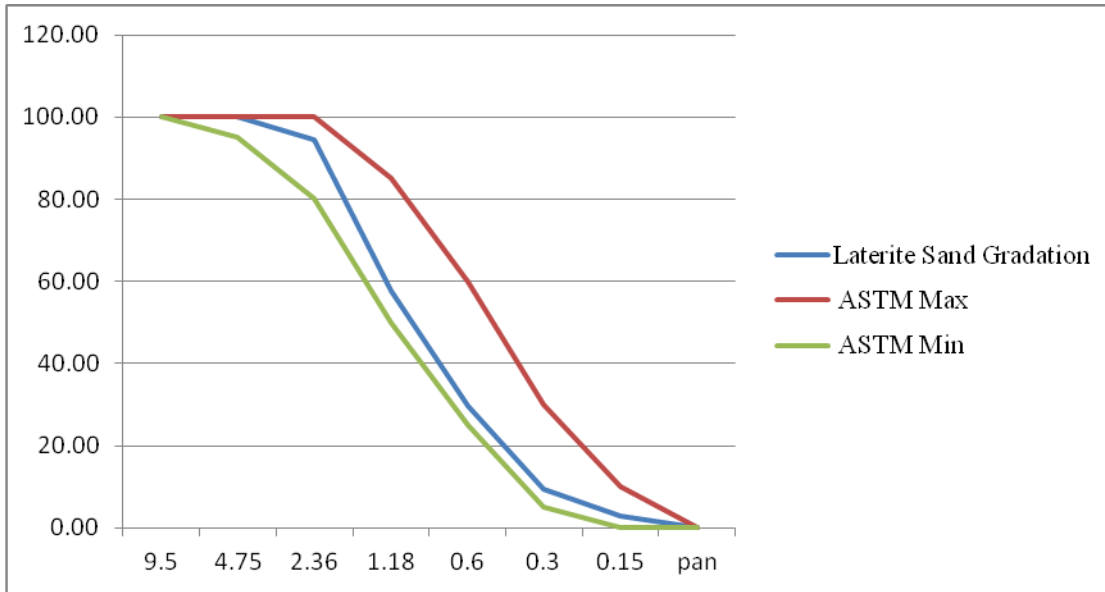


Figure 4. 4; Gradation curve for laterites sand

4.3. Chemical Composition

Samples of waste brick and laterite soil were submitted to the Ethiopian Survey of Ethiopia; Geoscience Laboratory Center and based on standards complete silicate analysis test on both waste brick and laterite soil was conducted. The chemical composition of river sand, waste brick, and laterite soil were referred from a different kinds of literature, and Table 4.6 shows

Table 4. 6; Complete silicate analysis of waste brick, laterite soil, river sand

Constituent	% of chemical composition				
	Waste brick	Laterite soil	River sand(literature)	Waste brick(literature)	Laterite soil (literature)
SiO ₂	58.06	48.94	49	63.21	21.55
Fe ₂ O ₃	7.86	19.46	13.74	6.05	29.4
Al ₂ O ₃	23.86	13.44	16.1	16.41	24.3
MgO	0.86	5.52	5.4	1.11	0.07
CaO	1.06	6.26	8.2	0.52	-
Na ₂ O	1.10	0.36	3.3	1.19	-
K ₂ O	1.64	<0.01	0.9	2.83	0.11
MnO	0.18	1	0.2	-	-
P ₂ O ₅	0.26	0.17	-	-	16.71
TiO ₂	0.7	0.48	2.4	-	-
H ₂ O	1.73	1.77	0.8	-	-
LoI	1.2	1.53	0.7	8.68	0.34

Based on the complete silicate analysis test result shows that waste brick is made of a major oxide of Aluminum Oxide (Al₂O₃), Silicon Oxide (SiO₂), and Iron Oxide (Fe₂O₃) whereas the minor oxides include Calcium Oxide (CaO), Magnesium Oxide (MgO), Sodium Oxide (Na₂O), Potassium Oxide (K₂O), Manganese Oxide (MnO), Phosphorus Oxide (P₂O₅), Titanium Oxide (TiO₂), Sulfur trioxide (SO₃), and Water (H₂O) along with Loss on Ignition (LoI). There is a slight difference between the tested sample and test result of waste brick on the other study, which was conducted by Duggal, (2000) in Turkey, none of the waste brick oxides met the chemical composition of sand.

Soil to be laterite soil having the ratios of silica to sesquioxide means SiO₂ / (Fe₂O₃+ Al₂O₃) should be less than 2. Since the ratio is 1.49 this ratio is less than 2 this soil fulfills the requirements to be laterite

soil. The major oxides of laterite soil are Silicon Oxide (SiO_2), Aluminum Oxide (Al_2O_3), Iron Oxide (Fe_2O_3), Calcium Oxide (CaO), and Magnesium Oxide (MgO), whereas the minor oxides include Sodium Oxide (Na_2O), Potassium Oxide (K_2O), Manganese Oxide (MnO), Phosphorus Oxide (P_2O_5), Titanium Oxide (TiO_2), Sulfur trioxide (SO_3), Water (H_2O), and Loss on Ignition (LoI). The test sample of laterite sand from the other study, which was conducted by (Abebaw, 2005), In Ethiopia isn't the same as the tested sample. Depending on the primary oxide composition laterite sand, waste brick, and sand are classified as siliceous aggregate since it's primarily composed of SiO_2 .

4.4. Concrete Test

4.4.1. Fresh Concrete Properties

Thirteen different concrete mixes were designed with varying levels of alternative sand replacement. The content used to replace a portion of the natural fine aggregate varies from 0%, 33%, 50%, 67%, 100% with 0% alternative sand replacement as the control mix (Mix-1). Control mix made with conventional fine aggregate (River Sand) was used for comparison. The results of the fresh concrete properties are provided below in Table 4.7. This table shows that the slump value of different concrete mixes remained affected due to the utilization of different replacement levels of alternative sand.

Table 4. 7; Properties of fresh concrete

Mix-no.	Fine Aggregate Replacement Levels	Slump (mm)
Mix 1	0% WB, 0% LS, 100% Sand	75mm
Mix 2	11% WB, 22% LS, 67% Sand	60mm
Mix 3	16.5% WB, 16.5% LS, 67% Sand	65mm
Mix 4	22% WB, 11% LS, 67% Sand	60mm
Mix 5	17% WB, 33% LS, 50% sand	70mm
Mix 6	25% WB, 25% LS, 50% sand	85mm
Mix 7	33% WB, 17% LS, 50% sand	95mm
Mix 8	22% WB, 44.7% LS, 33% Sand	70mm

Mix 9	33.5% WB,33.5% LS,33% Sand	75mm
Mix 10	44.7% WB,22.3% LS,33% Sand	90mm
Mix 11	33%WB,67% LS,0% Sand	70mm
Mix 12	50%WB,50% LS,0% Sand	75mm
Mix 13	67%WB,33% LS,0% Sand	100mm

Based on the test result except Mix 7, Mix 10, and Mix 13 the rest mixes slump test result shows above or equal to the control mix. This means the concrete mix which contains this alternative sand is relatively decrease in workability than the control mixes. This is mainly because both waste brick and laterite soil have a larger absorption, in turn, they need more water.

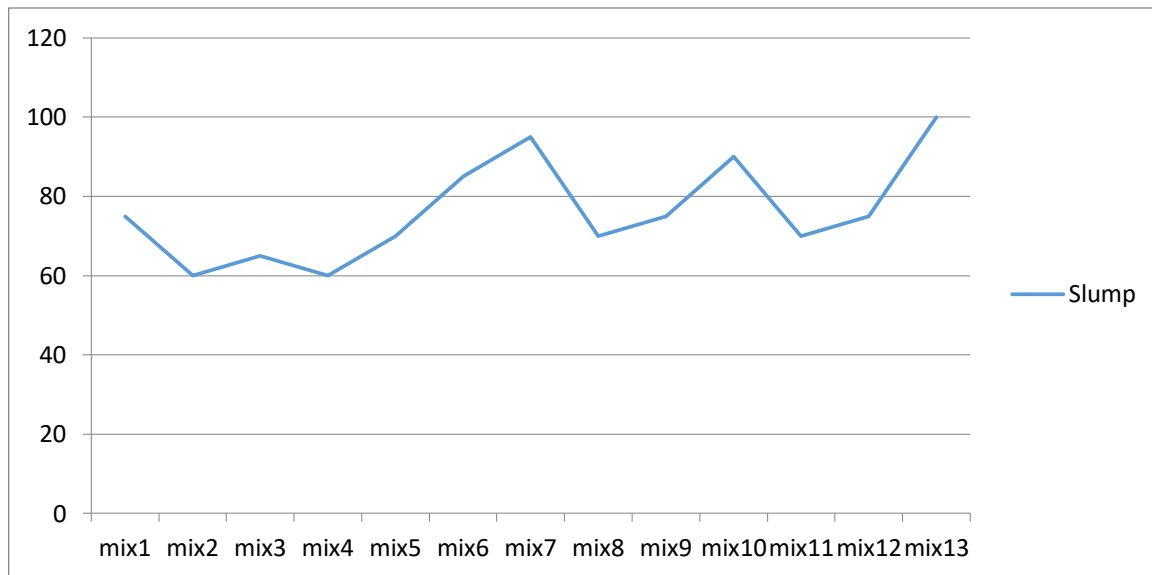


Figure 4. 5; Slump test

4.4.2. Hardened Concrete Properties

4.4.2.1. Compressive Strength

The compressive strength of the concrete specimens was determined by testing concrete cubes of size 150mm according to EBCS2:1995. All specimens were weighed and measured to determine the area of

the cube and the density of the concrete. The hardened properties of the concrete have been determined at the ages of 3, 7, and 28 days. At each age, a minimum of three specimens was tested to ensure the accuracy of test results. The use of laterite soil and waste brick by replacing wholly or partially the natural river sand had shown an effect on the compressive strength of concrete. The results are presented in Figure 4.6 and Table 4.8

Table 4. 8; Summary of mean compressive strength result of different concretes mixes

Mix No.	Compressive strength test result		
	3 day	7 day	28 day
Mix 1	18.9	22.6	35.6
Mix 2	19.2	25.27	39.23
Mix 3	16.87	25.03	41.2
Mix 4	24.57	29.7	42.9
Mix 5	17.1	21.97	35.87
Mix 6	18.67	23.13	38.77
Mix 7	17.87	22.97	39.7
Mix 8	16.8	19.8	30.13
Mix 9	18.87	21.6	35.3
Mix 10	18.7	21.4	39.4
Mix 11	15.63	17.7	30.13
Mix 12	14.1	17.5	30.07
Mix 13	15.47	20	33.43

The results show that, concrete mixes made with partial replacement of sand with waste brick and laterite sand improve the compressive strength and achieved the target mean strength of 33.5 MPa at 28 days, whereas 22%WB*45%LS(Mix8), 33%WB*67%LS (Mix11), and 50%WB50%*LS(Mix12) failed

to achieve the target mean strength. The concrete mix attains high early strength on the 3rd day when compared to the 7th and 28th-day compressive strength since high early strength ordinary Portland cement (OPC 42.5 R) was used to cast the concrete. Based on the test result, as the combined ratio of waste brick and laterite soil increase from 0% to 33 % for the laterite soil ratio is twice of the waste brick (Mix 2), when an equal replacement ratio of waste brick and laterite sand (Mix 3) and when the waste brick ratio is twice of the laterite soil (Mix 4) the concrete strength increase by 10.2%, 20.5%, and 15.73% respectively when compared to the control mix. When the partial replacement of sand with waste brick and laterite sand increase from 33% to 50 % for the laterite soil ratio is twice of the waste brick (Mix 5), when an equal replacement ratio of waste brick and laterite sand (Mix 6) and when the waste brick ratio is twice of the laterite sand (Mix 7) the concrete strength increase by 11.52%, 8.9%, and 0.76%, respectively when compared to the control mix since the presence of waste brick improve the concrete strength as it is also revealed by Saidi et al. (2015).

In addition to that when the partial replacement of sand with waste brick and laterite sand increased from 50% to 67%, the concrete strength for Mix 8 and Mix 9 degraded by 15.4%, 0.84% respectively. Whereas, Mix 10 improved concrete strength by 10.7% when compared to the control mix. As the replacement rate of sand with waste brick and laterite sand increases the strength is gradually reduced.

At 100%, replacement of sand with waste brick and laterite sand the strength is degraded by 15.4%, 15.5%, and 6.1% for Mix 11, Mix 12, and Mix 13 when compared to the control mix. From the above result, the strength of concrete with a full replacement rate of sand with waste brick and laterite sand is reduced when compared to the partial replacement. Moreover, to easily understand the difference the result is shown graphically in Figure 4.6.

The test results showed below that for all concrete mix proportions, concrete with 11%WB*22LS, 16.5%WB*16.5LS, 22%WB*11LS, 17%WB*33LS, 25%WB*25LS 33%WB*17LS and 45%WB*22LS waste brick and laterite sand were capable of achieving a higher compressive strength than concrete with river sand control mix. The use of laterite sand and waste brick for normal strength concrete production is more useful and special cares have to be taken to ensure that the concrete mix achieves a suitable finish. The raw data for the compressive strength values are shown in APPENDIX C.

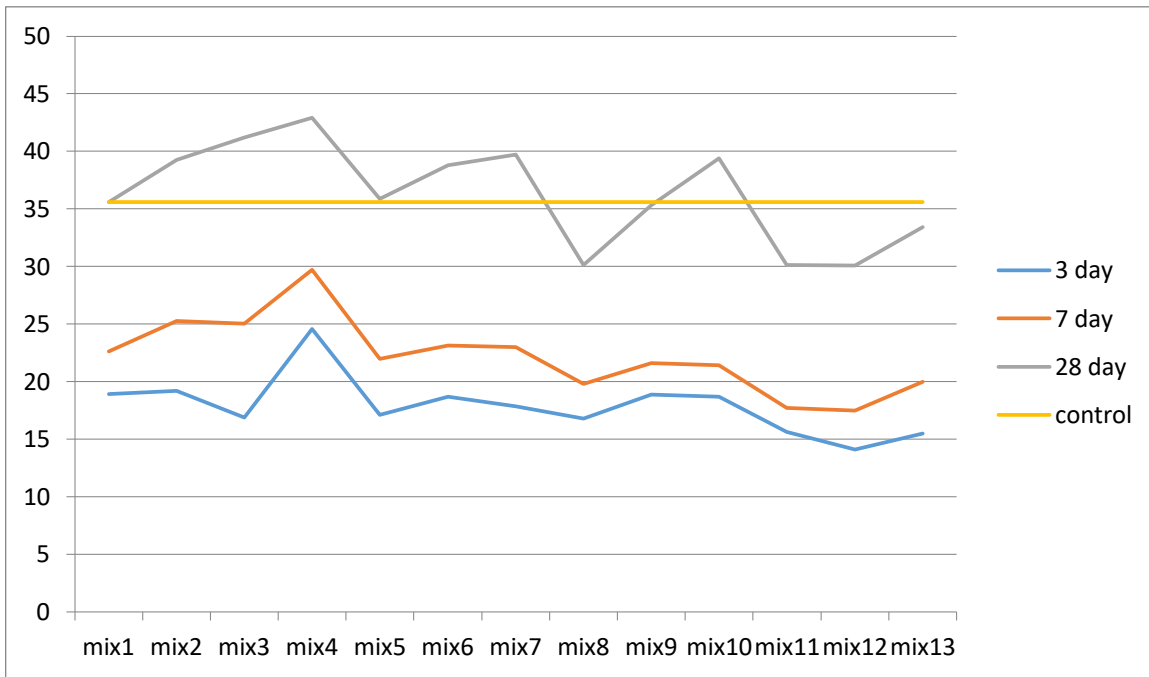


Figure 4. 6; Compressive strength of concretes

4.4.2.2. Water Absorption

One of the methods for assessing the durability properties of concrete is its absorption characteristics. Water absorption for all the mixes at their 28-day age is shown in Fig. 4.7. It can be seen that waste brick and laterite soil concrete has higher water absorption compared to the reference concrete. And as waste brick and laterite sand percentage increase 0 to 33% to 50% to 67% to 100% (Mix 1 to Mix 13), the water absorption percentage also increases. But all concretes contain waste brick and laterite soil where their water absorptions capacity was below 10%. The absorption of most good concretes is below 10% which was started by Neville (2008). The raw data for water absorption values are shown in APPENDIX E.

Table 4. 9; Water absorption of the concretes

Mix No.	w/c	Test Age	water absorption in percent			
			S1	S2	S3	Average
Mix1	0.49	28	5.29	4.68	4.23	4.73
Mix2	0.49	28	5.34	4.62	3.55	4.5
Mix3	0.49	28	4.94	4.15	3.64	4.24
Mix4	0.49	28	4.82	3.9	3.42	4.05
Mix5	0.49	28	5.4	4.35	4.25	4.67
Mix6	0.49	28	5.3	4.25	3.9	4.48
Mix7	0.49	28	5.4	4	3.99	4.46
Mix8	0.49	28	6.39	5.54	4.85	5.59
Mix9	0.49	28	7.17	3.16	4.94	5.23
Mix10	0.49	28	3.8	4.39	5.11	4.43
Mix11	0.49	28	6.74	5.53	4.79	5.69
Mix12	0.49	28	7.02	5.52	5.02	5.85
Mix13	0.49	28	5.89	4.84	4.3	5.01

The detailed test results for the water absorption of the concretes are given in Table 4.9 including their mean. The mean water absorption of the concretes varied from 4.05 to 5.85%. The water absorption capacity of the concrete containing waste brick and laterite sand decreased by 4.86%, 10.36%, and

14.38% for mix 2, mix 3 and mix 4 respectively, for a 33% combined rate when compared with the control.

At a 50% replacement rate, the concrete water absorption percentages were decreased by 1.27%, 5.29%, and 5.71% respectively when compared with the control.

For the replacement rate from 50% to 67% water absorption percentages increased by 18.2% and 10.57% for mix 8 and mix 9. But decreased by 6.34% for mix 10 when compared with the control.

In addition to that at a 100% combine replacement rate, the concrete water absorption percentages increased by 20.3%, 23.68%, and 5.92% respectively for the rest mix, when compared with the control. For more understanding, water absorption is depicted in Figure 4.7.

So, concrete containing this alternative material has good durability than normal concrete.

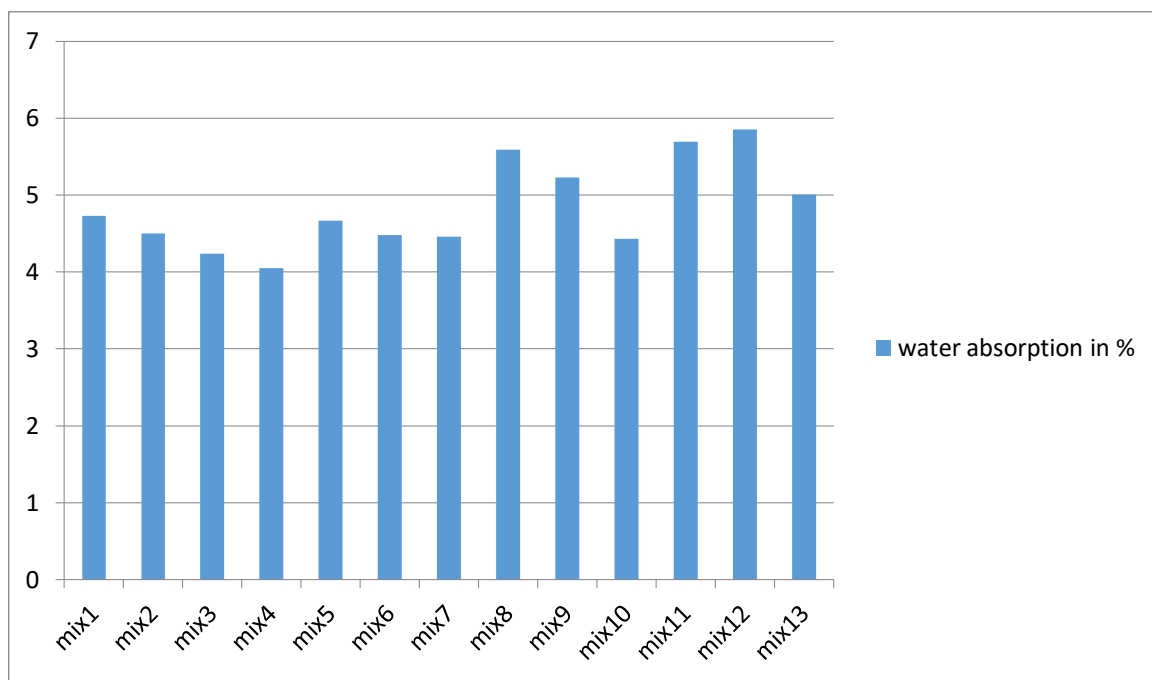


Figure 4. 7; Water absorption of concrete mixes at 28-day age

4.5. Modeling

When both waste brick and laterite soil interplay they could affect one another differently at equal, for different combined or partially combination rates variation ally, to generate varied natural constants in

the form of coefficients (β) and constant (α). So based on SPSS v20 for three mixed designs setting up mathematical modeling formulations was developed.

Since the replacement rate is the independent variable and compressive strength is the dependent variable. So for linear regression, the formula will be like (Kumari and Yadav, 2018).

$Y = \alpha + \beta X$, where X is replacement percentage and Y is the compressive strength

Table 4. 10; Estimated regression coefficient for compressive strength for equal of laterite soil and waste brick

Model	Unstandardized coefficients		Standardized coefficient	T	sig
	B	Std.Error	Beta		
(constant) replacement	39.409	2.560		14.861	.001
	-.077	.043	-.722	-1.810	.168

a. Dependent Variable: compressive strength

For all combined rates of laterite soil twice the waste brick or 2:1 ratio, based on regression analysis for 2:1, having coefficient (β) = -0.077 and constant (α) = 38.038. So our equation would be $y = 38.038 - 0.077x$. Where x is the percent of replacement and y is compressive strength.

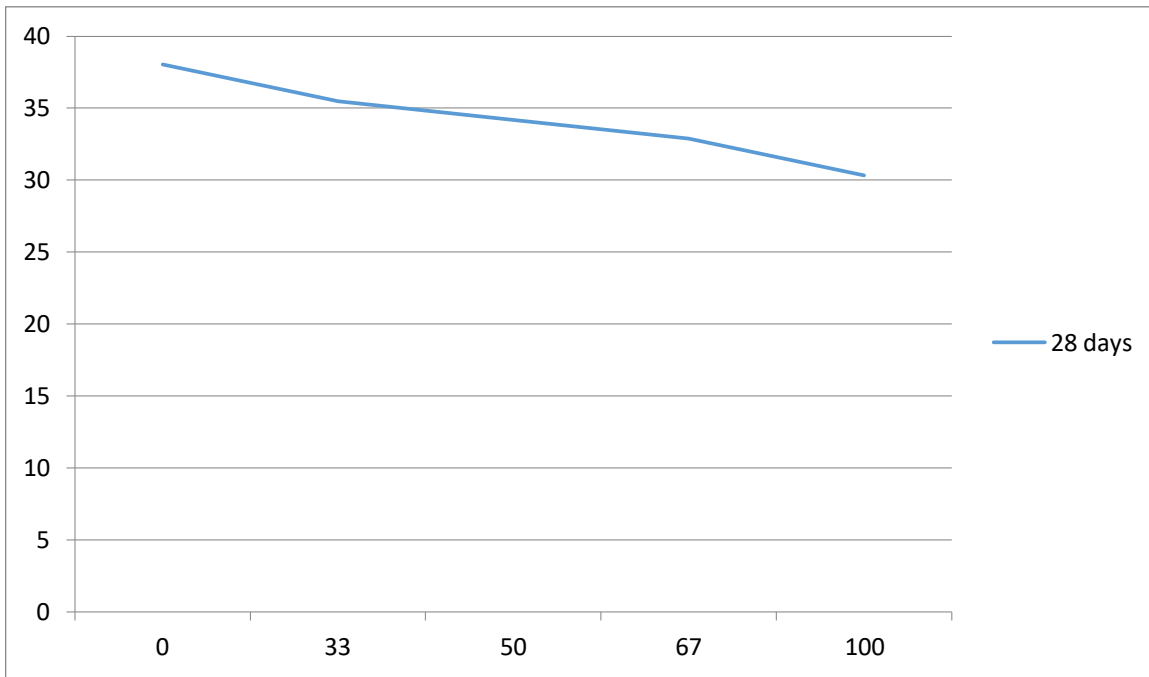


Figure 4. 8; Compressive strength graph for soil to waste brick 2:1 ratio

Model equations for laterite soil and waste brick having equal ratio using linear regression based on constant and coefficient are shown in Table 4.11

Table 4. 11; Compressive strength graph for laterites soil to waste brick 1:1 ratio

Model	Unstandardized coefficients		Standardized coefficient	T	sig
	B	Std.Error	Beta		
(constant) replacement	39.409	2.997		13.147	.001
	-.062	.050	-.583	-1.242	.303

So based on the regression analysis result for 1:1 or an equal ratio of waste brick and laterite soil replacement rate, having coefficient (β) = -0.062 and constant (α) = 39.409. So the equation would be $y=39.409 - 0.062x$. Where x is the percent of replacement and y is compressive strength.

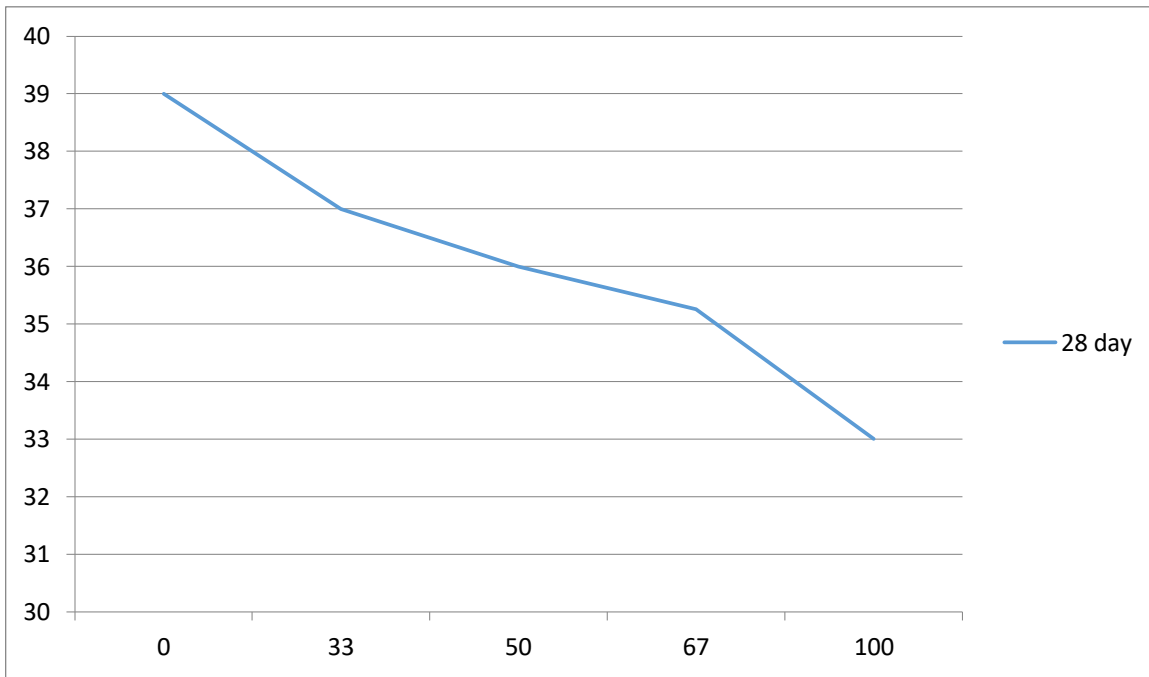


Figure 4. 9; Compressive strength graph for laterite soil to waste brick 1:1 ratio

The last model is prepared for the concrete mix with waste brick twice that of laterite soil using spss v-20. Where linear regression constant and coefficient are showed in Table 4.12.

Table 4. 12; Estimated regression coefficients for compressive strength for waste brick twice laterite soil

Model	Unstandardized coefficients		Standardized coefficient	T	sig
	B	Std.Error	Beta		
(constant)	39.712	3.294		12.054	.001
replacement	-.030	.055	-.303	-.550	.621

Based on regression analysis for waste brick twice laterite soil contains or 1:2 replacement rate coefficient (β) = -0.03 and constant (α) = 39.712. So the equation would be $y=39.712 - 0.03x$. Where x is the percent of replacement and y is compressive strength.

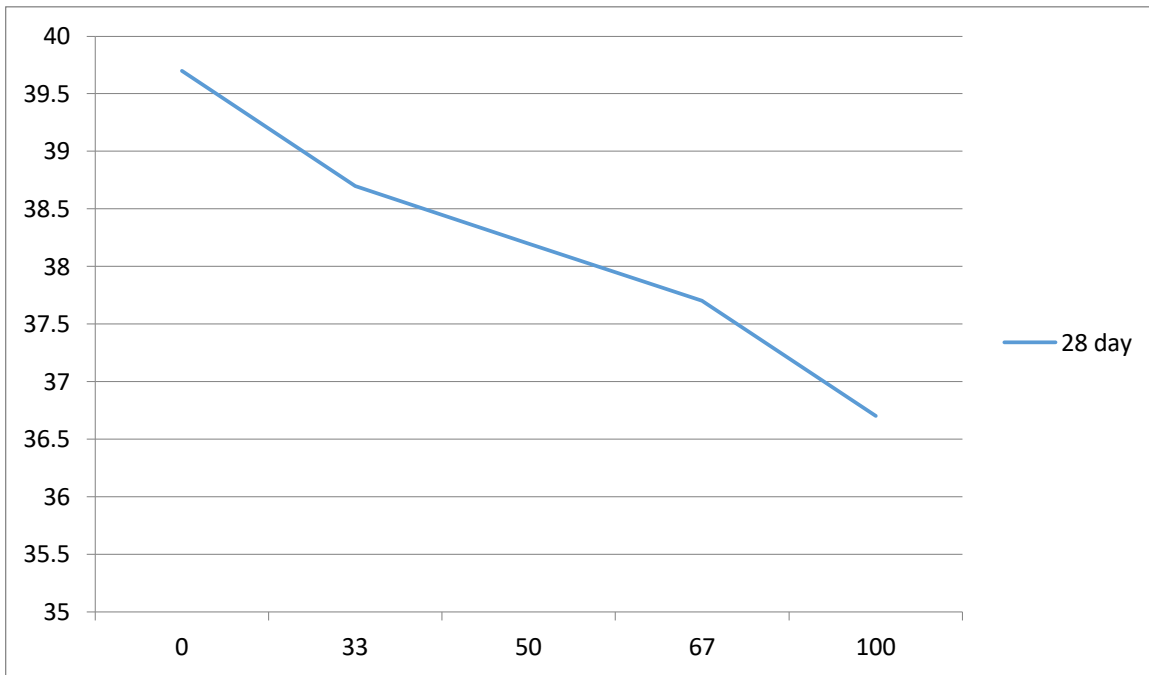


Figure 4. 10; Compressive strength graph for laterite soil to waste brick 1:2 ratio

Generally, from these three graphs at a replacement rate of waste brick twice laterite soil improved concrete compressive strength more than the rest ratios when compared with control concrete.

4.6 Statistical Analysis

In a factorial ANOVA, due to the presence of more than two variables, there will be multiple null and alternative hypotheses depending on the number of levels. The effects of those multiple independent variables can be categorized as Main effects and interaction effects. The main effect is the effects of a single independent variable on a dependent variable whereas the Interaction effect is the simultaneous effects of multiple independent variables on a dependent variable.

For this study, six major hypotheses are made: **Null Hypothesis (H0):**

- ✓ $\mu01$ =Replacement of sand by waste brick doesn't affect the compressive strength of concrete.
- ✓ $\mu02$ =Replacement of sand by laterite sand doesn't affect the compressive strength of concrete.
- ✓ $\mu03$ =Age doesn't affect the compressive strength of concrete.
- ✓ $\mu04$ =Replacement of sand by waste brick and laterite sand doesn't affect the compressive strength of concrete.

- ✓ μ_{05} =Age and replacement of sand by waste brick doesn't affect the compressive strength of concrete.
- ✓ μ_{06} =Age and replacement of sand by laterite sand doesn't affect the compressive strength of concrete.

4.6.1. Significant Factors Affecting the Compressive Strength of Concrete

Univariate Factorial ANOVA with a Confidence Interval of 95% and a Significant Level of $\alpha = 0.05$ is used to analyze the factors affecting compressive strength of concrete. The decision rule for the conducted F-test on SPSS for the main effect is: if P-value < 0.05, then the variable is considered as a significant factor which affects the compressive strength of concrete so the null hypothesis is rejected or for P-value ≥ 0.05 , the factor is reflected as non-significant and the null hypothesis will not be rejected.

Table 4. 13; Main effect and interaction effects of SPSS test results

Dependent Variable: compressive strength of test result

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2961.410 ^a	38	77.932	67.929	.000	.975
Intercept	25001.353	1	244469.724	8056.31	.000	.997
Age	2523.919	2	1261.96	415.483	.000	.972
Brick	56.024	2	28.012	9.223	.001	.435
Laterite	98.743	2	49.371	16.255	.000	.575
Age * Brick	54.849	20	2.742	.608	.798	.752
Age * Laterite	2893.317	32	90.416	7.967	.08	.977
Brick * Laterite	364.594	12	30.383	.304	0.983	.123

Error	.000	0	.			
Total	28550.154	39				
Corrected Total	2961.410	38				

Based on Table 4.13 the main effects such as brick, laterite sand, and age has a significant effect on the compressive strength of concrete since the p-value is less than 0.05 for 95% confidence interval, therefore the null hypothesis μ_{01} , μ_{02} and μ_{03} are rejected. The interaction effect is not significant the decision is not rejecting null hypothesis μ_{04} , μ_{05} , and μ_{06} since the p-value is greater than 0.05.

4.6.2. Post-hoc Test

Post-hoc test is applied for significant P-value with a factor that consists of three or more means and additional exploration of the differences among those means are significantly different within each level. Tukey HSD test is used; as it is one of the popular post-hoc test methods. The post-hoc test for waste brick, laterite sand and Age is illustrated in Table 4-14, Table 4-15 and Table 4-16 respectively.

Table 4. 14; Tukey HSD post-hoc analysis of waste brick

(I) Waste brick in percent	in (J) Waste brick in percent	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
11%	45%	5.6567*	1.42299	.019	.6137	10.6997
	50%	7.3433*	1.42299	.001	2.3003	12.3863
16.5%	45%	5.5467*	1.42299	.023	.5037	10.5897
	50%	7.2333*	1.42299	.001	2.1903	12.2763

17.5	50%	5.3900*	1.4229 9	.029	.3470	10.4330
22%	33%	5.5117*	1.0062 0	.001	1.9457	9.0776
	45%	7.2017*	1.2323 4	.000	2.8343	11.5690
	50%	8.8883*	1.2323 4	.000	4.5210	13.2557
	67%	5.8117*	1.2323 4	.003	1.4443	10.1790
25%	50%	6.6533*	1.4229 9	.004	1.6103	11.6963
33%	22%	- 5.5117*	1.0062 0	.001	-9.0776	-1.9457
45%	11%	- 5.6567*	1.4229 9	.019	- 10.6997	-0.6137
	16.5%	- 5.5467*	1.4229 9	.023	- 10.5897	-0.5037
	22%	- 7.2017*	1.2323 4	.000	- 11.5690	-2.8343
50%	0%	- 5.1433*	1.4229 9	.043	- 10.1863	-1.1003
	11%	- 7.3433*	1.4229 9	.001	- 12.3863	-2.3003
	16.5%	- 7.2333*	1.4229 9	.001	- 12.2763	-2.1903

	17%	- 5.3900*	1.4229 9	.029	- 10.4330	-0.3470
	22%	- 8.8883*	1.2323 4	.000	- 13.2557	-4.5210
	25%	- 6.6533*	1.4229 9	.004	- 11.6963	-1.6103
	22%	- 8.8883*	1.2323 4	.000	- 13.2557	-4.5210
67%	22%	- 5.8117*	1.2323 4	.003	- 10.1790	-1.4443

Percentage with significant effects since the other comparisons (i.e. 16.5-11, 22-11...) doesn't have a significant effect as shown in APPENDIX D: STATISTICAL ANALYSIS RESULT. The above table shows that 33.5 % waste brick replacement rate doesn't have a significant effect on the compressive strength of concrete when compared to the control mix, which has a p-value less than 0.05.

Table 4. 15; Tukay HSD post-hoc analysis of laterite sand

(I) Laterite sand in percent	(J) Laterite sand in percent	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0%	11%	-6.6900*	1.42299	.003	-11.7330	-1.6470
	50%	5.1433*	1.42299	.043	.1003	10.1863
11%	0%	6.6900*	1.42299	.003	1.6470	11.7330
	17%	5.6667*	1.42299	.019	.6237	10.7097
	22%	7.3183*	1.23234	.000	2.9510	11.6857

	25%	5.1800*	1.42299	.041	.1370	10.2230
	33%	7.6000*	1.23234	.000	3.2326	11.9674
	33.5%	7.1333*	1.42299	.002	2.0903	12.1763
	45%	5.8900*	1.42299	.013	.8470	10.9330
	50%	11.8333*	1.42299	.000	6.7903	16.8763
	67%	11.2467*	1.42299	.000	6.2037	16.2897
16.5%	50%	7.2333*	1.42299	.001	2.1903	12.2763
	67%	6.6467*	1.42299	.004	1.6037	11.6897
17%	11%	-5.6667*	1.42299	.019	-10.7097	-.6237
	50%	6.1667*	1.42299	.008	1.1237	11.2097
	67%	5.5800*	1.42299	.022	.5370	10.6230
22%	11%	-7.3183*	1.23234	.000	-11.6857	-2.9510
	50%	4.5150*	1.23234	.039	.1476	8.8824
25%	11%	-5.1800*	1.42299	.041	-10.2230	-.1370
	50%	6.6533*	1.42299	.004	1.6103	11.6963
	67%	6.0667*	1.42299	.010	1.0237	11.1097
33%	11%	-7.6000*	1.23234	.000	-11.9674	-3.2326
33.5%	11%	-7.1333*	1.42299	.002	-12.1763	-2.0903
45%	11%	-5.8900*	1.42299	.013	-10.9330	-.8470
	50%	5.9433*	1.42299	.012	.9003	10.9863

	67%	5.3567*	1.42299	.031	.3137	10.3997
50%	0%	-5.1433*	1.42299	.043	-10.1863	-.1003
	11%	-11.8333*	1.42299	.000	-16.8763	-6.7903
	16.5%	-7.2333*	1.42299	.001	-12.2763	-2.1903
	17%	-6.1667*	1.42299	.008	-11.2097	-1.1237
	22%	-4.5150*	1.23234	.039	-8.8824	-.1476
	45%	-5.9433*	1.42299	.012	-10.9863	-.9003
	67%	11%	-11.2467*	1.42299	.000	-16.2897
16.5%		-6.6467*	1.42299	.004	-11.6897	-1.6037
17%		-5.5800*	1.42299	.022	-10.6230	-.5370
25%		-6.0667*	1.42299	.010	-11.1097	-1.0237

Table 4-15 presents the laterite sand percentage with significant effects since the other comparisons (i.e. 16.5-11, 22-67...) don't have a significant effect as it's shown in APPENDIX D: STATISTICAL ANALYSIS RESULT. The above table shows that 0%, 11%, 16%, 17%, 22%, 25%, 33%, 33.5%, 45%, 50%, and 67% laterite sand replacement rate has a significant effect on the compressive strength of concrete when compared to the control mix, which has a p-value less than 0.05.

Table 4. 16; Tukey HSD post-hoc analysis of Age

Dependent Variable: compressive strength of test result

Tukey HSD

(I) concrete	Age of (J) of concrete	Age of concrete	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
3day	7 day	7 day	-4.3223*	.68358	.000	-6.0294	-2.6152
		28day	-18.8108*	.68358	.000	-20.5179	-17.1037
7 day	3day	3day	4.3223*	.68358	.000	2.6152	6.0294
		28day	-14.4885*	.68358	.000	-16.1956	-12.7814
28day	3day	3day	18.8108*	.68358	.000	17.1037	20.5179
		7 day	14.4885*	.68358	.000	12.7814	16.1956

Table 4-16 shows that as the age of conventional concrete increase the strength also increase, this also works for concrete containing waste brick and laterite sand since the p-value for all ages of concrete is less than 0.05 which means the age of concrete significantly affect the compressive strength of concrete.

4.7Economic Analysis

Virgin aggregate deposits have already been depleted in many areas of Gelan city. Therefore the use of virgin aggregates has a huge environmental impact. The effect of replacement of sand by waste brick and laterite sand on the cost of concrete, which is expressed by cost per cubic meter of concrete, is assessed based on the material prices collected from most common sources and suppliers within and around Gelan city. Moreover, the costs that were incorporated in the cost analysis of this study were ordinary Portland cement, sand, waste brick, laterite sand and water for the cement. Furthermore, the

benefit that was correlated with the concrete production cost in this study referred to the resulting. The mix design prepared for this study was adapted with 1-cubic meter volume, thus all unit costs were in terms of 1-cubic meter volume. In addition, all accounted costs were in Ethiopian birr currency.

The cost of concrete mix is determined by multiplying the number of ingredients computed by using the current market as shown in Table 4.17. The cost of materials is collected by interviewing local suppliers in Gelan city area from June 28, 2021 to June 29, 2021. In cost comparisons only the material costs are considered: the labor cost, equipment cost, profit and overhead costs are assumed to be equal for all cases.

Table 4. 17; Unit cost of ingredient in Birr/kg

Type of material	Name of cost	Cost(birr)	Unit cost (Birr/ kg)
Cement	Purchasing cost(1qtl)(100kg)	534	$534/100=5.34\text{Birr/kg}$
	Transportaion cost(3qtl)(300kg)	200	$220/300=0.67\text{Birr/kg}$
	Total unit cost		6.01Birr/kg
Sand	Purchasing cost (1truck of Sand (16 m ³) from source to site))	10,500	$10500/16=656.25\text{Birr/m}^3$ Where, $1\text{m}^3=1814.78\text{kg}$.So $656.25\text{Birr}/1814.78\text{kg}=0.362\text{Birr/kg}$
Waste brick	Purchasing cost	0	0Birr/kg
	Crushing cost		One sino truck stone is 4000m^3 .That means $1\text{m}^3=250\text{m}^3$. 1m^3 crushed sand= 650Birr . So granding cost= $650-250=400\text{m}^3$. And other costs like electric cost, labor cost, machine purchasing, maintenance,

			<p>profit,e.t.c=320birr/m³.So total crusing cost is 400m³-320birr/m³ =80 birr/m³</p> <p>Where, For crushed sand bulk density around azezo is 1m³ =1440kg.so</p> <p>80Birr/m³/1440kg/m³=0.06Birr/kg.</p>
	Transportation cost(1 truck of sino truck (16m ³) from source to site) including loadind cost	1333.33	<p>1333.33/3=83.3Birr/m³</p> <p>Where,1m³=1303.62Kg.</p> <p>So, 83.3/1303.62kg= 0.06Birr/kg</p>
	Total Unit cost		0.12Birr/kg
Laterite sand	Purchasing cost	0	0Birr/Kg
	Transportation cost(1 truck of sino truck (16m ³) from source to site) including loadind cost	1600	<p>1600/16=100Birr/m³</p> <p>Where,1m³=1303.62Kg.</p> <p>So, 100/1303.62kg= 0.08Birr/kg</p>
	Total Unit cost		0.08Birr/kg
Coarse aggregate	Purchasing cost (1truck of 02 size coarse aggregate (16 m ³) from source to site))	9200	<p>9200/16=575Birr/m³</p> <p>Where, 1m³=1747.03kg.So</p> <p>575Birr/1747.03kg=</p> <p>0.33Birr/kg</p>
Water	Purchasing cost(20litter)	1	1/20=0.05Birr/L=0.05Birr/kg

Table 4. 18; Total cost of ingredient material of concrete production in birr/m3 based on the unit cost of Table 4.17

Mix	Material	Quantity (kg/m ³)	Unit rate (Birr/kg)	Cost (Birr/m ³)	Differential Cost with CC(%)
Mix1	Cement	394	6.01	2367.94	0
	Sand	713.84	0.362	258.41	
	Coarse aggregate	1175.68	0.33	388	
	Water	204.67	0.05	10.23	
	Total cost			3,024.58	
Mix2	Cement	394	6.01	2367.94	2.19
	Sand	487.08	0.362	176.32	
	Coarse aggregate	1160.89	0.33	383.1	
	Waste brick	55.3	0.177	9.79	
	Laterite sand	129.93	0.08	10.39	
	Water	213.6	0.05	10.68	
	Total cost			2958.22	
Mix3	Cement	394	6.01	2367.94	1.84
	Sand	486.49	0.362	176.11	
	Coarse aggregate	1162.45	0.33	383.61	
	Waste brick	82.47	0.177	14.6	
	Laterite sand	97.09	0.08	7.77	
	Water	215.74	0.05	10.79	
	Total cost			2968.82	
Mix4	Cement	394	6.01	2367.94	

	Sand	485.26	0.362	175.66	2.02
	Coarse aggregate	1164.02	0.33	384.13	
	Waste brick	110.01	0.177	19.47	
	Laterite sand	64.8	0.08	8.29	
	Water	221.81	0.05	11.09	
	Total cost				
M5	Cement	394	6.01	2367.94	3.24
	Sand	354	0.362	128.15	
	Coarse aggregate	1180.92	0.33	389.7	
	Waste brick	83.16	0.177	14.72	
	Laterite sand	190.54	0.08	15.24	
	Water	215.33	0.05	10.77	
	Total cost				
M6	Cement	394	6.01	2367.94	3.12
	Sand	356.71	0.362	129.13	
	Coarse aggregate	1177.46	0.33	388.56	
	Waste brick	123.25	0.177	21.81	
	Laterite sand	145.07	0.08	11.6	
	Water	224.41	0.05	11.22	
	Total cost				
M7	Cement	394	6.01	2367.94	
	Sand	356.71	0.362	129.13	
	Coarse aggregate	1175.7	0.33	387.98	

	Waste brick	162.68	0.177	28.79	3.02
	Laterite sand	100.15	0.08	8.01	
	Water	229.38	0.05	11.47	
	Total cost			2933.32	
Mix8	Cement	394	6.01	2367.94	4.53
	Sand	244.38	0.362	88.46	
	Coarse aggregate	1145.73	0.33	378.1	
	Waste brick	114.11	0.177	20.2	
	Laterite sand	269.24	0.08	21.54	
	Water	224.07	0.05	11.2	
	Total cost			2887.44	
Mix9	Cement	394	6.01	2367.94	4.35
	Sand	243.48	0.362	88.14	
	Coarse aggregate	1148.84	0.33	379.12	
	Waste brick	170.33	0.177	30.44	
	Laterite sand	201.04	0.08	16.08	
	Water	232.57	0.05	11.63	
	Total cost			2893.05	
Mix10	Cement	394	6.01	2367.94	4.16
	Sand	242.59	0.362	87.82	
	Coarse aggregate	1152	0.33	380.16	
	Waste brick	227.06	0.177	40.19	
	Laterite sand	133.33	0.08	10.67	

	Water	241	0.05	12.05	
	Total cost			2898.83	
Mix11	Cement	394	6.01	2367.94	6.86
	Sand	0	0.362	0	
	Coarse aggregate	1132.14	0.33	373.61	
	Waste brick	171.96	0.177	30.44	
	Laterite sand	410.96	0.08	32.88	
	Water	243.41	0.05	12.17	
	Total cost			2817.04	
Mix12	Cement	394	6.01	2367.94	6.58
	Sand	0	0.362	0	
	Coarse aggregate	1135.62	0.33	374.75	
	Waste brick	259.6	0.177	45.95	
	Laterite sand	305.58	0.08	24.45	
	Water	247.57	0.05	12.38	
	Total cost			2825.47	
Mix13	Cement	394	6.01	2367.94	6.28
	Sand	0	0.362	0	
	Coarse aggregate	1140.86	0.33	376.48	
	Waste brick	345.36	0.177	61.13	
	Laterite sand	200.23	0.08	16.02	
	Water	260.38	0.05	13.02	
	Total cost			2834.59	

As shown in Table 4.16, partial replacement of sand at 67% by waste brick and laterite soil having waste brick twice laterite sand can save 4.16% cost than the control mix. A contractor can save approximately 125,750Birr from a 1000m³ of concrete than conventional concrete. Waste brick and laterite sand with 50% replacement of the control mix is around 3.13% averagely cheaper than the control mix. Even this alternative material with a 33% partial replacement is also cheaper than the control mix by 2.02% on averagely. Generally, partial replacement of sand by waste brick and laterite soil is pretty much cheaper than the control mix and it can be a potential solution for an increasing cost of virgin aggregate. It is important to note that this estimate covers only the cost of materials for making concrete mixes. The summary of the cost analysis is summarized using Figure 4.11.

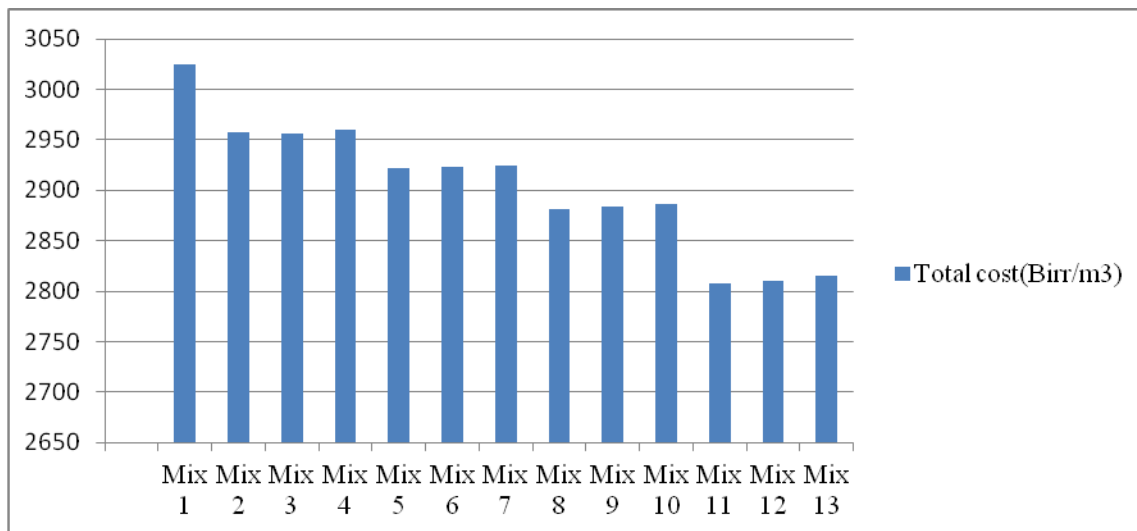


Figure 4. 11; Cost comparison indifferent mix with conventional concrete

4.8. Optimization of Replacement of Sand with Waste Brick and Laterite Soil

Optimization of the concrete mix design is a process of a search for a mix having the sum of the costs of the ingredients is lowest, but fulfills the required workability, strength, and durability. From the previous sections, replacement of sand with waste brick and laterite soil has a significant positive effect on the strength of hardened concrete, the workability of fresh mix, and a non-significant effect on the

cost when compared to strength and workability. Table 4.14, shows the percentage increase/decrease in strength, workability, and cost of concrete due to the replacement of sand with waste brick and laterite soil.

Table 4. 19; Percentage increase /decrease in strength, workability and cost

Mix no	A differential in compressive strength%	A differential in workability in %	A differential in cost %
Mix 1	0	0	0
Mix 2	10.2	-21.33	2.19
Mix3	15.73	-13.33	1.84
Mix 4	20.51	-21.33	2.02
Mix 5	0.75	-6.67	3.24
Mix 6	8.89	13.33	3.12
Mix 7	11.52	26.67	3.02
Mix 8	-15.37	-6.67	4.53
Mix 9	-0.84	0	4.35
Mix 10	10.67	20	4.16
Mix 11	-15.45	-6.67	6.86
Mix 12	-15.53	0	6.58
Mix 13	-6.1	33.3	6.28

The optimum or effective substitution of concrete containing waste brick and laterite soil is selected depending on the percentage increase/decrease of strength, cost, and workability with the control mix is shown in Figure 4.12.

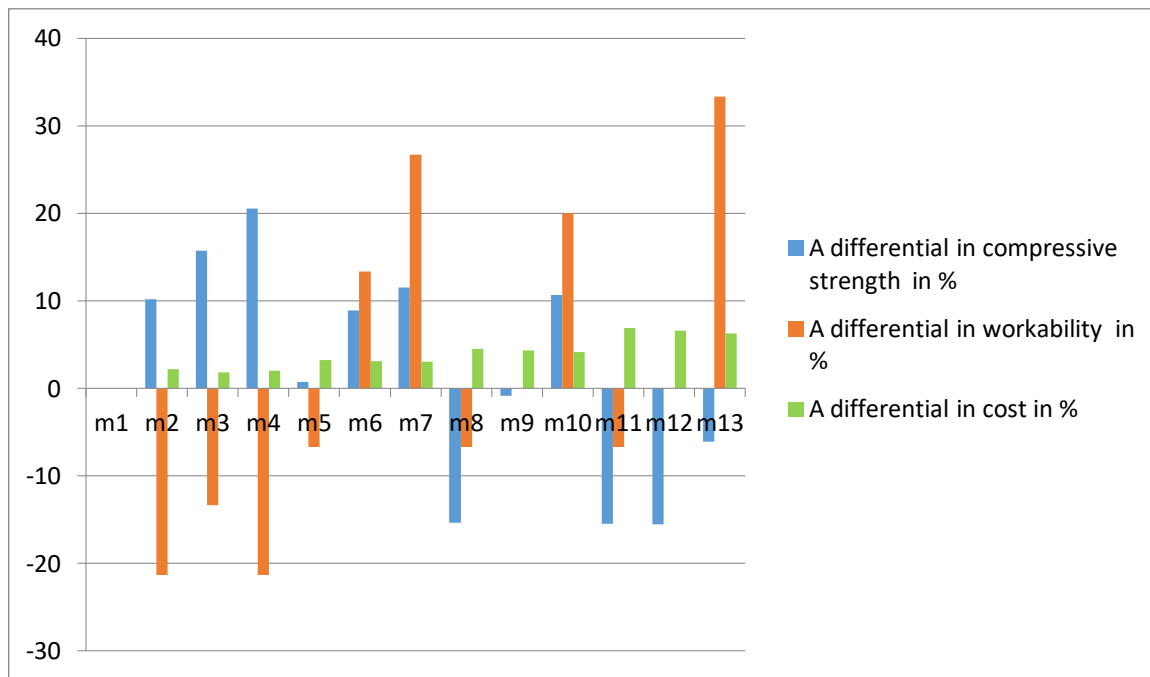


Figure 4. 12; Percentage increase/decrease in strength, workability and cost mixes%

Based on Figure 4.12, tradeoffs are made between strength, workability, and cost, Mix 1 has a 0% increase/decrease since it's a reference mix. Mix 2, Mix 3, Mix 4, Mix 5, Mix 6, Mix 7, and Mix 10 have an increase in strength when compared to reference mixes. Mix 2, Mix 3, and Mix 4 have a better increase in strength and decrease in workability; Mix 11 has an economic benefit. In Mix 8, Mix 9 Mix 11, and Mix 12 the strength is gradually decreasing as well as the slump decrease whereas Mix 10 has better economic benefit, workability, and strength when compared to other mixes.

4.9. Summary of the Finding

According to the analysis and discussions carried out the overall result is summarized the following as a major key research finding. The experimental test consists of two parts, the first part comprises the material properties of a material, part two comprise related to workability and hardened concrete tests using compressive strength water absorption, and part three is related to statistical analysis using SPSS and Economical analysis.

- ✓ Tests on cement test fulfill the required Ethiopian standard recommendation for cement test like consistency and setting timed

- ✓ In addition to that material properties of crushed waste brick, laterite soil, river sand, and coarse aggregate fulfill the requirement of ASTM standard requirement tests like moisture content, water absorption, and sieve analysis.
- ✓ Based on the test result except Mix 7, Mix 10, and Mix 13 the rest of the mixes slump test result shows above or equal to the control mix. This means the concrete mix which contains this alternative sand is a relative decrease in workability than the control mixes. This is mainly because both waste brick and laterite soil have a larger absorption, in turn, they need more water.
- ✓ From the hardened concrete test result concrete containing waste brick and laterite soil improve the compressive strength and achieved the target mean strength of 33.5MPa at 28 days except for 22%WB*45%LS(Mix8), 33%WB*67%LS (Mix11), and 50%WB50%*LS(Mix12) and 67%WB*33%LS (Mix13) failed to achieve the target mean strength.
- ✓ From three SPSS models a replacement rate of waste brick twice laterite soil improved concrete compressive strength more than for equal ratio and for laterite soil twice waste bricks. Based on the main effects and interaction table such as brick, laterite soil, and age has a significant effect on the compressive strength of concrete for a 95% confidence interval. Whereas the p-value is greater than 0.05 for their interaction that means doesn't affect compressive strength. So the post hoc table was done for the p-value is less than 0.05.
- ✓ Mix 2, Mix 3, and Mix 4 have a better increase in strength and decrease in workability; Mix 11 has an economic benefit. In Mix 8, Mix 9 Mix 11, and Mix 12 the strength is gradually decreasing as well as the slump decrease whereas Mix 10 has better economic benefit, workability, and strength when compared to other mixes.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The objective of this study was to study the workability, strength, optimum amount of replacement, and cost of partially replacing sand with waste brick and laterite soil for normal strength concrete. In the study, the physical property and chemical property of waste brick and laterite soil is determined by applicable standards. The mechanical property and effective substitution of concrete containing waste brick and laterite soil are determined and also the effect of materials was studied by performing statistical analysis and developing cost-effective and eco-friendly concrete making materials.

Based on the result of the experimental investigation, the following conclusions are drawn by replacing waste brick and laterite soil added to concrete.

1. Waste brick is mainly composed of Silicon Oxide (SiO_2), Aluminum Oxide (Al_2O_3), and Iron Oxide (Fe_2O_3) on the other hand laterite soil is composed of Silicon Oxide (SiO_2), Aluminum Oxide (Al_2O_3), Iron Oxide (Fe_2O_3), Calcium Oxide (CaO), and Magnesium Oxide (MgO).
2. The partial replacement of sand with waste brick and laterite soil up to 67% can improve the compressive strength of concrete up to 10.67% with having 4.43% water absorption. However, a further increase in the replacement of waste brick and laterite soil decreases the compressive strength. Whereas, the combined replacement rate of waste brick and laterite soil increases the workability and water absorption of concrete.
3. Based on the cost estimation, it was established that concrete contains this alternative material made of waste brick and laterite soil can save 4.58 % of the total cost than using ordinary concrete production.
4. The combined replacement rate of 67% waste brick and laterite soil, which is 45% waste brick and 22% laterite soil gives an effective and optimum natural sand substitution rate from strength, durability, workability, and cost point of view for C-25, 0.49 water to cement ratio.

5.2. Recommendation

Following the above conclusion the recommendations stipulated are:

1. Further studies and standardization should be done on laterite soil as fine aggregate and coarse aggregate replacement due to its abundance in Ethiopia.
2. Waste brick has pozzolanic properties so, blending it with laterite sand will give a better compressive strength than the conventional concrete, besides having good quality and eco-friendly concrete, so the regulatory body should encourage the use of waste brick and laterite sand in concrete production.
3. An extra study should be conducted for different compressive strengths containing waste brick and laterite soil.

5.3. Further Study Suggestions

This study emphasizes the workability and compressive strength properties of concrete containing waste brick and laterite soil as partial replacement of sand. However, further studies are suggested in the following areas:

- ✓ The effect of the partial replacement of cement and sand with waste brick and laterite soil separately should be studied.
- ✓ The potential of partial replacement of sand with waste brick and laterite soil for high strength concrete.
- ✓ The effect of the partial replacement of sand with waste brick and laterite soil by incorporating admixture should be studied.
- ✓ Further studies and standardization should be done on laterite soil as fine aggregate and coarse aggregate replacement due to its abundance in Ethiopia.

REFERENCES

- 1) Abebaw, Z. (2005). Basic Engineering Properties of Lateritic Soils found in Nedjo-Mendi Road Construction Project. *M.Sc. thesis, Addis Ababa University, Department of Civil Engineering, AAiT* .
- 2) Abebe, D. (2002). Construction material laboratory manual.
- 3) Adepegba, D. (1975). A comparative study of normal concrete with concrete which contained laterite instead of sand. *Building Science*, , 10(2), 135–141.
- 4) Aeslina, A. K., & Noor, A. S. (2012). .An Overview of Wastes Recycling in Fired Clay Bricks Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia (UTHM). *International Journal of Integrated Engineering*, , Vol. 4 No. 2.
- 5) Afolayan, J., Oriola, F., Sani, J., & Amao, J. (2019). Effects of Partial Replacement of Normal Aggregates with Lateritic Stone in Concrete. *Department of Civil Engineering, Nigerian Defence Academy, Kaduna, Nigeria. J. Appl. Sci. Environ. Manage.* , Vol. 23.
- 6) Ajeet, S., & Pankaj, R. M. (2016). Improvement of Compressive Strength of Specified Concrete With Adding Waste Red Sand Stone Powder in Place of Fine Aggregate,. *International Journal for Research in Applied Science & Engineering Technology, Volume* .
- 7) Akshay C, S. ., (2014). Recent Trends in Replacement of Natural sand with different Alternatives. *international conference on advance in Engineering and Technology* .
- 8) Alaa, A. S., & Ali, A. M. (2013). Manufacturing of Bricks in the Past, in the Present and in the Future: A state of the Art Review. *International Journal of Advances in Applied Sciences (IJAAS)* , Vol. 2, No. 3, , pp. 145~156 ISSN: 2252-8814.
- 9) Aleva, G. (1994). Laterites. Concepts, Geology, Morphology and Chemistry. 169 pp. ISRIC, Wageningen, The Netherlands, ISBN 90-6672- 053-0.
- 10) Altayework Tadesse Belayneh. (2013). Effects of firing temperature on some physical properties of burnt clay bricks produced around Addis. *M.Sc. thesis, Addis Ababa University, Department of Civil Engineering, AAiT*.
- 11) Anayat, A., & Shamshad, A. (2019). Partial replacement of fine aggregate with brick dust, department of civil engineering, sharda university. *International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES). Research Symposium on Ad* .
- 12) Anteneh, G. (2017). Suitability of Crushed jema sandstone for concrete production as alternative to river sand.

- 13) Anzar Hamid mir. (2015). improved concret properties using Quarry dust as replacement for Natural sand . *international journal of engineering research and development* , 11,PP,46-52.
- 14) Aregaw, M. (2010). Investigation of Calcite and Volcanic Ash for Their Utilizations as cement Filling and Additive Materials. *M,SC thesis ,Addis Ababa university,Department of Civil Engineering,AAIT* .
- 15) Ashenafi G/Meskel. (2018). Crushed ambo sandstone as a partial replacement of sand for c-25 concrete production . *M.sc thesis Adiss Ababa scince and technology universty school of Graduate studies* .
- 16) Ashwin, S., Aishwarya, B. R., Praveen, H. R., Shwetha, N., & Adarsh, U. (2017). An Experimental Study on Concrete with Partial Replacement of Fine Aggregates by Laterite Sand. Department of Civil Engineering, Rajeev Institute of Technology, Hassan,.
- 17) Asiedu Emmanuel and Agbenyega Allan. . (2014). Suitability of Laterite Fines as a Partial Replacement for Sand in the Production of Sandcrete Bricks. *ISSN 2250-2459, ISO 9001:2008 Certified Journal, , Volume 4, Issue 10*).
- 18) Awolusi, T. F., Sojobi, A. O., & Afoloyan, J. O. (2017). SDA and laterite applications in concrete: Prospects and effects of elevated temperature. *Civil & Environmental Engineering* .
- 19) Beins, B. C., & McCarthy, M. A. (2012). Research Methods and Statistics.
- 20) Bia.org. (2016). Dimensioning and Estimating Brick Masonry (pdf file) Retrieved 8. *Technical Note 10*.
- 21) Biju, M., Dr Freeda, C. c., Souyma, c., & Dr Benny, J. (2014). The experimental study of physical property of aggregate with replacement of laterite for mix design. *International conference on advanced trends in Engineering and Technology*.
- 22) Biju, M., Dr, F., C, C., Souyma, C., & Dr.Benny. (2016). Study on Strength of Concrete by Partial Replacement of Fine Aggregate with M-Sand and Laterite with Super plasticizers. *International Journal of Engineering Trends and Technology (IJETT)* . , Volume 38. .
- 23) Brick Industry Association. (2016). Specifications for and Classification of Brick. Retrieved 28. *Technical Note 9A* , .
- 24) Cachim, P. B. (2009). "Mechanical Properties of Brick Aggregate Concrete." *Construction and Building Materials* 23,. 1292-1297.
- 25) Charles, C. (2019). fresh concrete. *retrieved from department of civil engineering at the university of memphis* .

- 26) D. A. (2005). .Handling of Concrete Making Materials in the Ethiopian Construction Industry, Addis Ababa, Ethiopia:. *M.Sc. thesis*, .
- 27) Edward G,Nawy. (2008). Concrete Construction Engineering. (2nd, Ed.)
- 28) ERA. (2001). *Design Manua*. Addis Ababa, Ethiopia.
- 29) Hall, A. (1990). "Using Computer-Aided Manufacturing to Build Better Brick," ., *The American Ceramic Society Bulletin* , pp. 80-82.
- 30) Hamilton, R. (1964). Microscopic studies of laterite formation in Ghana.
- 31) Hariharan, S., & Jebarj, G. (2018). Manufacture of bricks with partial replacement of clay with waste glass powder. *International journal of research in computer applications and robotics*. , Vol.6 Issue 2, Pg.: 1-2.
- 32) Honnun. (2004). *production and Utilization of manufactured sand for concrete purosos*. Nordic Atlantic co-operation report.
- 33) Jonathan, H. (2019). Concret production produces eight percent of the world's carbon dioxide emission. *The Architect's Newspaper* .
- 34) Joshua, Opeyemi, Lekan, M. A., olabosipo, I., Fagbenle, & P, O. K. (2016). Effects of partial replacement of sand with lateritic soil in sandcrete blocks. *Covenant Journal of Research in the Built Environment 1, no. 2*.
- 35) Kae, L. L., Hsiu, H. W., Chao, L. H., & An, C. (2010). Recycling waste brick from construction and demolition of buildings as pozzolanic materials. *Waste Management & Research*. DOI: 10.1177/0734242X09358735.
- 36) kosmatka, s. \$. (2003). *Design and control of concrete mixtures,portland cement Association*. (4th, Ed.) USA.
- 37) Kosmatka, s., Kerkhoff, B., & Panarese, W. (2003). *Design and Control of Concrete Mixtures, portland cement Association*. (4th, Ed.) USA.
- 38) Kothari, C. R. (2004). Research Methodology; ., Methods and Techniques. *New Age International (P) Ltd* .
- 39) kucche, k., Jamkar, S. S., & Sadgir, P. A. (2015). Quality of Water for making concrete. *international Journal of scientific and research publication* , 5,ISSN:2250-3153.
- 40) Lin, K. L., & Chang, J. C. (2013). Feasibility of recycling waste diatomite and fly ash cosintered as porous ceramics. *Environ. Prog. Sustain. Energy 2013, 32, 25–34*.

- 41) Liu, Q., Tong, T., Liu, S., Yang, D., & Yu, Q. (2014). Investigation of using hybrid recycled powder from demolished concrete solids and clay bricks as a pozzolanic supplement for cement. *Constr. Build. Mater.* 73, 754–763.
- 42) M.Usha Rani, and J.Martina Jenifer. (2016). An Experimental Study on Partial Replacement of Sand with Crushed Brick in Concrete. *Department of Civil Engineering. R.M.K. Engineering College, Chennai, Tamilnadu, India. IJSTE -International Journal of Science Techno .*
- 43) Marck C Wayn. (1998). property of freshly mix concrete.
- 44) Marius, D. G. (2017). Environmental Impacts of Sand Exploitation. *Analysis of Sand Market. Sustainability. , Volume 9. (Issue 7.), Pg. 1-26.*
- 45) Mohammed, A. (2018). Effect of sand on the plasticity of laterite. *Civil Engineering Department .Federal University of Technology, Minna.*
- 46) Monteiro, M. P. (2015). *Concret: Microstructure, Properties, and materials.* USA: McGraw Hill.
- 47) Naceri, A., Chikouche, H., & Grosseau, P. (2009). Physico-Chemical Characteristics of Cement Manufactured with Artificial Pozzolan (Waste Brick). *International Journal of Civil and Environmental Engineering , Volume: 3 (No: 4).*
- 48) Narendra, B. K., Ganesh, B., Murthy, G., & Chandrika, k. (2017). 43. K Narendra Brahmaji, B Ganesh, GVLN Murthy and K Chandrika.2017. An Experimental Analysis On Usage Potential Of Lateritic Soil As Part/Full Replacement For Fine Aggregates In Concrete. *International Journal Of Current Engineering And Scientific Resear. International Journal Of Current Engineering And Scientific Resear .*
- 49) Neville, A.M. (1986). *properties of concrete, longman scientific & Technical series.* (Fifth, Ed.) London: Pearson Education Limited.
- 50) Neville, A. M. (2008). *Properties of Concrete.* (1. edition., Ed.) CTP-VVP.
- 51) Neville, A. M., & Books, J. J. (1987). *Concrete Technology.*, New York: Longman Scientific and Technical Series.
- 52) Pasetto, M., & Baldo, N. (2015,). Experimental analysis of hydraulically bound mixtures made with waste foundry sand and steel slag. *Mater. Struct. Construction and Building Materials* 23, , 48, 2489–2503.
- 53) Peter, D., & John, I. (2010). *Construction Material Their Nature and Behavior.* (4th, Ed.) London: New York: spon press.

- 54) Prabhu, G. G. (2014). Effects of Foundary Sand as a Fine Aggregate In Concrete Production. *Construction and Building Materials*.
- 55) Richards, R. W. (1990). "Brick Manufacturing from Past to Present,". *The American Ceramic Society Bulletin* , pp. 807-813.
- 56) Robayo-Salazar, R., Rivera, J., & Mejía de Gutiérrez, R. (2017). Alkali-activated building materials made with recycled construction and demolition wastes. *Constr. Build. Mater.* 149, 130–138.
- 57) s. A., & M. G. (2019). Properties of Brick Waste as Coarse Aggregate Material in Concrete. *Department of Civil Engineering, Faculty of Civil and Environmental Engineering* , .
- 58) S.K. Duggal. (2000). Building materials. (T. edition, Ed.) *Motilal Nehru institute of technology Allahabad (U.P.)*, .
- 59) Safiuddin, M., Mahmud, H. B., & Jumaat, M. Z. (2011). Jumaat Efficacy of ASTM Saturation Techniques for Measuring the Water Absorption of Concrete. *Arab J Sci Eng* , Volume 36. (No. 5.), Pg. 761–768.
- 60) Saidi, M. S. (2015). Improved behaviour of mortars at a high temperature by using refractory brick wastes. . *International Journal of Microstructure and Materials Properties*, 10.
- 61) Salau, M, & Balogun, L. (1998). Shrinkage deformations of lateritized concrete. *Building and Environment*,. 34(2), 165–173.
- 62) Shewaferaw Dinku. (2006). The Use of manufactured sand in concrete Production. *Test Result and Cost Comparison* .
- 63) The McGraw-Hill Companies.,. (2004). Masonry design and detailing for Architects and Contractors. Retrieved from:(accessed on 15 June.
- 64) Thomas Varghese and Byju.G. (1993). Laterite soils, their distribution, characteristics classification and management, Published by State Committee on Science, Technology and Environment, Government of Kerala, Thiruvananthapuram.
- 65) Tunc, E. (2019). Recycling of Marble waste: A Review based on Strength of Concrete containing Marble Waste. *Journal of Environmental Management*,. pp. 86-97.
- 66) U.S. Environmental protection agency. (2003). office of air quality planning and standards innovative strategies and economics group. *Economic impact analysis for the brick and structural clay products manufacturing NESHAP: Final rule, United States env* .

- 67) Yajurved, R. M., Swetha, D. V., & Dhani, s. k. (2015). Study on Properties of Concrete with Manufactured Sand as Replacement to Natural Sand. International . . . *Journal of Civil Engineering and Technology* , Volume 6. (Issue 8.), .Pg.29-42.

APPENDIX A: MATERIALS TEST RESULTS

A.1. Properties of cement

A.1.1. Normal consistency of Dangote OPC cement

Test No	Sample weight [gm]	Water added [gm]	% of Water	Penetration [mm]	Water cement ratio at 10 mm penetration
1	500	140	28	22	From the calculation the w/c ratio for normal consistency is approximately 30%
2	500	150	30	11	
3	500	160	32	0	

According to the Ethiopian Standard, it is recommended the usual range of water-cement ratio for normal consistency is between 26% to 33%. So Dangote OPC cement fulfill the the requirements.

A.1.2. Setting time of Dangote OPC cement

Test NO	Sample weight [gm]	Water added [gm]	% of Water	Initial setting time	Final setting time
1	500	150	30	190 minutes	510minutes

According to the Ethiopian Standard recommends that the initial setting time for cement not to be less than 45minutes and the final setting time not to exceed 10 hr. So Dangote OPC cement fulfill the requirements.

A.2. Properties of Fine Aggregate

The following tests were conducted for fine aggregate as per ASTM standards.

A.2.1. Silt content

Silt Content of fine aggregates			
Sand type	Amount of Silt deposit	Amount of clear	Silt content %
River sand	1ml	29 ml	3.45%
Waste brick	1.5ml	28.5ml	5.26%
Laterite sand	1ml	29	3.45%

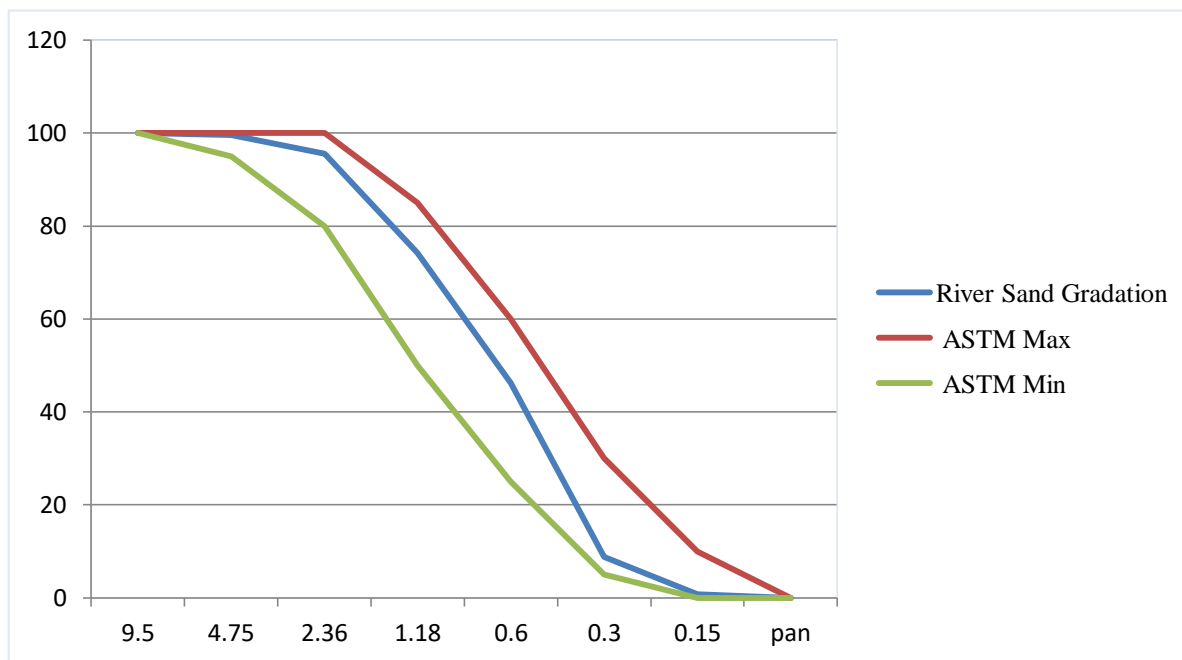
According to the Ethiopian Standard, it is recommended to wash fine aggregates or reject if the silt content exceeds a value of 6%. So the fine aggregates fulfill the requirements.

A.2.2. Sieve analysis

A.2.2.1. Sieve analysis river sand

River sand						
Sieve size	Weight Retained (gm)	Percentage retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)	ASTM limit	Remark
9.5 mm	0	0	0	100	100	Ok!
4.75 mm	2	0.4	0.4	99.6	95-100	Ok!
2.36 mm	20	4	4.4	95.6	80-100	Ok!
1.18 mm	107	21.4	25.8	74.2	50-85	Ok!
600	140	28	53.8	46.2	25-60	Ok!

μm						
300 μm	187	37.4	91.2	8.8	5-30	Ok!
150 μm	40	8	99.2	0.8	0-10	Ok!
Pan	4	0.8	-	-	-	Ok!
Total	500	100	274.8			
<p>Fineness Modulus= $\sum \text{cumulative}/100=274.8/100=2.75$</p>						

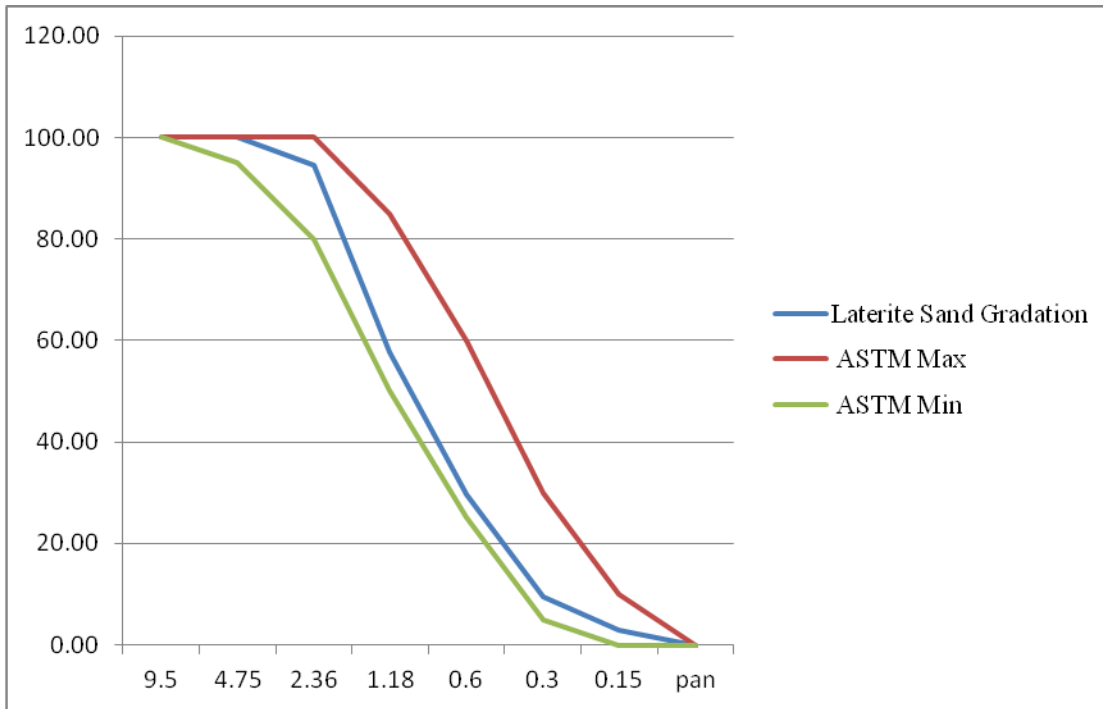


- Therefore, according to the result, the river sand fulfills the gradation standard of ASTM. The recommended Fineness modulus is between 2.3-3.1 and the given waste brick is 2.75. So, it is within the range.

A.2.2.2. Sieve analysis laterite sand

Laterite sand						
Sieve size	Weight Retained (gm)	Percentage retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)	ASTM limit	Remark
9.5 mm	0	0	0	100	100	Ok!
4.75 mm	0	0	0	100	95-100	Ok!
2.36 mm	27	5.41	5.41	94.59	80-100	Ok!
1.18 mm	184	36.87	42.28	57.72	50-85	Ok!
600 μm	140	28.06	70.34	29.66	25-60	Ok!
300 μm	101	20.24	90.58	9.42	5-30	Ok!
150 μm	33	6.61	97.19	2.81	0-10	Ok!
Pan	14	2.81	-	-	-	Ok!
Total	499	100	305.81			
Total sample before sieved = 500						
Fineness Modulus = $\sum \text{cumulative} / 100 = 305.81 / 100 = 3.06$						

--	--	--

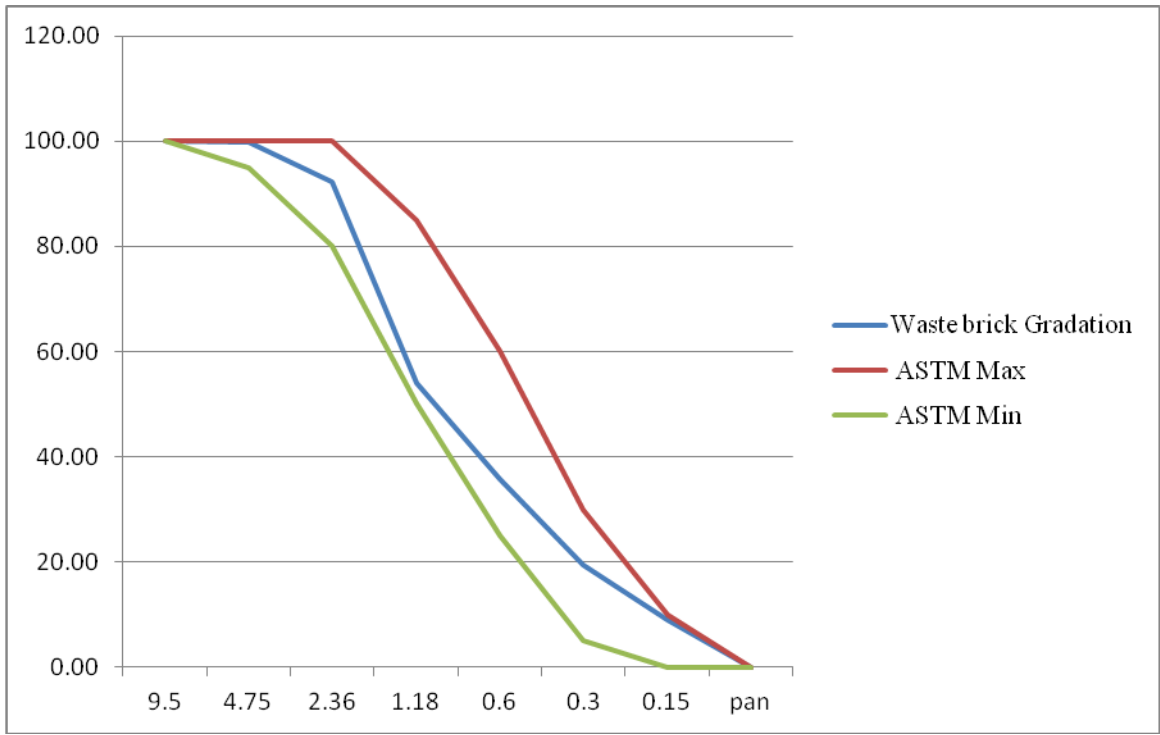


Therefore, according to the result, the laterite sand fulfills the gradation standard of ASTM. The recommended Fineness modulus is between 2.3-3.1 and the given laterite sand is 3.06. So, it is within the range.

A.2.2.3. Sieve analysis waste brick

Waste brick

Sieve size	Weight Retained (gm)	Percentage retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)	ASTM limit	Remark
9.5 mm	0	0	0	100	100	Ok!
4.75 mm	1	0.2	0.2	99.8	95-100	Ok!
2.36 mm	37	7.43	7.63	92.37	80-100	Ok!
1.18 mm	191	38.35	45.98	54.02	50-85	Ok!
600 μm	91	18.27	64.26	35.74	25-60	Ok!
300 μm	81	16.27	80.52	19.48	5-30	Ok!
150 μm	52	10.44	90.96	9.04	0-10	Ok!
Pan	45	9.04	-	-	-	Ok!
Total	498	100	289.56			
Total sample before sieved = 500						
Fineness Modulus= $\sum \text{cumulative}/100=289.56/100=2.9$						



Therefore, according to the result, the waste brick fulfills the gradation standard of ASTM. The recommended Fineness modulus is between 2.3-3.1 and the given waste brick is 2.9 So, it is within the range.

A.2.3. Moisture Content Test

According to ASTM C 566, moisture content test is the test that shows the amount of water or moisture in fine aggregate.

Observation and Calculation

A.2.3.1. Moisture Content of river sand

The following data are the results of the test;

Item	Symbol	Weight
Weight of original sample	A	1000

Weight of oven dry sample	B	972
$W = \text{Moisture content}(\%) = (A - B) * 100 / B = ((1000 - 972) / 972) * 100 = 2.88\%$		

- Since the river sand moisture and this moisture content is within the range of ASTM C 566 maximum limit that 8% for fine aggregate. This is the amount of added water should be adjusted to compensate for any observed variation in the moisture content. So, the free moisture should be subtracted from the mix water requirement on the mix design.

A.2.3.2. Moisture Content of latrite sand

The following data are the results of the test;

Item	Symbol	Weight
Weight of original sample	A	500
Weight of oven dry sample	B	436
$W = \text{Moisture content}(\%) = (A - B) * 100 / B = ((500 - 436) / 436) * 100 = 14.68\%$		

- This is the amount of added water should be adjusted to compensate for any observed variation in the moisture content.so, the free moisture should be subtracted from the mix water requirement on the mix design.

A.2.3.3. Moisture content of waste brick

The following data are the results of the test;

Item	Symbol	Weight
Weight of original sample	A	500
Weight of oven dry sample	B	498
$W = \text{Moisture content}(\%) = (A - B) * 100 / B = ((500 - 498) / 498) * 100 = 0.4\%$		

- This is the amount of added water should be adjusted to compensate for any observed variation in the moisture content.so, the free moisture should be subtracted from the mix water requirement on the mix design.

A.2.4. Absorption capacity

According to ASTM C 128 to test the increase in weight of aggregate due to water in the pore of the material.

Observation and Calculation

A.2.4. 1.Absorption capacity of river sand

The following data are the results of the test;

Item	Symbol	Weight
Weight of SSD sample on air	A	482
Weight of oven dry sample on air	B	464
$W = \text{Moisture content}(\%) = (A - B) * 100 / B = ((482 - 464) / 464) * 100 = 3.88\%$		

- Absorption is a measure of the total pore volume accessible to water. It's also useful for mix design moisture adjustment. The absorption of 3.88% is well within the maximum limit of 4%.

A.2.4. 1.Absorption capacity of laterite sand

The following data are the results of the test;

Item	Symbol	Weight
Weight of SSD sample on air	A	400
Weight of oven dry sample on air	B	343
$W = \text{Moisture content}(\%) = (A - B) * 100 / B = ((500 - 498) / 498) * 100 = 16,62\%$		

- Based upon a 24hour absorption test conducted in accordance with the procedures of ASTM C 127 and ASTM C 128, structural grade lightweight aggregates will absorb from 5 to more than 25 percent moisture by mass of dry aggregate. The absorption of 16.62% is well within the maximum limit.

A.2.4. 1.Absorption capacity of waste brick

The following data are the results of the test;

Item	Symbol	Weight
Weight of SSD sample on air	A	500
Weight of oven dry sample on air	B	434
$W = \text{Moisture content}(\%) = (A - B) * 100 / B = ((500 - 434) / 434) * 100 = 15.2\%$		

- Based upon a 24hour absorption test conducted in accordance with the procedures of ASTM C 127 and ASTM C 128, structural grade lightweight aggregates will absorb from 5 to more than 25 percent moisture by mass of dry aggregate. The absorption of 15.2% is well within the maximum limit

A.2.5. Specific Gravity Test of Fine aggregate

The specific gravity of sand performed as per ASTM C 128.

Observation and Calculation

A.2.5. 1.Specific gravity of river sand

The following data are the results of the test;

Item	Symbol	Weight
Weight of sand sample, SSD	A	482

Weight of pycnometer + water	B	1554
Weight of pycnometer + water + sand	C	1860
Weight of oven dry sample on air	D	464
<p>Bulk specific gravity= $D/(B+A-C) = 464/(1554+482-1860) = 484/176 = 2.64$</p> <p>Bulk specific gravity(SSD)= $A/(B+A-C) = 482/(1554+482-1860) = 482/176 = 2.74$</p> <p>Apparent specific gravity(SSD)= $D/(B+D-C) = 464/(1554+464-1860) = 464/158 = 2.94$</p>		

- Therefore, the bulk specific gravity of fine aggregates ranges between 2.6 to 2.8. Consequently, a sample having a bulk specific gravity of 2.74 is suitable for concrete production.

A.2.5. 2. Specific gravity of latrite sand

The following data are the results of the test;

Item	Symbol	Weight
Weight of sand sample, SSD	A	400
Weight of pycnometer + water	B	1554
Weight of pycnometer + water + sand	C	1776
Weight of oven dry sample on air	D	343
<p>Bulk specific gravity= $D/(B+A-C) = 343/(1554+400-1776) = 343/178 = 1.93$</p> <p>Bulk specific gravity(SSD)= $A/(B+A-C) = 400/(1554+400-1776) = 400/178 = 2.25$</p> <p>Apparent specific gravity(SSD)= $D/(B+D-C) = 343/(1554+343-1776) = 343/121 = 2.83$</p>		

- Therefore, the bulk specific gravity of latrite sand determined from the test result is 2.25.

A.2.5. 2. Specific gravity of waste brick

The following data are the results of the test;

Item	Symbol	Weight
Weight of sand sample, SSD	A	500
Weight of pycnometer + water	B	1554
Weight of pycnometer + water + sand	C	1827
Weight of oven dry sample on air	D	434
Bulk specific gravity= $D/(B+A-C) = 434/(1554+500-1827)=434/227= 1.9$ Bulk specific gravity(SSD)= $A/(B+A-C)= 500/(1554+500-1827)=500/227=2.2$ Apparent specific gravity(SSD)= $D/(B+D-C)=434/(1554+434-1827)=496/161=3.08$		

➤ Therefore, the bulk specific gravity of latrite sand determined from the test result is 2.2.

A.2.6. Unit weight Test of Fine Aggregate

Unit weight is also known as bulk density and conducted according to ASTM C 29; it helps to determine the weight of sand in a given volume of graded sand.

Observation and Calculation

A.2.6.1. Unit weight test of river sand

The following data are the results of the test;

Item	Symbol	Weight
Loose weight of sample + measure	A	15.619
Rodded weight of sample + measure	B	16.55
Weight of the measure	C	4.028
Volume of measure	D	0.0069m ³

Loose unit weight= $A-C/D=15.619-4.028/0.0069=1679.9\text{kg/m}^3$

Rodded unit weight= $B-C/D=16.55-4.028/0.0069=1814.78\text{kg/m}^3$

- Therefore, the approximate bulk density of fine aggregate commonly used in concrete ranges from about 1280 to 1920 kg/m³. Hence, the sample is in this range and acceptable for use.

A.2.6.1. Unit weight test of laterite sand

The following data are the results of the test;

Item	Symbol	Weight
Loose weight of sample + measure	A	11.658
Rodded weight of sample + measure	B	13.023
Weight of the measure	C	4.028
Volume of measure	D	0.0069m ³
Loose unit weight= $A-C/D=11.66-4.028/0.0069=1106.09\text{kg/m}^3$		
Rodded unit weight= $B-C/D=13.385-4.028/0.0069=1303.62\text{kg/m}^3$		

- Therefore, the approximate dry loose bulk density of lightweight aggregate commonly used in concrete is less than 1120 kg/m³. Hence, the sample is in this range and acceptable for concrete production.

A.2.6.1. Unit weight test of waste brick

The following data are the results of the test;

Item	Symbol	Weight
Loose weight of sample + measure	A	10.383
Rodded weight of sample + measure	B	11.323
Weight of the measure	C	4.028
Volume of measure	D	0.0069m ³

$$\text{Loose unit weight} = A - C/D = 10.383 - 4.028 / 0.0069 = 913.2 \text{ kg/m}^3$$

$$\text{Rodded unit weight} = B - C/D = 13.385 - 4.028 / 0.0069 = 1055.7 \text{ kg/m}^3$$

- Therefore, the approximate dry loose bulk density of lightweight aggregate commonly used in concrete is less than 1120 kg/m³. Hence, the sample is in this range and acceptable for concrete production.

A.3. Properties of Coarse Aggregate

The following tests were conducted for fine aggregate as per ASTM standards.

A.3.1. Sieve analysis

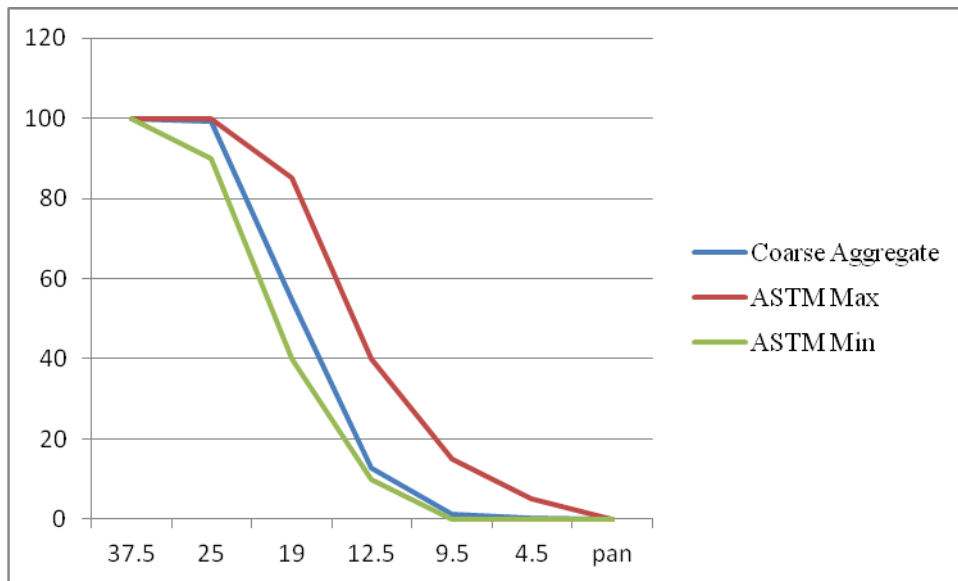
Gradation test was performed as per ASTM C136. Aggregates having a particle size larger than 4.75 mm is considered as coarse aggregate and 25 mm nominal maximum aggregate size was taken to conduct this study.

Observation and Calculation

The following data are the results of the test;

Coarse Aggregate						
Sieve size	Weight Retained (gm)	Percentage retained (%)	Cumulative Coarser (%)	Cumulative Passing (%)	ASTM limit	Remark
37.5 Mm	0	0	0	100	100	Ok!
25 mm	17	0.85	0.85	99.15	90-100	Ok!
19 mm	886	44.3	45.15	54.85	40-85	Ok!

12.5 mm	841	42.05	87.2	12.8	10-40	Ok!
9.5 mm	234	11.7	98.9	1.1	0-15	Ok!
4.75 mm	20	1	99.9	0.1	0-5	Ok!
Pan	2	0.1	100	-	-	Ok!
Total	2000	100				
Total sample before sieved = 2000						
Fineness Modulus= $\sum \text{cumulative}/100=332/100=3.32$						



➤ Therefore, according to the result, the coarse aggregate fulfills the gradation standard of ASTM.

A.3.2. Moisture Content Test

According to ASTM C 566, moisture content test is the test that shows the amount of water or moisture in fine aggregate.

Observation and Calculation

The following data are the results of the test;

Item	Symbol	Weight
Weight of original sample	A	2000
Weight of oven dry sample	B	1995
$W = \text{Moisture content}(\%) = (A - B) * 100 / B = ((2000 - 1995) / 1995) * 100 = 0.25\%$		

- The moisture content is greater than the absorption of coarse aggregate. According to ASTM C 566 the maximum moisture content of coarse aggregate is 6%. Since the test result is within this range and it is applicable for concrete production. The aggregate will provide water for the mix without adjustment; the mixing water should be reduced in order to account for moisture content.

A1.4. Specific Gravity and Absorption Test

According to ASTM C 127, specific gravity is the ratio of the mass of a unit volume of material to the mass of the same volume of water at stated temperature while water absorption is the increase in the weight of aggregate due to water in the pore of materials.

Observation and Calculation

The following data are the results of the test;

Item	Symbol	Weight
Weight of oven dry sample in air (mass A)	A	1991
Weight of saturated surface dry sample in air	B	2002
Weight of saturated sample in water	C	1316

$$\text{Bulk specific gravity} = A/(B-C) = 1991/(2002-1316) = 1991/686 = 2.9$$

$$\text{Bulk specific gravity(SSD)} = B/(B+A-C) = 2002/(2002-1316) = 2002/686 = 2.92$$

$$\text{Apparent specific gravity(SSD)} = A/(A-C) = 1991/(1991-1316) = 1991/675 = 2.95$$

$$\text{Absorption capacity(\%)} = (B-A)*100/A = (2002-1991)*100/1991 = 19.5*100/1991 = 0.55\%$$

- Therefore, both the bulk specific gravity and absorption are within the range between 2.4 and 3.0 and 0.5% and 4% respectively. It can be used for concreting.

A1.3. Unit weight Test

Unit weight also known as bulk density and conducted according to ASTM C 29; it is the weight of aggregate in a given volume of graded aggregate. It includes the aggregate and the void space between the aggregate.

Observation and Calculation

The following data are the results of the test;

Item	Symbol	Weight
Loose weight of sample + measure	A	14.65
Rodded weight of sample + measure	B	16.1
Weight of the measure	C	4.028
Volume of measure	D	0.0069m ³
Loose unit weight= $A-C/D = 14.65 - 4.028 / 0.0069 = 10.622 / 0.0069 = 1537.2 \text{ kg/m}^3$		
Rodded unit weight= $B-C/D = 16.1 - 4.028 / 0.0069 = 12.072 / 0.0069 = 1747.03 \text{ kg/m}^3$		

- Therefore, the unit weight for normal weight concrete ranges from 1120 to 1920 kg/m³. Hence, the sample falls in the range and is suitable for concreting practice.

APPENDIX B: MIX DESIGN

Mix Design Procedure

Mix 1: (100 % sand, 0% Waste brick and 0% Laterite) (control mix)

Mix design for normal concrete is done as per Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (ACI 211.1-91) for concrete having 25 MPa compressive strength [C-25].

Required average Compressive Strength when data are not available to establish standard deviation presented in the table below.

Specified compressive strength, f'_c , MPa	Required average compressive strength, f'_{cr} , MPa
Less than 21	$f'_c + 7.0$
21 to 35	$f'_c + 8.5$
Over 35	$1.10 f'_c + 5.0$

Source ACI 318

For characteristic strength of 25 MPa, the required average strength at 28th day is calculated as: $f'_{cr} = f'_c + 8.5$ because 25MPa is between 21 and 35MPa: i.e. $f'_{cr} = f'_c + 8.5 = 25 + 8.5 = 33.5$ Mpa.

The following material test results conducted in the laboratory are summarized in the table below:

Summary of Materials Test Result

Material type	Material Specification
Characteristic strength	25 MPa
Required average strength	33.5 MPa
Age	28 days
Cement	Dangote, strength class of 42.5 R

The specific gravity of cement	3.15(assumed)
Coarse aggregate type	Crushed
Sand	Uncrushed (Natural)
Required slump	75-100 mm
Fineness modulus of sand	2.75
Fineness modulus of waste brick	2.9
Fineness modulus of laterite	3.06
Water used	Potable tap water from the laboratory
The specific gravity of coarse aggregate	2.92
The specific gravity of sand	2.74
The specific gravity of waste brick	2.2
The specific gravity of laterite	2.25
Bulk density of coarse aggregate	1747.03 kg/m ³
Bulk density of sand	1814.78 kg/m ³
Bulk density of waste brick	1055.7kg/m ³
Bulk density of laterite	1303.62kg/m ³
Water absorption coarse aggregate	0.55%
Water absorption for sand	3.88%
Water absorption for waste brick	15.21 %
Water absorption for laterite sand	16.62%
Moisture Content of Coarse aggregate	0.25 %
Moisture Content of sand	2.88%
Moisture Content of waste brick	0.4%

Moisture Content of laterite sand	14.67 %
Sieve analysis of coarse aggregate	Conforming to ASTM C-33
Sieve analysis of sand	Conforming to ASTM C-33
Sieve analysis of waste brick	Conforming to ASTM C-33
Sieve analysis of laterite	Conforming to ASTM C-330
Silt content of sand	3.45 %
Silt content of waste brick	5.26%
Silt content of laterite sand	3.45%
Source of sand	Metahra and langano, oromia region ,Ethiopia
Source of waste brick	Demolish works around Gelan city ,Ethiopia
Source of laterite sand	Tulu dimtu, AdissAbeba, Ethiopia
Source of crushed coarse aggregate	Tukurabay and Gendekora, Geln city, Ethiopia
Concrete type	Non-Air entrained concrete

Step 1: Slump selection

- ✓ 75-100 mm (Recommended and used by (Ashwin S et al., 2017) for laterite and since, both of them have greater absorption capacity than river sand due to its porosity.

Step 2: Maximum size of aggregate selection

- ✓ 25 mm maximum Nominal aggregate size was used.

Step 3: Estimation of water content

- ✓ From ACI 211.1-91 table 9.5, for a slump of 75 to 100 mm and the maximum size of aggregate of 25mm, the water requirement is approximated 193 kg/m^3 with a corresponding 1.5 % air.

Step 4: Selection of water-cement ratio:

- ✓ From ACI 211.1-91 table 9.3, the water-cement ratio of 0.49 for concrete with compressive strength of 33.5 MPa (using interpolation).

Step 5: Calculation of cement content:

- ✓ Cement content= $WW/C=193/0.49=394 \text{ kg/m}^3$.

Step 6: Estimation of coarse aggregate content:

- ✓ For maximum size aggregate of 25 mm and sand fineness modulus of 2.75, ACI 211.1-9 table 9.4 gives 0.689 for a bulk volume of oven-dry rodded coarse aggregate (using interpolation). Given the bulk density of coarse aggregate 1747 kg/m^3 .
- ✓ The mass of coarse aggregate is given by: $= 0.675 * 1747.03 = 1179.22 \text{ kg/m}^3$.

Step 7: Estimation of fine aggregate content:

- ✓ To calculate the mass of sand, it's better first to determine the absolute volume of other ingredients as indicated hereunder:
- ✓ Volume of water= $193/1000 = 0.193 \text{ m}^3$.
- ✓ Solid volume of cement = $394/3.15 * 1000 = 0.125 \text{ m}^3$.
- ✓ Solid volume of coarse aggregate = $1179.22 / (2.92 * 1000) = 0.404 \text{ m}^3$.
- ✓ Volume of entrapped air = 0.015 m^3 .
- ✓ So total volume of all ingredients except fine aggregate = $(0.193 + 0.125 + 0.404 + 0.015) = 0.737 \text{ m}^3$.
- ✓ So that, volume of sand = $1 - 0.696 = 0.263 \text{ m}^3$
- ✓ Hence the mass of sand is $0.263 * 2.74 * 1000 = 721.05 \text{ kg/m}^3$.

The estimated mass of each of the ingredient before adjustment for moisture content is described as follows:

Weight of ingredients before adjustment

Concrete ingredients	Weight of ingredients before adjustment
Weight of cement	394 kg/m^3
Weight of water	193 kg/m^3
Weight of sand	721.05 kg/ m^3
Weight of coarse aggregate	1179.22 kg/ m^3

Step 8: Adjustment for water, coarse and fine aggregate:

- ✓ Coarse aggregate adjustment (it absorbs 0.55 % and has moisture content of 0.25%), so that adjusted C.A. content:

$$= 1179.22 - (0.55/100 * 1179.22) + (0.25/100 * 1179.22) = 1175.68 \text{ kg/m}^3.$$

- ✓ Adjustment sand (it absorbs 3.88 % and has moisture content of 2.88 %), so that FA content:

$$= 721.05 - (3.88 / 100 * 857.62) + (2.88 / 100 * 857.62) = 713.84 \text{ kg/m}^3.$$

- ✓ Water adjustment (additional water is required for the amount absorbed by coarse and fine aggregate),

$$= 193 + ((0.55 - 0.25) / 100 * 1032.22) + ((3.88 - 2.88) / 100 * 857.62) = 204.67 \text{ kg/m}^3.$$

Concrete ingredients	Weight of ingredients After adjustment
Weight of cement	394 kg/m ³
Weight of water	204.67 kg/m ³
Weight of sand	713.84 kg/ m ³
Weight of coarse aggregate	1175.68 kg/ m ³

The proportion of ingredients for the trial mix in nine cubes are calculated below but before we proceed with the required quantity of each ingredient let us calculate the total required volume of fresh concrete for trial mix:

- ✓ Trial mix volume = $[(0.15 * 0.15 * 0.15) * 9] + 20\%$ of wastage = 0.0365 m³

Now, the required quantity per trial mix of each ingredient is calculation is shown below:

	Water (kg)	Cement (kg)	Coarse aggregate (kg)	Sand (kg)
Per m ³	204.67	394	1175.68	713.84
Per trial mix of 0.0365 m ³	7.47	14.4	42.91	26.05

Mix 2: (67 % sand, 11 % waste brick and 22 % laterite sand)

Step 1: Slump selection

- ✓ 75-100 mm (Recommended and used by (Ashwin S et al., 2017) for laterite and since, both of them have greater absorption capacity than river sand due to its porosity.

Step 2: Maximum size of aggregate selection

- ✓ 25 mm maximum Nominal aggregate size was used.

Step 3: Estimation of water content

- ✓ From ACI 211.1-91 table 9.5, for a slump of 75 to 100 mm and the maximum size of aggregate of 25mm, the water requirement is approximated 193 kg/m^3 with a corresponding 1.5 % air.

Step 4: Selection of water-cement ratio:

- ✓ From ACI 211.1-91 table 9.3, the water-cement ratio of 0.49 for concrete with compressive strength of 33.5 MPa (using interpolation)

Step 5: Calculation of cement content:

- ✓ Cement content = $W/C = 193/0.49 = 394 \text{ kg/m}^3$.

Step 6: Estimation of coarse aggregate content:

- ✓ For maximum nominal size aggregate of 25 mm and fineness modulus of sand, waste brick and laterite sand were used based on their proportion ($2.75*0.67+2.9*0.11+3.06*0.22=2.835$), ACI 211.1-9 table 9.4 gives 0.667 for a bulk volume of oven-dry rodded coarse aggregate (using interpolation). Given the bulk density of coarse aggregate 1747.03 kg/m^3 .
- ✓ The mass of coarse aggregate is given by: $= 0.667*1747 = 1164.38 \text{ kg/m}^3$.

Step 7: Estimation of fine aggregate content:

- ✓ To calculate the mass of sand, waste brick and laterite sand its better first to determine the absolute volume of other ingredients as indicated hereunder:
- ✓ Volume of water = $193/1000 = 0.193 \text{ m}^3$.
- ✓ Solid volume of cement = $394/3.15*1000 = 0.125 \text{ m}^3$.
- ✓ Solid volume of coarse aggregate = $1164.38/(2.92*1000) = 0.399 \text{ m}^3$.
- ✓ Volume of entrapped air = 0.015 m^3 .

- ✓ So total volume of all ingredients except fine aggregates = (0.193 + 0.125 + 0.399 + 0.015) = 0.732 m³.
- ✓ So total volume of all ingredients except fine aggregates = (0.193 + 0.125 + 0.399 + 0.015) 0.732 m³.
- ✓ So that, total volume of fine aggregates = 1-0.732 = 0.268 m³.
- ✓ The mass of sand is 0.268*2.74*1000*0.67= 492 kg/m³.
- ✓ The mass of waste brick is 0.268*2.2*1000*0.11= 64.9 kg/m³.
- ✓ Hence the mass of laterite sand is 0.268*2.25*1000*0.22= 132.5 kg/m³.

The estimated mass of each of the ingredient before adjustment for moisture content is described as follows:

Weight of ingredients before adjustment

Concrete ingredients	Weight of ingredients before adjustment
Weight of cement	394 kg/m ³
Weight of water	193 kg/m ³
Weight of sand	492 kg/ m ³
Weight of waste brick	64.9 kg/ m ³
Weight of laterite sand	132.5 kg/ m ³
Weight of coarse aggregate	1164.38 kg/ m ³

Step 8: Adjustment for water, coarse and fine aggregate:

- ✓ Coarse aggregate adjustment (it absorbs 0.55 % and has moisture content of 0.25%), so that adjusted C.A. content:

$$= 1164.38 - (0.55/100 * 1164.38) + (0.25/100 * 1164.38) = 1160.89 \text{ kg/m}^3.$$

- ✓ Adjustment for sand (it absorbs 3.88 % and has moisture content of 2.88 %), so that FA content:

$$= 492 - (3.88/100 * 492) + (2.88/100 * 492) = 487.08 \text{ kg/m}^3.$$

- ✓ Adjustment for waste brick (it absorbs 15.21% and has moisture content of 0.41%), so that FA content:

$$= 64.9 - (15.21 / 100 * 64.9) + (0.41 / 100 * 64.9) = 55.3 \text{ kg/m}^3.$$

- ✓ Adjustment for laterite sand (it absorbs 16.62 % and has moisture content of 14.68 %), so that FA content:

$$= 132.5 - (16.62 / 100 * 132.5) + (14.68 / 100 * 132.5) = 129.93 \text{ kg/m}^3.$$

- ✓ Water adjustment (additional water is required for the amount absorbed by coarse and fine aggregate),

$$= 193 + ((0.55 - 0.25) / 100 * 1164.38) + ((3.88 - 2.88) / 100 * 492) + ((15.21 - 0.41) / 100 * 64.9) + ((16.62 - 14.68) / 100 * 132.5) = 213.6 \text{ kg/m}^3.$$

Concrete ingredients	Weight of ingredients After adjustment
Weight of cement	394 kg/m ³
Weight of water	213.6 kg/m ³
Weight of sand	487.08 kg/ m ³
Weight of waste brick	55.3 kg/ m ³
Weight of laterite sand	129.93 kg/ m ³
Weight of coarse aggregate	1160.89 kg/ m ³

The proportion of ingredients for the trial mix in nine cubes are calculated below but before we proceed with the required quantity of each ingredient let us calculate the total required volume of fresh concrete for trial mix:

- ✓ Trial mix volume = $[(0.15 * 0.15 * 0.15) * 9] + 20\%$ of wastage = 0.0365 m³

Now, required quantity per trial mix of each ingredient is calculation is shown below:

	Water (kg)	Cement (kg)	Coarse aggregate (kg)	Sand (kg)	Waste brick (kg)	Laterite sand (kg)

Per m ³	213.6	394	1160.89	487.08	55.3	129.93
Per trial mix of 0.0365 m ³	7.8	14.4	42.37	17.8	2.02	4.74

✓ All the rest mix proportion was performed in the same procedure of the above mix design.

APENDEX C: COMPRESIVE STRENGTH RESULT

The 3rd day compressive strength result

3 rd day										
Mix	Sample 1			Sample 2			Sample 3			Average Compressive Strength (Mpa)
	Load(K N)	Stress (Mpa)	Weight (Kg)	Load(K N)	Stress (Mpa)	Weight (Kg)	Load(K N)	Stress (Mpa)	Weight (Kg)	
Mix1	425.2	18.9	9.13	433.5	19.3	9.23	417.6	18.6	8.92	18.9
Mix2	432.6	19.2	8.78	437	19.4	8.8	428.1	19	8.84	19.2
Mix3	394.6	17.5	8.53	359.3	15.9	9.05	387.3	17.2	8.91	16.87
Mix4	526.4	23.3	9.24	567.6	25.2	8.84	568.1	25.2	9.14	24.57
Mix5	400.7	17.8	8.44	374.8	16.6	8.59	380	16.9	8.4	17.1
Mix6	439.5	19.5	8.64	405.8	18	8.57	416.6	18.5	8.55	18.67
Mix7	391.3	17.3	8.71	433.1	19.2	8.63	385.9	17.1	8.75	17.87
Mix8	402.2	17.8	9.36	376.6	16.3	8.59	368.2	16.3	9.02	16.8
Mix9	447.7	18.9	9.26	442.4	19.6	8.88	408.7	18.1	8.85	18.87
Mix10	432.8	19.2	8.71	412.6	18.3	8.47	420.6	18.9	8.62	18.7
Mix11	354.6	15.7	8.59	353.6	15.7	8.7	349.3	15.5	8.3	15.63
Mix12	316,6	14	8.17	320	14.2	8.77	318.2	14.1	8.31	14.1
Mix1	298.6	13.2	8.76	371.5	16.5	8.32	377.7	16.7	8.82	15.47

3										
---	--	--	--	--	--	--	--	--	--	--

The 7th day compressive strength test result

7 th day										
Mix	Sample 1			Sample 2			Sample 3			Average Compressive Strength (Mpa)
	Load(K N)	Stress (Mpa)	Weight (Kg)	Load(K N)	Stress (Mpa)	Weight (Kg)	Lod(K N)	Stress (Mpa)	Weight (Kg)	
Mix1	505.5	22.5	8.92	523.1	23.2	9.46	496	22.1	8.84	22.6
Mix2	563.9	25	8.86	563.6	25	8.68	581.8	25.8	9.05	25.27
Mix3	530.4	23.5	8.85	568.7	25.2	8.5	596.4	26.4	8.7	25.03
Mix4	649.2	28.8	8.95	686.8	30.5	8.8	671.5	29.8	9.42	29.7
Mix5	488.6	21.7	8.75	495.3	22.0	8.87	499.7	22.2	8.9	21.97
Mix6	515.6	22.9	8.82	523.3	23.3	8.91	521.4	23.2	8.76	23.13
Mix7	509.8	22.7	8.88	517.4	23	8.95	521.8	23.2	8.93	22.97
Mix8	415.5	18.4	8.8	462.2	20.5	9.2	462.4	20.5	8.7	19.8
Mix9	482.6	21.4	8.174	485.5	21.5	9.21	495.2	21.9	8.72	21.6
Mix10	496.7	22	9.02	513.5	22.8	8.56	437.7	19.4	8.6	21.4
Mix11	405	17.9	8.28	380.4	16.8	8.34	415.5	18.4	8.6	17.7
Mix12	413.2	18.3	8.23	384.6	17	8.58	388.7	17.2	8.43	17.5
Mix13	433.2	19.2	8.82	422.1	18.7	8.16	496.1	22	8.7	20

The 28th day compressive strength test result

28 th day										
Mix	Sample 1			Sample 2			Sample 3			Average Compressive Strength (Mpa)
	Load(K N)	Stress (Mpa)	Weight (Kg)	Load(K N)	Stress (Mpa)	Weight (Kg)	Load(K N)	Stress (Mpa)	Weight (Kg)	
Mix1	841.3	37.4	9.36	805.4	35.8	9.31	759.9	33.78	8.99	35.66
Mix2	955.8	42.4	8.81	836.7	37.1	8.71	861.8	38.2	8.76	39.23
Mix3	951.2	42.2	8.76	915	40.7	8.9	916	40.6	8.82	41.2
Mix4	990.8	44	9.24	993	44.1	9.03	914.5	40.6	8.93	42.9
Mix5	871.2	38.7	8.85	863.7	38.4	8.82	881.1	39.2	8.77	38.77
Mix6	890.5	39.6	8.91	903.1	40.1	9.03	896.4	39.8	8.98	39.83
Mix7	885	39.3	8.94	876	38.9	8.99	894.7	39.8	9.1	39.33
Mix8	692.3	30.7	8.7	707.8	31.4	9.12	638	28.3	9.04	30.13
Mix9	756.6	33.6	8.76	801.3	35.5	8.9	829.4	36.8	8.53	35.3
Mix10	884.6	39.2	8.4	894.2	39.7	8.4	885.6	39.3	8.28	39.4
Mix11	701.9	31.1	8.41	685.7	30.4	8.48	651.1	28.9	8.71	30.1
Mix12	708.9	31.4	8.58	632.8	28.1	8.25	8.6	693.2	30.7	30.07
Mix13	856.3	38	8.51	741.7	32.9	7.96	797.3	35.4	8.46	35.43

APPENDIX D: STATISTICAL ANALYSIS RESULT

D.1 Post hock table of waste brick

Multiple Comparisons

Dependent Variable: compressive strength of test result

Tukey HSD

(I) Waste brick in percent	(J) Waste brick in percent	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0%	11%	-2.2000	1.4229 9	.889	-7.2430	2.8430
	16.5%	-2.0900	1.4229 9	.916	-7.1330	2.9530
	17%	-.2467	1.4229 9	1.00 0	-5.2897	4.7963
	22%	-3.7450	1.2323 4	.140	-8.1124	.6224
	25%	-1.5100	1.4229 9	.990	-6.5530	3.5330
	33%	1.7667	1.2323 4	.927	-2.6007	6.1340
	33.5%	.4433	1.4229 9	1.00 0	-4.5997	5.4863
	45%	3.4567	1.4229 9	.390	-1.5863	8.4997

	50%	5.1433*	1.4229 9	.043	.1003	10.1863
	67%	2.0667	1.4229 9	.922	-2.9763	7.1097
	0%	2.2000	1.4229 9	.889	-2.8430	7.2430
	16.5%	.1100	1.4229 9	1.00 0	-4.9330	5.1530
	17%	1.9533	1.4229 9	.944	-3.0897	6.9963
	22%	-1.5450	1.2323 4	.968	-5.9124	2.8224
	25%	.6900	1.4229 9	1.00 0	-4.3530	5.7330
11%	33%	3.9667	1.2323 4	.098	-.4007	8.3340
	33.5%	2.6433	1.4229 9	.737	-2.3997	7.6863
	45%	5.6567*	1.4229 9	.019	.6137	10.6997
	50%	7.3433*	1.4229 9	.001	2.3003	12.3863
	67%	4.2667	1.4229 9	.151	-.7763	9.3097
	0%	2.0900	1.4229 9	.916	-2.9530	7.1330
16.5%	11%	-.1100	1.4229 9	1.00 0	-5.1530	4.9330

	17%	1.8433	1.4229 9	.961	-3.1997	6.8863
	22%	-1.6550	1.2323 4	.951	-6.0224	2.7124
	25%	.5800	1.4229 9	1.00 0	-4.4630	5.6230
	33%	3.8567	1.2323 4	.118	-.5107	8.2240
	33.5%	2.5333	1.4229 9	.780	-2.5097	7.5763
	45%	5.5467*	1.4229 9	.023	.5037	10.5897
	50%	7.2333*	1.4229 9	.001	2.1903	12.2763
	67%	4.1567	1.4229 9	.174	-.8863	9.1997
	0%	.2467	1.4229 9	1.00 0	-4.7963	5.2897
	11%	-1.9533	1.4229 9	.944	-6.9963	3.0897
	16.5%	-1.8433	1.4229 9	.961	-6.8863	3.1997
17%	22%	-3.4983	1.2323 4	.202	-7.8657	.8690
	25%	-1.2633	1.4229 9	.998	-6.3063	3.7797
	33%	2.0133	1.2323 4	.853	-2.3540	6.3807

	33.5%	.6900	1.4229 9	1.00 0	-4.3530	5.7330
	45%	3.7033	1.4229 9	.301	-1.3397	8.7463
	50%	5.3900*	1.4229 9	.029	.3470	10.4330
	67%	2.3133	1.4229 9	.856	-2.7297	7.3563
	0%	3.7450	1.2323 4	.140	-.6224	8.1124
	11%	1.5450	1.2323 4	.968	-2.8224	5.9124
	16.5%	1.6550	1.2323 4	.951	-2.7124	6.0224
	17%	3.4983	1.2323 4	.202	-.8690	7.8657
	25%	2.2350	1.2323 4	.762	-2.1324	6.6024
22%	33%	5.5117*	1.0062 0	.001	1.9457	9.0776
	33.5%	4.1883	1.2323 4	.068	-.1790	8.5557
	45%	7.2017*	1.2323 4	.000	2.8343	11.5690
	50%	8.8883*	1.2323 4	.000	4.5210	13.2557
	67%	5.8117*	1.2323 4	.003	1.4443	10.1790

25%	0%	1.5100	1.4229 9	.990	-3.5330	6.5530
	11%	-.6900	1.4229 9	1.00 0	-5.7330	4.3530
	16.5%	-.5800	1.4229 9	1.00 0	-5.6230	4.4630
	17%	1.2633	1.4229 9	.998	-3.7797	6.3063
	22%	-2.2350	1.2323 4	.762	-6.6024	2.1324
	33%	3.2767	1.2323 4	.275	-1.0907	7.6440
	33.5%	1.9533	1.4229 9	.944	-3.0897	6.9963
	45%	4.9667	1.4229 9	.056	-.0763	10.0097
33%	50%	6.6533*	1.4229 9	.004	1.6103	11.6963
	67%	3.5767	1.4229 9	.345	-1.4663	8.6197
	0%	-1.7667	1.2323 4	.927	-6.1340	2.6007
	11%	-3.9667	1.2323 4	.098	-8.3340	.4007
	16.5%	-3.8567	1.2323 4	.118	-8.2240	.5107
	17%	-2.0133	1.2323 4	.853	-6.3807	2.3540

	22%	-5.5117*	1.0062 0	.001	-9.0776	-1.9457
	25%	-3.2767	1.2323 4	.275	-7.6440	1.0907
	33.5%	-1.3233	1.2323 4	.989	-5.6907	3.0440
	45%	1.6900	1.2323 4	.944	-2.6774	6.0574
	50%	3.3767	1.2323 4	.240	-.9907	7.7440
	67%	.3000	1.2323 4	1.00 0	-4.0674	4.6674
	0%	-.4433	1.4229 9	1.00 0	-5.4863	4.5997
	11%	-2.6433	1.4229 9	.737	-7.6863	2.3997
	16.5%	-2.5333	1.4229 9	.780	-7.5763	2.5097
	17%	-.6900	1.4229 9	1.00 0	-5.7330	4.3530
33.5%	22%	-4.1883	1.2323 4	.068	-8.5557	.1790
	25%	-1.9533	1.4229 9	.944	-6.9963	3.0897
	33%	1.3233	1.2323 4	.989	-3.0440	5.6907
	45%	3.0133	1.4229 9	.577	-2.0297	8.0563

	50%	4.7000	1.4229 9	.083	-.3430	9.7430
	67%	1.6233	1.4229 9	.983	-3.4197	6.6663
	0%	-3.4567	1.4229 9	.390	-8.4997	1.5863
	11%	-5.6567*	1.4229 9	.019	-10.6997	-.6137
	16.5%	-5.5467*	1.4229 9	.023	-10.5897	-.5037
	17%	-3.7033	1.4229 9	.301	-8.7463	1.3397
	22%	-7.2017*	1.2323 4	.000	-11.5690	-2.8343
45%	25%	-4.9667	1.4229 9	.056	-10.0097	.0763
	33%	-1.6900	1.2323 4	.944	-6.0574	2.6774
	33.5%	-3.0133	1.4229 9	.577	-8.0563	2.0297
	50%	1.6867	1.4229 9	.978	-3.3563	6.7297
	67%	-1.3900	1.4229 9	.995	-6.4330	3.6530
	0%	-5.1433*	1.4229 9	.043	-10.1863	-.1003
50%	11%	-7.3433*	1.4229 9	.001	-12.3863	-2.3003

	16.5%	-7.2333*	1.4229 9	.001	-12.2763	-2.1903
	17%	-5.3900*	1.4229 9	.029	-10.4330	-.3470
	22%	-8.8883*	1.2323 4	.000	-13.2557	-4.5210
	25%	-6.6533*	1.4229 9	.004	-11.6963	-1.6103
	33%	-3.3767	1.2323 4	.240	-7.7440	.9907
	33.5%	-4.7000	1.4229 9	.083	-9.7430	.3430
	45%	-1.6867	1.4229 9	.978	-6.7297	3.3563
	67%	-3.0767	1.4229 9	.549	-8.1197	1.9663
	0%	-2.0667	1.4229 9	.922	-7.1097	2.9763
	11%	-4.2667	1.4229 9	.151	-9.3097	.7763
	16.5%	-4.1567	1.4229 9	.174	-9.1997	.8863
67%	17%	-2.3133	1.4229 9	.856	-7.3563	2.7297
	22%	-5.8117*	1.2323 4	.003	-10.1790	-1.4443
	25%	-3.5767	1.4229 9	.345	-8.6197	1.4663

33%	-3.000	1.23234	1.000	-4.6674	4.0674
33.5%	-1.6233	1.42299	.983	-6.6663	3.4197
45%	1.3900	1.42299	.995	-3.6530	6.4330
50%	3.0767	1.42299	.549	-1.9663	8.1197

D.2 Post hock table of laterite sand

Multiple Comparisons

Dependent Variable: compressive strength of test result

Tukey HSD

(I) Laterite sand in percent	(J) Laterite sand in percent	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0%	11%	-6.6900*	1.42299	.003	-11.7330	-1.6470
	16.5%	-2.0900	1.42299	.916	-7.1330	2.9530
	17%	-1.0233	1.42299	1.000	-6.0663	4.0197
	22%	.6283	1.23234	1.000	-3.7390	4.9957
	25%	-1.5100	1.42299	.990	-6.5530	3.5330
	33%	.9100	1.23234	.999	-3.4574	5.2774

	33.5%	.4433	1.42299	1.000	-4.5997	5.4863
	45%	-.8000	1.42299	1.000	-5.8430	4.2430
	50%	5.1433 *	1.42299	.043	.1003	10.1863
	67%	4.5567	1.42299	.102	-.4863	9.5997
	0%	6.6900 *	1.42299	.003	1.6470	11.7330
	16.5%	4.6000	1.42299	.096	-.4430	9.6430
	17%	5.6667 *	1.42299	.019	.6237	10.7097
	22%	7.3183 *	1.23234	.000	2.9510	11.6857
	25%	5.1800 *	1.42299	.041	.1370	10.2230
11%	33%	7.6000 *	1.23234	.000	3.2326	11.9674
	33.5%	7.1333 *	1.42299	.002	2.0903	12.1763
	45%	5.8900 *	1.42299	.013	.8470	10.9330
	50%	11.8333 *	1.42299	.000	6.7903	16.8763
	67%	11.2467 *	1.42299	.000	6.2037	16.2897
16.5%	0%	2.0900	1.42299	.916	-2.9530	7.1330
	11%	-4.6000	1.42299	.096	-9.6430	.4430

	17%	1.0667	1.42299	.999	-3.9763	6.1097
	22%	2.7183	1.23234	.522	-1.6490	7.0857
	25%	.5800	1.42299	1.000	-4.4630	5.6230
	33%	3.0000	1.23234	.387	-1.3674	7.3674
	33.5%	2.5333	1.42299	.780	-2.5097	7.5763
	45%	1.2900	1.42299	.997	-3.7530	6.3330
	50%	7.2333*	1.42299	.001	2.1903	12.276 3
	67%	6.6467*	1.42299	.004	1.6037	11.689 7
	0%	1.0233	1.42299	1.000	-4.0197	6.0663
	11%	-5.6667*	1.42299	.019	-10.7097	-6.237
	16.5%	-1.0667	1.42299	.999	-6.1097	3.9763
	22%	1.6517	1.23234	.951	-2.7157	6.0190
	25%	-.4867	1.42299	1.000	-5.5297	4.5563
17%	33%	1.9333	1.23234	.880	-2.4340	6.3007
	33.5%	1.4667	1.42299	.992	-3.5763	6.5097
	45%	.2233	1.42299	1.000	-4.8197	5.2663
	50%	6.1667*	1.42299	.008	1.1237	11.209 7
	67%	5.5800*	1.42299	.022	.5370	10.623 0
	0%	-.6283	1.23234	1.000	-4.9957	3.7390
22%	11%	-7.3183*	1.23234	.000	-11.6857	-2.9510

	16.5%	-2.7183	1.23234	.522	-7.0857	1.6490
	17%	-1.6517	1.23234	.951	-6.0190	2.7157
	25%	-2.1383	1.23234	.804	-6.5057	2.2290
	33%	.2817	1.00620	1.000	-3.2843	3.8476
	33.5%	-1.850	1.23234	1.000	-4.5524	4.1824
	45%	-1.4283	1.23234	.981	-5.7957	2.9390
	50%	4.5150 [*]	1.23234	.039	.1476	8.8824
	67%	3.9283	1.23234	.105	-.4390	8.2957
	0%	1.5100	1.42299	.990	-3.5330	6.5530
	11%	-5.1800 [*]	1.42299	.041	-10.2230	-.1370
	16.5%	-.5800	1.42299	1.000	-5.6230	4.4630
	17%	.4867	1.42299	1.000	-4.5563	5.5297
	22%	2.1383	1.23234	.804	-2.2290	6.5057
25%	33%	2.4200	1.23234	.673	-1.9474	6.7874
	33.5%	1.9533	1.42299	.944	-3.0897	6.9963
	45%	.7100	1.42299	1.000	-4.3330	5.7530
	50%	6.6533 [*]	1.42299	.004	1.6103	11.6963
	67%	6.0667 [*]	1.42299	.010	1.0237	11.1097
	0%	-.9100	1.23234	.999	-5.2774	3.4574
33%	11%	-7.6000 [*]	1.23234	.000	-11.9674	-3.2326
	16.5%	-3.0000	1.23234	.387	-7.3674	1.3674

	17%	-1.9333	1.23234	.880	-6.3007	2.4340
	22%	-.2817	1.00620	1.000	-3.8476	3.2843
	25%	-2.4200	1.23234	.673	-6.7874	1.9474
	33.5%	-.4667	1.23234	1.000	-4.8340	3.9007
	45%	-1.7100	1.23234	.940	-6.0774	2.6574
	50%	4.2333	1.23234	.063	-.1340	8.6007
	67%	3.6467	1.23234	.163	-.7207	8.0140
	0%	-.4433	1.42299	1.000	-5.4863	4.5997
	11%	-7.1333*	1.42299	.002	-12.1763	-2.0903
	16.5%	-2.5333	1.42299	.780	-7.5763	2.5097
	17%	-1.4667	1.42299	.992	-6.5097	3.5763
33.5%	22%	.1850	1.23234	1.000	-4.1824	4.5524
	25%	-1.9533	1.42299	.944	-6.9963	3.0897
	33%	.4667	1.23234	1.000	-3.9007	4.8340
	45%	-1.2433	1.42299	.998	-6.2863	3.7997
	50%	4.7000	1.42299	.083	-.3430	9.7430
	67%	4.1133	1.42299	.184	-.9297	9.1563
	0%	.8000	1.42299	1.000	-4.2430	5.8430
	11%	-5.8900*	1.42299	.013	-10.9330	-.8470
45%	16.5%	-1.2900	1.42299	.997	-6.3330	3.7530
	17%	-.2233	1.42299	1.000	-5.2663	4.8197
	22%	1.4283	1.23234	.981	-2.9390	5.7957

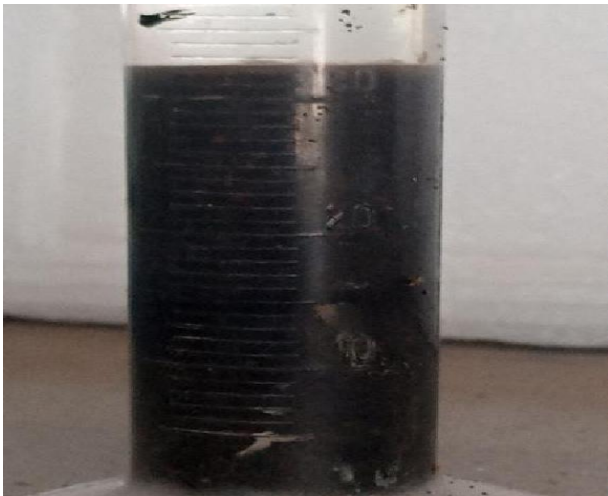
	25%	-0.7100	1.42299	1.000	-5.7530	4.3330
	33%	1.7100	1.23234	.940	-2.6574	6.0774
	33.5%	1.2433	1.42299	.998	-3.7997	6.2863
	50%	5.9433*	1.42299	.012	.9003	10.9863
	67%	5.3567*	1.42299	.031	.3137	10.3997
	0%	-5.1433*	1.42299	.043	-10.1863	-1.1003
	-					
	11%	11.8333*	1.42299	.000	-16.8763	-6.7903
	16.5%	-7.2333*	1.42299	.001	-12.2763	-2.1903
	17%	-6.1667*	1.42299	.008	-11.2097	-1.1237
50%	22%	-4.5150*	1.23234	.039	-8.8824	-1.1476
	25%	-6.6533*	1.42299	.004	-11.6963	-1.6103
	33%	-4.2333	1.23234	.063	-8.6007	.1340
	33.5%	-4.7000	1.42299	.083	-9.7430	.3430
	45%	-5.9433*	1.42299	.012	-10.9863	-9.9003
	67%	-5.867	1.42299	1.000	-5.6297	4.4563
	0%	-4.5567	1.42299	.102	-9.5997	.4863
	-					
67%	11%	11.2467*	1.42299	.000	-16.2897	-6.2037
	16.5%	-6.6467*	1.42299	.004	-11.6897	-1.6037

17%	-5.5800*	1.42299	.022	-10.6230	-.5370
22%	-3.9283	1.23234	.105	-8.2957	.4390
25%	-6.0667*	1.42299	.010	-11.1097	-1.0237
33%	-3.6467	1.23234	.163	-8.0140	.7207
33.5%	-4.1133	1.42299	.184	-9.1563	.9297
45%	-5.3567*	1.42299	.031	-10.3997	-.3137
50%	.5867	1.42299	1.000	-4.4563	5.6297

APENDEX E; SAMPLE GALLERY TAKEN DURING RESEARCH



E1 and E2; during consistency test



E.3: Silt content test



E.4: During checking SSD condition of sand



E.5: During bulk density test of waste brick E.6: During water absorption test of laterite sand



E.7,8and9:During water absorption and Specific gravity test of coarse aggregate



E.10,12 and 13: During sieve analysis test



E.14 and E.15 :During dry and wet mix of concrete production respectively



E.16: Curing of concrete

E.17: Failure Mode of waste brick and laterite sand



E18 and 19 Controls compressive strength machine



E.20 and E.21: Test result readings of Controls compressive strength machine




G.22 and G.23: Curing of concrete for water absorption test



G.24. oven drying of samples

G.25. Waste of samples of concrete

APPENDIX F; CHEMICAL ANALYSIS TEST RESULT




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


Customer Name: - Meron Tsehaye Issue Date: - 26/07/2021
 Request No:- GLD/RQ/145/21
 Sample type:- soil Report No:- GLD/RQ/612/21
 Date Submitted: - 15/06/2021 Sample Preparation: - 200 Mesh
 Number of Sample:- Two (2)

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

Collector's code	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₃	TiO ₂	H ₂ O	LOI
laterite	48.94	13.44	9.46	5.52	6.26	0.36	<0.01	1.00	0.17	0.48	1.77	11.53
Brick Teast	58.06	23.86	7.86	1.06	0.86	1.10	1.64	0.18	0.26	0.70	1.73	1.20

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

Analysts	Checked By	Approved By	Quality Control
Lidet Endeshaw			
Tizita Zemene	Yohannes Getachew	Gosa Haile	Negasi Worku
Kindie Kassahun			
Elsa Fisseha			



F1; for waste brick and laterite sand