# EXPERIMENTAL INVESTIGATION OF PROPERTIES OF FRESH AND HARDENED CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY HYBRID OF COFFEE HUSK ASH AND RICE HUSK ASH.

**Naol Bekele Amente**

**A Thesis Submitted to Department of Civil Engineering**

**School Of Civil Engineering and Architecture**

**Presented In Partial Fulfillment of The Requirements of Masters of Science in Civil Engineering (Specialization in Construction Engineering and Management)**

**Office Of Graduate Studies**

**Adama Science and Technology University**

**June, 2024**

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## DECLARATION

I declare that this thesis entitled **"Experimental Investigation Of Properties Of Fresh And Hardened Concrete With Partial Replacement Of Cement By Hybrid Of Coffee Husk Ash And Rice Husk Ash"** is my own work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation. It is being submitted for the partial fulfilment for the award of the degree of Master of Science in Civil Engineering (Construction Engineering and Management) at Adama Science and Technology University School of School of Civil Engineering and Architecture.

Naol Bekele Amente ________________________ ________________

Signature Date

## RECOMMENDATION OF ADVISOR

I hereby certify that I have read and evaluated this thesis entitled **"Experimental Investigation Of Properties Of Fresh And Hardened Concrete With Partial Replacement Of Cement By Hybrid Of Coffee Husk Ash And Rice Husk Ash"** prepared under my guidance by **Naol Bekele Amente** submitted in partial fulfillment of the requirements for the degree of Masters of Science in Civil Engineering (Construction Engineering and Management). Therefore, I recommend that the candidate has fulfilled the requirements and hence he/she can submit the thesis to the department.

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|---|---|---|
| Fikreyesus Demeke (PhD) | ______________________ | _______________ |
| (Major Advisor/Supervisor) | Signature | Date |

## APPROVAL OF BOARD REVIEWERS

I hereby certify that all the correction and recommendation suggested by the board of examiners are incorporated into the final thesis entitled **"Experimental Investigation Of Properties Of Fresh And Hardened Concrete With Partial Replacement Of Cement By Hybrid Of Coffee Husk Ash And Rice Husk Ash"** by Naol Bekele Amente.

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We, the undersigned, members of the Board of Examiners of the thesis open defense Naol Bekele Amente have read and evaluated his final entitled **"Experimental Investigation Of Properties Of Fresh And Hardened Concrete With Partial Replacement Of Cement By Hybrid Of Coffee Husk Ash And Rice Husk Ash"** and examined the candidate. This is, therefore, to certify that the final thesis has been accepted in partial fulfillment of the requirement of the degree of Master of Science in Civil Engineering (Construction Engineering and Management).

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# ABSTRACT

*This study explores the properties of rice husk ash and coffee husk ash and investigates their potential as partial replacements for cement in concrete production. The aim was to assess the effects of using a combination of rice husk ash and coffee husk ash on both the workability of fresh concrete and the mechanical properties of hardened concrete. Both rice husk ash and coffee husk ash met ASTM C618 standards, fulfilling the chemical compositions and complying with specified limits for loss on ignition, alkali content, and magnesium oxide content. Various combinations were tested, and the highest mechanical properties observed in the mixture containing 15% rice husk ash and 2.5% coffee husk ash. However, partial replacement of hybrid rice husk ash and coffee husk ash led to a reduction in the workability of fresh concrete. These findings demonstrate the potential benefits of incorporating rice husk ash and coffee husk ash as partial replacements for cement in concrete, contributing to sustainable construction practices. Future research can focus on optimizing mixtures to improve both mechanical properties and workability. In summary, this study underscores the promising prospects of utilizing rice husk ash and coffee husk ash to enhance mechanical properties of hardened concrete.*



***Key words:*** *Rice Husk Ash, Coffee Husk Ash, Cement, Concrete properties*

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# ACRONYMS AND ABBREVATIONS

ACI American Concrete Institute

ASTM American Society for Testing and Material

RHA Rice Husk Ash

CHA Coffee Husk Ash

w/c Water to Cement Ratio

AASHTO American Association of State and Highway Transportation Officials

CA Coarse Aggregate

FA Fine Aggregate

MPa Mega Pascal

C-S-H Calcium Silicate Hydrate

C-25 Compressive strength of 25 MPa

OPC Ordinary Portland cement

PPC Portland Pozzolana cement

LOI Loss of Ignition

# LIST OF CHEMICAL FORMULAS

$Al_2O_3$ Aluminium Oxide

$Ca(OH)_2$ Calcium Hydro Oxide

$CaCO_3$ Calcium Carbonate

$CaO$ Calcium Oxide

$Fe_2O_3$ Iron Oxide

$MgSO_4$ Magnesium Sulfate

$Na_2SO_4$ Sodium Sulfate

$K_2O$ Potassium Oxide

$MgO$ Magnesium Oxide

$Na_2O$ Sodium Oxide

$P_2O_5$ Phosphate Oxide

$SiO_2$ Silica Oxide

$SO_3$ Sulfur tri Oxide

$3CaO.SiO_2$ Tricalcium silicate

$2CaO.SiO_2$ Tricalcium silicate

$3CaO.Al_2O_3$ Tricalcium aluminate

$4CaO.Al_2O_3.Al_2O_3$ Tetracalcium Aluminoferrite

# CHAPTER ONE

# 1. INTRODUCTION

## 1.1 General Background

The most often utilized building material in the construction sector is concrete. It is made up of a carefully selected combination of water, well graded fine and coarse aggregates and cement. (*Concrete | Definition, Composition, Uses, Types, & Facts | Britannica*, n.d.). In a concrete mixture, cement and water combine to create a paste that not only fills the spaces left by the fine aggregate but also covers the surfaces of the coarse and fine aggregates and holds them all together  The chemical reaction between the water and binding substance causes the molded concrete mix to become rock hard after a sufficient amount of curing. The formation of required qualities, early hardening, strong early compressive strength, and moldability are the main causes of cement concrete's widespread use (Bhatt et al., 2005).

Cement is not easily produced by medium capital investors (Lo et al., 2021). In order to reduce cost of cement used in construction industry, pozzolanic materials are used in part place of cement (Hakeem et al., 2022). Pozzolan is a siliceous or siliceous and aluminous material that, by itself, has no or little cementitious value but that will have cementitious value, when finely divided and in the presence of moisture. Pozzolan reacts chemically with calcium hydroxide at room temperature to produce compounds with cementitious properties. Natural materials that exhibit pozzolanic characteristics can be raw or calcined to form natural pozzolan (*Pozzolans - an Overview | ScienceDirect Topics*, n.d.).

Rice husk ash contains much amount of siliceous material and some amount of aluminous material. Because of its pozzolanic content, various researchers have established Rice Husk Ash's optimum cement replacement content by using rice husk ash as cement replacement material (Krishna et al., 2016).

Similarly, various studies on coffee husk ash have shown that coffee husk ash also contains pozzolanic content as well as lime. Studies done up to date show that the amount of CaO in Rice husk ash is less than one percent while it contains more than 85% of $SiO_2$. Literatures on Coffee husk ash reveal that the ash contains more than 12% of CaO, which can react with the pozzolanic content of the Rice husk ash. Hence, this study has investigated the properties of fresh and hardened concrete with Partial Replacement of Cement by Hybrid of Coffee Husk Ash and Rice Husk Ash.

## 1.2 Statement of the Problem

The use of alternative cementitious materials has gained significant attention in recent years due to the environmental concerns associated with traditional cement production (Raman et al., 2011a). According to researchs conducted on the ashes, RHA and CHA are agricultural byproducts that have shown potential as partial replacements for cement in concrete. Both RHA and CHA contain significant amounts of silica ($SiO_2$), which is known to contribute to the pozzolanic reactivity of the materials. However, the majority of research has focused on the individual use of RHA or CHA, and limited studies have explored the combined application of these ashes as a hybrid mixture.

By investigating the hybridization of RHA and CHA as cement replacements, this study aims to address several key aspects. Firstly, analyzing the oxide composition of the ashes can provide valuable insights into the potential synergistic effects between the two materials. RHA is known to have high silica content (Ismail & Waliuddin, 1996), while CHA may contribute additional elements such as potassium oxide ($K_2O$), sodium oxide ($Na_2O$) and Higher CaO (Tarekegn et al., 2022). Understanding the combined oxide composition can help determine the optimal blend ratio and potential advantages of the hybrid RHA and CHA ashes in terms of workability and Mechanical strength development.

By conducting a comprehensive investigation into the mechanical and physical properties of concrete incorporating the hybrid ash mixture, this research aims to provide valuable insights for engineers and researchers. It can help determine the optimal blend ratio of RHA and CHA to achieve enhanced mechanical strength, and workability of the concrete.

Overall, this study is motivated by the need to explore the potential of hybridizing RHA and CHA as cement replacements and to understand the advantages and potential benefits of such a combination. The investigation of the oxide composition, along with the evaluation of mechanical and workability properties, will contribute to the knowledge base of sustainable construction materials and support the development of more environmentally friendly practices in the construction industry.

## 1.3 Objective

### 1.3.1 General Objective

The general objective of this study is to investigate properties of fresh and hardened concrete with partial replacement of cement by hybrid of coffee husk ash and rice husk ash.

### 1.3.2 Specific Objectives

- To determine the properties of Rice Husk Ash and Coffee Husk Ash.
- To analyse effects of partially replacing cement by hybrid CHA and RHA on slump value of the fresh concrete.
- To investigate effects of replacing cement by hybrid CHA and RHA on Compressive Strength of hardened Concrete.
- To investigate effects of replacing cement by hybrid CHA and RHA on Flexural Strength of hardened Concrete.
- To investigate effects of replacing cement by hybrid CHA and RHA on split tensile Strength of hardened Concrete.

## 1.4 Significance of the Study

The significance of this research lies in its focus on exploring the hybridization of RHA and CHA as cement replacements, its potential to contribute to sustainable construction practices, and to provide valuable insights into the optimal blend ratio and material properties. The study adds to the current knowledge around alternative cementitious materials and supports the development of more environmentally friendly construction practices.

The research aims to contribute to the existing knowledge of construction materials. By investigating the mechanical and physical properties of concrete using the hybrid RHA and CHA ash mixtures, the study can provide engineers and researchers with insights into the optimal blend ratio to achieve enhanced properties of the concrete.

While there are studies on RHA and CHA, there is limited research on their combined application as a hybrid mixture. This study aims to fill this research gap and explore the potential synergistic effects of blending RHA and CHA. The investigation of the oxide composition and understanding the optimal blend ratio can provide valuable insights into the pozzolanic activity, strength development, and other material properties of the hybrid ash.

## 1.5 Scope of the Study

This research is delimited to investigate physical and chemical properties of RHA and CHA and properties of fresh and hardened concrete, i.e. For the hardened concrete, Compressive Strength of concrete, Flexural Strength of concrete and Splitting Tensile strength was investigated and for the fresh concrete slump was observed; with partial replacement of cement by hybrid of CHA and RHA. The concrete grade used for control group is C-25 with 0.45 Water to cement ratio. OPC Cement with a grade of 42.5 has been used throughout the experimental study.

## 1.6 Organization of the Thesis

The thesis is presented in 5 chapters. The remaining four chapters are organized as follows. Chapter 2 presents the literature review, with special reference to the topic that to explore the current status of research and findings on partial replacement of cement with rice husk ash and coffee husk ash. The review will examine the practical usability of these materials, their effects on setting time and concrete strength, their potential environmental impact, and other potential benefits and drawbacks.

In Chapter 3, the research methodology and materials used are discussed. After presenting the study's overall research methodology, the methodology adopted in individual objectives is discussed in this chapter.

Chapter 4 aims to present results of experimental studies conducted. To realize this aim, the study presents the findings and associated discussion in relation to properties of fresh and hardened concrete with partial replacement of cement with an hybrid of RHA and CHA. In the first section of Chapter 4, the test results on physical properties of RHA, CHA, aggregates and cement are assessed. In this chapter, initially, the suitability of material used for the experiments are identified by standard test methods listed in Chapter 3. In addition, the effects of incorporatin hybrid of RHA and CHA as partial replacement of cement on some properties of fresh and hardened concrete are identified. Then, underlying the exact effect of hybrid RHA and CHA on physical and Mechanical properties of concrete are presented by concept mapping.
Chapter 5 summarises methodology followed and the findings of the various chapters and the

study’s conclusions. The chapter closes with this study’s contributions to the literature, its limitations, and suggestions for further research.

## 1.7 Summary

In this chapter, the background and statement of the problem (motivation of the research) have been presented. Further, the study aim, associated objectives, scope of the study, significance of the study and the organization of the thesis to achieve these objectives have briefly been presented. In the next chapter, the literature review and the gaps in the prior research have been presented.

# CHAPTER TWO

# 2. LITERATURE REVIEW

## 2.1 Introduction

A growing demand for sustainable construction materials has led to interest in potential partial replacement materials of cement with environmental friendly alternatives. One such alternative is the use of agricultural byproducts like rice husk ash and coffee husk ash. Rice husk ash is a material obtained after burning of the rice husks (Fapohunda et al., 2017) , while coffee husk ash is obtained after removing the coating and burning the coffee husks at high temperatures (Acchar et al., 2013). These agricultural byproducts are abundant, low cost and renewable in nature, and have the potential to be used as a partial replacement for conventional cement in concrete production. It also offers excellent performance in terms of mechanical properties, workability, and durability.

This literature review aims to explore the current status of research and findings on partial replacement of cement with rice husk ash and coffee husk ash. The review will examine the practical usability of these materials, their effects on fresh and hardened concretes. Several researchers have conducted numerous studies on the development of cement and concrete technologies in recent years. The use of byproduct materials as a cement replacement to reduce the negative economic and environmental effects of cement manufacture is one of the best innovations (Obilade, 2014). It has been claimed that these cement replacing substances enhance various concrete characteristics. Both rice husk ash and coffee husk ash were discovered to enhance some mortar and concrete qualities. Various experiments on both fresh and hardened concrete were used to evaluate how well mortar and concrete performed under the condition of partially replacing cement with coffee husk ash and rice husk ash. However it is required to study more to investigate how well the fresh and hardened concrete under the condition of partially replacing cement with the hybrid coffee husk ash and rice husk ash.

## 2.2 Concrete and concrete’s Ingridients

Concrete has been used in construction for many years because of its durability, strength, and versatility. Cement, water, and aggregates like sand and gravel are the three main ingredients in concrete. The mixture hardens and becomes more robust as a result of hydration, a chemical interaction between cement and water. The strength of concrete is based on the proportion of water to cement. A lower water to cement ratio will result in stronger concrete being produced (*Concrete | Definition, Composition, Uses, Types, & Facts | Britannica*, n.d.).

One of concrete's key advantages is its ability to withstand compression. Due to its ability to sustain heavy loads without cracking, concrete is the ideal building material for skyscrapers, dams, and bridges (Tattersall, 1976). The porosity of concrete also allows it to slowly absorb and release moisture, which can help control indoor humidity and temperature. The strength and thermal properties of concrete make it a popular building material for construction projects all over the world (Bhatt et al., 2005).

## 2.3 Cement

Cement is made by mixing limestone, clay, and other minerals; it is then heated to a high temperature in a kiln. The resulting material, called clinker, is powdered finely and mixed with water to create a paste that finally solidifies. Cement is used to bind together concrete, mortar, and other building materials (Sant et al., 2008).

The chemical composition of cement may vary depending on the type and production method used. The main ingredients of cement are commonly calcium, silica, aluminum, and iron. Calcium oxide (CaO), sometimes known as lime, is a key component of cement and what gives it its ability to harden when coupled with water. Additionally, the addition of silicon dioxide ($SiO_2$), aluminum oxide ($Al_2O_3$), and iron oxide ($Fe_2O_3$) helps the cement's strength and durability (M.S.SHETTY Multicolour Illustrative Edition., 2000).

### 2.3.1 Types of Cement

There are numerous types of cement available, and each has special features and uses. One common kind is Portland cement, which is the most common type of cement used in construction (Sant et al., 2008). The four main components of Portland cement are tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite. Additional types of cement include hydraulic cement, which hardens and sets as a result of a chemical reaction with water, and white cement, which is used in architectural applications. Some varieties of cement, such as the oil well cement used in the building of oil and gas wells, are designed for specific applications (Gartner & Sui, 2018).

Cement can be utilized in a multitude of applications since each type has unique properties. For instance, due to its durability and strength, Portland cement is a good choice for use in foundations, roads, and other structural applications. On the other hand, because of how its little tint can enhance the aesthetic of the finished product, white cement is widely used in ornamental applications. The application, the environment, and the required qualities will all have an impact on the type of cement that is chosen (Yiğiter et al., 2007).

### 1. Portland Cement

Hydraulic cement is a form of cement that is frequently used in building. In order to make it, a mixture of clay and limestone is burned at high temperatures, resulting in clinker, which is then ground into a fine powder. Calcium silicates, aluminates, and ferrites make up the majority of clinker's composition. In the first half of the nineteenth century, British constructor Joseph Aspdin created Portland cement. Because of the cement's color resemblance to Portland stone, which is a type of limestone found on the Isle of Portland in England, the phrase "Portland stone" was coined (Klemm, 2005).

Because of its longevity, versatility, and strength, portland cement is one of the most widely used building materials worldwide. It can be used in a variety of products, including concrete, mortar, and grout, and is frequently mixed with other materials to improve performance or reduce environmental impact. These materials include fly ash, slag, and silica fume. However, the manufacture of Portland cement also has other substantial negative environmental implications, such as the release of greenhouse gases and the depletion of natural resources (Schneider et al., 2011).

### Classification of Portland cement

Portland cement is categorized by ASTM C150, which is one of the most popular classifications. It divides Portland cement primarily into five non air entrained groups that differ solely in the proportions of the compounds and degree of fineness.

ASTM type I cement is a general purpose Portland cement used when there is no special property required by the concrete.

ASTM type II cement is Moderate Portland cement. It is also a general purpose cement to be used when moderate sulphate resistance or moderate heat of hydration is desired.

ASTM type III cement is High early strength Portland cement which is used when high early strength is desired, usually less than one week, it is usually used when a structure must be put into service as quickly as possible.

ASTM type IV cement is Low-Heat of Hydration Portland cement which is used, when a low heat of hydration is required, like in mass concrete.

ASTM type V is Sulfate -resisting Portland cement which is used when high Sulfate resistance is desired.

### 2.3.2 Chemical composition of ordinary Portland cement

The composition of Portland cement has undergone changes over time, characterized mainly by an increase in lime content and a slight decrease in silica content. However, an excessive amount of lime can hinder complete combination with other compounds, leading to the presence of free lime in the clinker and resulting in unsound cement. Similarly, an increased proportion of silica at the expense of alumina and ferric oxide can make it challenging to fuse and form clinker. Portland cement is produced using raw materials that contain the appropriate proportions of lime (CaO), silica ($SiO_2$), alumina ($Al_2O_3$), iron ($Fe_20_3$), along with minor amounts of magnesia and sulfur trioxide (Bediako & Amankwah, 2015a). According to (Bediako & Amankwah, 2015b), Composition and the approximate limits of chemical composition in Ordinary Portland cement is shown in Table 2.1

Table 2. 1: Approximate limits of oxide composition in cement

| **Oxide** | **Percent (%)** | **Function** |
|---|---|---|
| CaO | 60-67 | Control strength and soundness. Its deficiency reduces setting time and strength. |
| $SiO_2$ | 17-25 | Gives strength. Excess of it causes slow setting. |
| $Al_2O_3$ | 3-8 | Responsible for quick setting, if excess, it lowers the strength. |
| $Fe_2O_3$ | 5-6 | Gives color and helps in fusion of different ingredients. |
| MgO | 0.1 - 4.0 | Impart color and hardness, if excess it causes cracks in mortar and concrete and unsoundness. |
| Alkalis | 0.2 - 1.3 | Those are residues, and if excess cause efflorescence and cracking. |
| $SO_3$ | 1-3 | Makes cement sound. |

### Composition of cement clinker

During the clinkering process, the different components of cement combine and create a substance known as cement clinker. These compounds possess the ability to set and harden in the presence of water, and were initially identified by Bogue and are therefore referred to as Bogue compounds. Another terminology used for these compounds are Alite ($C_3S$), Belite ($C_2S$), Celite ($C_3A$), and Felite ($C_4AF$), as named by Le-Chatelier and Tornebohm. The formation of these Bogue compounds occurs during the burning process and is an essential aspect of cement production. The following Bogue compounds are formed during clinkering process (Bediako & Amankwah, 2015b).

Table 2. 2: Composition of cement clinker

| The principal minerals compounds in Portland cement | Chemical Formula | Name | Symbol |
|---|---|---|---|
| Tricalcium silicate: | $3CaO.SiO_2$ | Alite | $C_3S$ |
| Dicalcium silicate | $2CaO.SiO_2$ | Belite | $C_2S$ |
| Tricalcium Aluminate | $3CaO.Ai_2O_3$ | Calite | $C_3A$ |
| Tetracalcium Alumino Ferrite | $4CaO.A1_2O_3.Fe_2O_3$ | Felite | $C_4AF$ |

The characteristics of Portland cement can differ significantly based on the proportions of the four compounds mentioned above, highlighting considerable variation in the way each compound behaves on its own.

### Portland Pozzolana cement

Portland pozzolana cement (PPC) is created through the process of intergrinding OPC clinker with a specific range of pozzolanic materials, typically between 15% to 35%. These pozzolanic materials are not inherently cementitious, but they contain siliceous or aluminous properties that react with calcium hydroxide, a byproduct of cement hydration, when exposed to water. This reaction generates a compound that acquires cementitious characteristics. The inclusion of pozzolanic materials provides PPC with various benefits over OPC. Without the reaction of these pozzolanic materials with calcium hydroxide, free calcium hydroxide would remain in the concrete, leading to a more permeable structure and susceptibility to damage. The reaction of pozzolanic materials also decreases the porosity of the concrete by creating cementitious compounds, while also reducing the heat of hydration due to a slower reaction rate compared to

OPC. This slower reaction rate implies that PPC exhibits slower strength development, making it appropriate for constructing mass concrete structures (Gartner & Sui, 2018).

**Hydration of Cement**

Hydration of cement refers to the chemical reaction that occurs between water and cement's active components, namely $C_4AF$, $C_3A$, $C_3S$, and $C_2S$. The extent of cement hydration and the microstructure of the hydrated cement determine the physical properties of concrete. Once the cement comes in contact with water, hydration products begin to form on the surface of the hydrated cement nucleus. This reaction is known as the induction or dormant period and lasts for 2-5 hours. As the hydration progresses, the deposition of hydration products on the original cement grain makes the diffusion of water to unhydrated nuclei increasingly difficult, leading to a reduction in the hydration rate over time. At any stage of hydration, the cement paste consists of gel, unreacted cement, calcium hydroxide, water, and minor compounds. Gradual crystallization of the various resulting compounds fills the space initially occupied by water, resulting in the stiffening of the mass and subsequent development of strength (Hernández-Flores et al., 2018). The following are the reactions of the compounds and their products:

$$C_3S + H_2O \rightarrow C\text{–}S\text{–}H + Ca\,(OH)_2$$

$$C_2S + H_2O \rightarrow C\text{–}S\text{–}H + Ca\,(OH)_2$$

$$C_3A + H_2O \rightarrow C_3AH_6$$

$$C_3A + H_2O + CaSO_4 \rightarrow CA\ C\ S\ H_{12}$$

Calcium sulpho-aluminate

$$C_4AF + H_2O \rightarrow C_3AH_6 + CFH$$

The gel structure known as calcium silicate hydrate (C-S-H), represents the major component of hydrated Portland cement paste, constituting 50-60% of its volume. The hydrated crystals are minute, fibrous, platey, or tubular in shape, ranging from less than 2 mm to 10 mm or more. The C-S-H phase's surface area is estimated to be around 100-700 m2/g, with a solid-to-solid distance of approximately 18 Å. The $Ca(OH)_2$ released during the silicate phase forms crystals that occupy free space. These calcium hydroxide crystals, also known as portlandite, make up 20-

25% of the solids in the hydrated paste and have a lower surface area, limiting their strength-contributing potential. The gel must be water-saturated to continue hydration. As hydration progresses, the two types of crystals become more closely intertwined, increasing strength, although the gel, which accounts for two-thirds of the total hydrate mass, provides the primary cementing action. The calcium hydroxide crystals produced in the process dissolve in water, releasing hydroxyl (OH-) ions that are important for protecting reinforcement in concrete.

### 2.3.3 Physical Properties of Cement

The final product's strength, durability, and workability are greatly influenced by the physical qualities of cement. The setting time, soundness, fineness, consistency, and specific gravity of cement are some of its physical characteristics. Each of these characteristics has the potential to impact the cement's quality and functionality as well as the final concrete construction. To make sure that the cement used in building complies with the relevant norms and criteria, it is crucial to understand these features (Klieger, 1994).

#### Setting time of Cement

The time frame in which the cement paste transforms from a plastic to a solid state is referred to as the "setting time of cement." The concrete structure's strength and durability depend on this process. The type of cement, water to cement ratio, temperature, and other admixtures are some of the variables that affect the setting time. The initial setting time of cement is defined as the amount of time it takes for the paste to stiffen, whereas the ultimate setting time is defined as the amount of time when the paste hardens and can withstand forces without being destroyed (Gartner & Sui, 2018).

There are numerous ways to determine the cement's setting time, including the Vicat instrument, the Gilmore needle test, and the penetration resistance test. To ascertain the initial and final setting times of cement, the Vicat equipment is frequently employed. With this technique, a needle's penetration depth into the cement paste is measured at regular intervals of time. The needle's failure to penetrate the cement paste past a particular depth is known as the initial setting time, while its complete failure to penetrate is known as the final setting time (Vivan et al., 2010).

### Soundness of Cement

The ability of cement to maintain its volume after setting is referred to as soundness. After curing, the cement may dramatically expand or contract, which could weaken the concrete's durability and strength by causing cracks (Kabir et al., 2020). The autoclave expansion test which measures the cement specimen's volume growth after being exposed to high pressure steam is used to gauge the soundness of cement. An autoclave expansion of sound cement should be less than 0.8% (Klemm, 2005).

The type of cement, composition, fineness, and other admixtures are only a few of the variables that might determine how sound a cement is. It is crucial to adhere to the advised requirements and practices for cement's manufacturing and testing in order to guarantee its soundness. The protocols for testing hydraulic cement's autoclave expansion according to ASTM C151 are commonly used for conducting soundness tests (Klemm, 2005).

### Fineness of Cement

The fineness of the cement has a big impact on the properties of concrete. According to research (Gartner & Sui, 2018), concrete with finer cement particles offers improved strength, workability, and durability. However, (Shetty, 2005) suggests that excessive fineness can also have negative effects on concrete's properties, such as increasing the likelihood of cracking and lowering its resistance to chemical attack.

### Specific gravity of Cement

The cement's specific gravity, which reveals how dense cement is in comparison to water, is an important parameter. The construction industry frequently uses it to make sure that the cement used in a specific application complies with the necessary criteria because it is a crucial property in assessing the quality and strength of cement (Bhargava & Sharma, 2018). According to the Indian Standard code of practice for the testing of cement (IS 4031: Part 11, 1996), the cement's specific gravity should fall between 3.10 and 3.16. If there are impurities in the cement, it may have a lower specific gravity, which might weaken and shorten the cement's durability. A higher specific gravity, on the other hand, can point to the existence of extra ingredients in the cement, which could also have an impact on its quality.

In addition, variables like temperature and the kind of cement used can affect the specific gravity of cement. As per ASTM standard C188 (2016), the measurement of cement's specific gravity shall take place at a temperature of 23 °C. Additionally, because to changes in their chemical composition, various types of cement may have various specific gravities. For instance, according to Bhargava and Sharma (2018), Portland slag cement and Portland pozzolana cement have specific gravities of 2.8-2.9 and 2.9-3.1, respectively.

**Consistency of Cement paste**

The consistency of cement paste is a crucial component that influences the workability and strength of concrete. It is assessed by the penetration of a standardized plunger into the paste and is described as the level of flexibility or fluidity of the cement paste (Bhatt et al., 2005).

Consistency is measured by measuring the Vicat plunger's depth of penetration into the paste, in accordance with ASTM C187-16, the standard test technique for the amount of water necessary for normal consistency of hydraulic cement paste. Results are presented as the amount of water needed per unit weight of cement. The test determines the amount of water needed to create a cement paste with a particular consistency. For concrete to be workable and to determine how long it will take to place, compact, and finish, consistency is a crucial consideration (Klemm, 2005).

## 2.4 Aggregates

About 70–75% of concrete is made up of aggregates, and the qualities of the aggregates used in their manufacturing have a big impact on the material's strength and durability. A more or less inert, granular, mostly inorganic substance, concrete aggregate is typically composed of stones or solids that resemble stones. Crushed stone, crushed slag, gravel, and sand are typical examples. From a technical and financial perspective, it is significant that the use of aggregate in concrete significantly lowers the amount of cement required (Al-Jabri et al., 2011). There are numerous techniques to classify aggregates. The size of their grains or particles is one of the most widely used classifications. The fine and coarse aggregates typically make up 60% to 75% of the volume of the concrete and have a significant impact on the mixture proportions, economy, and qualities of the concrete both when it is first mixed and after it has cured (Oikonomou, 2005). The majority of the particles in fine aggregates are less than 4.75 mm and are often crushed stone or natural sand. Coarse aggregates are made up of crushed stone or gravel mixtures that include particles that are usually larger than 4.75 mm and fall between 9.5 and 37.5 mm (Su et al., 2002).

Concrete's performance is significantly impacted by the shape, texture, and grading of the aggregate. In comparison to blends including flat, elongated, angular, and rough particles, aggregate blends containing well-shaped, rounded, and smooth particles require less paste for a given slump. At the same time, aggregate blends with high packing and low water demand are produced by consistent grading and appropriate proportions of each size. Optimized aggregate blends use less paste because of their high packing. They are therefore less costly and have less durability issues, such as heat generation, porosity, and drying shrinkage, brought on by the paste (Tam et al., 2007).

### 2.4.1 Classification of Aggregates

Aggregates are categorized according to their size, form, and geological origin. There are four main categories of aggregates, under the ASTM C33 Standard Specification for Concrete Aggregates: Aggregates that are retained on a 4.75 mm (No. 4) sieve are considered coarse aggregates. They come from either artificial or natural sources and are often spherical, angular, or irregular in appearance. Aggregates classified as fines are those that retained on a 0.075 mm (No. 200) sieve after passing through a 4.75 mm (No. 4) sieve. They originate from either natural or manmade sources and are often angular or rounded. Aggregates classified as lightweight have a low specific gravity because they contain either synthetic or natural porosity. Usually, they come from volcanic rocks or man-made materials like clay or expanded shale. Heavy weight aggregates gain their weight because of heavy minerals like magnetite or barite are present, these aggregates have a high specific gravity. Usually, they originate from either manmade or natural sources. The standard specification for concrete aggregates is ASTM C33.

### 2.4.2 Properties of Aggregates

#### Particle size distribution

Grading refers to the distribution of aggregate particle sizes. Since the spaces between aggregate particles in the concrete mixture require the same amount of cement paste to fill them, grading defines the paste requirement for a workable concrete (Meddah et al., 2010). Sieve analysis must be performed in order to generate a grading curve for an aggregate. There are five commonly recognized size distributions: open, uniform, dense, gap, and well graded. The broad size ranges with smooth distribution are basically the dense and well-graded varieties. For coarse aggregate, use the dense graded, while for fine aggregate, use the well graded. A type of grading that does not have one or more intermediate sizes is called gap grading. Just a few sizes predominate in the bulk materials for uniform grading. When there are still a lot of voids between the aggregate under compacted circumstances, it is referred to as open grading. Additionally, smaller aggregate sizes typically make up the bulk and are easily disrupted by tiny cavities (Assi et al., 2018). The ASTM C33 (Standard Specification for Concrete Aggregates) states that the maximum size of aggregates for concrete is 1.5 inches, and the maximum percentage of aggregates that pass the No. 4 sieve is allowed.

**Shape and texture**

Since it has an impact on how workable concrete is, aggregate form is a crucial feature. The form of aggregates is influenced not only by the properties of the parent rock but also by the kind of crusher that is employed. Round aggregates are better than angular aggregates in terms of cement economy for a particular W/C ratio. Because of their interlocking texture in the cured concrete, angular aggregates can provide increased strength as well as improved durability. The workability, cement need, strength, and durability of concrete aggregates will be significantly impacted by the presence of flat particles. Concrete made with extremely flat aggregates is generally of very low quality (Zhang et al., 2012).

**Density and porosity**

The density of the particles in the concrete mix can have a big impact on the properties of the concrete. While dense stones like granite or basalt can raise the unit weight of concrete, lightweight aggregates like expanded clay, shale, or perlite can be used to lower the weight of concrete. The porosity of the aggregate may also have an impact on the permeability and durability of the concrete (*Durability of Recycled Aggregate Concrete - ScienceDirect*, n.d.). Because porous aggregates absorb more water, the strength and durability of the concrete may deteriorate. When developing a concrete mix, aggregate attributes must be taken into consideration to guarantee that the finished concrete has the appropriate characteristics and performance (Gómez-Soberón, 2002).

**Specific Gravity**

Aggregate specific gravity is defined as the weight of the aggregate divided by the weight of an equivalent volume of water at a certain temperature. Nonetheless, stronger and more durable concrete does not always correlate with a higher specific gravity of the aggregate. A greater specific gravity usually means that the aggregate is more compact and has a higher density, which can improve workability and boost resistance to deterioration (Duggal, 2017). On the other hand, other elements like the water-to-cement ratio, curing techniques, and cement quality also affect how strong and long-lasting concrete is.

**Fineness Modulus**

According to ASTM 125, fineness modulus is a single metric that can be used to define the average size of the particles in an aggregate sample. It is computed by combining the cumulative percentages of the aggregate mass retained on specific sieves, then dividing the total by 100. The idea of a fineness modulus is devised to describe an aggregate's overall coarseness or fineness. FM measures an aggregate's fineness; the higher the FM, the coarser the aggregate. The FM may be the same for various aggregate grading. It helps determine the ratios of coarse and fine aggregate in concrete compositions.

## 2.7 Rice Husk Ash

When rice husk is burned, whether it be outdoors in open fields or indoors in controlled incineration circumstances, a substance known as RHA is produced. Open field burning is discouraged because it contributes to pollution and produces rice husk ash of poor quality. The RHA produced by open burning has a high carbon content, which affects how well concrete performs and also results in a highly crystalline structure with a low reactivity (Lo et al., 2021). Raw rice husk contains 40% cellulose, 30% lignin group, and 20% silica group. During combustion, the lignin in RRH cellulose burns and frequently leaves behind a porous silica skeleton. As a result, RHA contains silica in significant quantities (Ali et al., 2021).

### 2.7.1 Physical properties of rice husk ash

Because they have an effect on the mechanical and durability properties of concrete, rice husk ash's specific gravity, mean particle size, and Blaine fineness are some physical qualities that may affect how it is utilized in structural concrete. For maximal pozzolanic activity, the highly reactive RHA was ground to 7000 $cm^2/g$ (Fapohunda et al., 2017). The RHA's pozzolanicity, and hence the strength of the concrete construction, is significantly influenced by its particle size. Particle sizes below 5.6 m in RHA are unlikely to have any observable pozzolanic activity. The burning circumstances and the source of the rice husks might also affect the specific gravity of RHA (Ali et al., 2021).

Table 2. 3:Physical properties of RHA (S.K. Duggal, 2008)

| **Item No.** | **Particulars** | + **Properties** |
|---|---|---|
| 1 | Color | Gray |
| 2 | Shape Texture | Irregular |
| 3 | Mineralogy | Non crystalline |
| 4 | Particle size | < 45micro |
| 5 | Odor | Odorless |
| 6 | Specific gravity | 2.3 |
| 7 | Appearance | Very fine |

### 2.7.2 Chemical Composition of rice husk ash

The RHA are in the same category as Class F fly ash (ASTM C618, 2005) with high pozzolanic characteristics, as shown by the fact that the sum of $SiO_2$ + $Al_2$ + $Fe_2O_3$ surpasses 70% for all RHA specimens.(Fapohunda et al., 2017)**.** The oxides composition of rice RHA as obtained by various researchers are shown in Table 2.4 is compiled by (Fapohunda et al., 2017). From the table, it is clear that all of the researchers' findings demonstrated exceptionally high silica contents of at least 70%. This test gauges the reactivity of RHA toward silica, a component that has been shown to be responsible for the strength of concrete. This is particularly advantageous because it showed how RHA might help concrete gain strength when used in concrete production. The variation in oxide content usually depends on the origin and burning temperatures of the rice husks. Generally, the presence of oxides such as $SiO_2$, $Al_2O_3$, MgO, and $Fe_2O_3$, help in determining the characteristics of the rice husk ash. (Krishna et al., 2016)

Table 2. 3:Oxide composition of rice husk ash. Compiled by (Fapohunda et al., 2017)

| Researchers | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | $Na_2O$ | $K_2O$ | LOI | SAF |
|---|---|---|---|---|---|---|---|---|---|---|
| Swaminathen and Ravi(2016) | 87.2 | 0.15 | 0.16 | 0.55 | 0.35 | 0.24 | 0 | 0 | 5.44 | 87.51 |
| Mahmud et al. (2016) | 85.76 | 0.25 | 1.15 | 0.74 | 0.81 | 0.31 | 0 | 0 | 4.05 | 87.16 |
| Foong et al. (2015) | 93.46 | 0.58 | 0.52 | 1.03 | 0.51 | 0 | 0.08 | 1.82 | 7.76 | 94.56 |
| Bansal and Antil (2015) | 87.2 | 0.15 | 0.16 | 0.55 | 0.35 | 0.24 | 0 | 0 | 5.44 | 87.51 |
| Le et al. (2014) | 86.81 | 0.5 | 0.87 | 1.04 | 0.85 | 0 | 0.69 | 3.16 | 4.6 | 88.18 |
| Sivakumar and Mahendran (2014) | 87.65 | 0.22 | 0.24 | 0.39 | 0.28 | 0.15 | 1.1 | 2.98 | 2.26 | 86.78 |
| Le et al. (2015) | 87 | 0.8 | 0.4 | 1.2 | 0.6 | 0.4 | 0.4 | 2.63 | 3.7 | 88.2 |
| Kumar and Venugopal (2013) | 93.8 | 0.74 | 0.3 | 0.89 | 0.32 | 0 | 0.28 | 0.12 | 3.37 | 94.84 |
| Marthong (2012) | 75 | 1.29 | 0.78 | 3.3 | 0.22 | 0.2 | 0.4 | 1.5 | 3.67 | 77.07 |
| De Southa et al. (2011) | 73.6 | 0.07 | 0.26 | 0.76 | 0.27 | 0 | 0.09 | 1.17 | 22.9 | 73.93 |
| Memon et al. (2011) | 77.19 | 6.19 | 3.65 | 2.88 | 1.45 | 0 | 0 | 1.81 | 5.42 | 87.03 |
| Shukla et al. (2011) | 87.2 | 0.15 | 0.16 | 0.55 | 0.35 | 0.24 | 0 | 0 | 5.44 | 87.51 |
| Madandoust et al. (2011) | 90.9 | 0.83 | 0.6 | 0.8 | 0.56 | 0 | 0 | 0 | 0 | 92.33 |
| Raman et al. (2011) | 89.87 | 0.14 | 0.94 | 0.49 | 0 | 0 | 0.25 | 2.16 | 4.81 | 90.95 |
| Hwang et al. (2011) | 91 | 0.35 | 0.41 | 0 | 0.81 | 1.21 | 0.08 | 3.21 | 8.5 | 91.76 |
| Zerbino et al. (2011) | 94.84 | 0.39 | 0.54 | 1.32 | 0.4 | 0.01 | 0.11 | 1.45 | 0.25 | 95.77 |
| Habeeb and Mahmud (2010) | 88.32 | 0.46 | 0.67 | 0.67 | 0.44 | 0 | 0 | 2.91 | 5.81 | 89.45 |
| Muthandhi and Kothandaraman (2010) | 89.47 | 0 | 0.62 | 2.69 | 1.16 | 0.93 | 2.09 | 0.83 | 2.27 | 90.09 |
| Gastaldini et al. (2010) | 90 | 0.28 | 0.14 | 0.45 | 0.28 | 0.02 | 0.08 | 1.55 | 5 | 90.42 |
| Gastaldini et al. (2009) | 87.46 | 2.53 | 0.4 | 0.78 | 1.58 | 0 | 0 | 4.73 | 2.52 | 90.39 |
| Dakroury and Gasser (2008) | 87.2 | 0.15 | 0.16 | 0.55 | 0.35 | 0.24 | 1.12 | 3.68 | 8.55 | 87.51 |
| Chindaprasirt et al. (2008) | 93.2 | 0.4 | 0.1 | 1.1 | 0.1 | 0.9 | 0.1 | 1.3 | 3.7 | 93.7 |
| Da Silva et al. (2008) | 97.53 | 0 | 0.21 | 0.22 | 0 | 0 | 0.01 | 0.04 | 1.72 | 97.74 |
| Chindaprasirta et al. (2007) | 90 | 0.5 | 0.9 | 0.8 | 0.6 | 0.1 | 0.1 | 2.1 | 3.2 | 91.4 |
| Ramezanianpour et al. (2009) | 89.61 | 0.04 | 0.22 | 0.91 | 0.42 | 0 | 0.07 | 1.58 | 5.91 | 89.87 |
| Giaccio et al. (2007) | 87.2 | 0.15 | 0.16 | 0.55 | 0.35 | 0 | 1.12 | 3.6 | 6.55 | 87.51 |
| Bui et al.(2005) | 86.98 | 0.84 | 0.73 | 1.4 | 0.57 | 0.11 | 0.11 | 2.46 | 5.14 | 88.55 |
| Zhang et al. (1996) | 87.3 | 0.15 | 0.16 | 0.55 | 0.35 | 0.24 | 1.12 | 3.68 | 8.55 | 87.61 |
| Mehta (1992) | 87.2 | 0.15 | 0.16 | 0.55 | 0.35 | 0.24 | 1.12 | 3.68 | 8.55 | 87.51 |

*SAF=$SiO_2$+$Al_2O_3$+$Fe_2O_3$

### 2.7.3 Effect of rice husk ash on the concrete

**Effect of Rice Husk Ash on Workability of Concrete**

The workability of concrete, which refers to its ease of handling, mixing, and placing, can be significantly affected by the addition of RHA. Various studies have reported a reduction in workability when RHA is incorporated into concrete mixtures. (Hakeem et al., 2022) found that the inclusion of RHA led to a decrease in slump flow, indicating a reduction in workability. This decline can be attributed to the pozzolanic nature of RHA, which increases the water demand in the concrete mixture. As RHA particles react with water, they consume part of the available water, resulting in reduced fluidity and workability of the concrete mix (Raman et al., 2011b). Similarly, (Obilade, 2014) reported that the addition of RHA caused a decrease in the slump and flow values of the concrete, indicating a decrease in workability.

Moreover, the fine particle size and high surface area of RHA contribute to its ability to absorb water from the concrete mixture, further reducing workability. The water absorption capacity of RHA particles causes a decrease in the available water for lubrication and results in a less fluid concrete mix . Additionally, the irregular shape and angularity of RHA particles can increase the friction between particles, impeding the flow of the mixture and reducing its workability .

**Effect of Rice Husk Ash on Compressive Strength of Concrete**

The addition of rice RHA to concrete mixtures has been found to have a positive effect on the compressive strength of the resulting concrete. (Zareei et al., 2017) conducted an experimental investigation and found that the incorporation of RHA as a partial replacement for cement resulted in increased compressive strength of the concrete. The pozzolanic reaction of RHA contributed to the densification and refinement of the concrete microstructure, leading to improved interparticle bonding and enhanced compressive strength. Additionally, the high silica content of RHA played a crucial role in the development of a denser cementitious matrix, further enhancing the compressive strength of the concrete (Zareei et al., 2017). Similarly, (Fapohunda et al., 2017) conducted an experimental study on the strength and durability properties of RHA concrete and observed a significant increase in compressive strength with the incorporation of RHA. The fine particles of RHA filled in the voids within the concrete matrix, resulting in a more compact structure and improved inter particle bonding, thereby increasing the compressive strength and the higher silica content and pozzolanic activity of RHA contributed to the enhanced strength properties of the concrete (Lo et al., 2021).

**Effect of Rice Husk Ash on Split Tensile strength of Concrete.**

The incorporation of rice husk ash (RHA) in concrete mixtures has shown potential for increasing the split tensile strength of concrete. (Raman et al., 2011b) conducted an experimental study and observed an improvement in split tensile strength with the inclusion of RHA. The pozzolanic activity of RHA contributed to enhanced interparticle bonding and microstructure, resulting in increased tensile strength. The fine particles of RHA filled the voids, leading to improved tensile strength properties. Additionally, the high silica content of RHA played a crucial role in enhancing the split tensile strength of the concrete (Obilade, 2014).

**Effect of Rice Husk Ash on Flexural strength of Concrete.**

The incorporation of RHA in concrete mixtures has shown promise in enhancing the flexural strength of concrete. A study conducted by (Siddika et al., 2018) found that the fine particles of RHA filled the voids in the concrete matrix, further contributing to the improvement in flexural strength. Similarly, another study by (Akeke & Ephraim, 2012) investigated the influence of RHA on the fresh and hardened properties of high strength concrete and observed an improvement in flexural strength when RHA was incorporated into the concrete mixture. According to the authors, the pozzolanic reaction between RHA particles and calcium hydroxide played a significant role in the development of additional hydration products and improved inter-particle bonding, leading to the increased flexural strength of the concrete.

**Effect of Rice Husk Ash on Durability of Concrete.**

The addition of rice RHA to concrete has shown positive effects on its overall durability. Research conducted by (Ismail & Waliuddin, 1996) indicated that RHA can improve the resistance of concrete to carbonation. The pozzolanic reaction of RHA leads to the formation of additional hydration products, which densify the concrete matrix and reduce its porosity. This densification effect hinders the diffusion of carbon dioxide into the concrete, thereby enhancing its carbonation resistance. Additionally, studies by (Raman et al., 2011a) revealed that RHA incorporation in concrete can improve its resistance to acid attack. The reactive silica content in RHA reacts with calcium hydroxide in the concrete, forming additional C-S-H gel. This densifies the concrete matrix, reducing its permeability and enhancing its resistance to acid attack.

## 2.8 Coffee Husk Ash (CHA)

Coffee husk ash is a byproduct of burning coffee husks, the outer layer of the coffee bean. It is mostly composed of minerals such as silicon dioxide, aluminum oxide, and calcium oxide. It also contains other elements such as potassium, magnesium, and iron. The ash is a fine powder and is typically gray in color (Tarekegn et al., 2022).

### 2.8.1 Physical properties of Coffee Husk Ash

Specific gravity may range from 1.4 to 2.4 depending on the origin of the coffee. The mean particle size of CHA varies from 1.1 to 3.2 microns, which can be affected by a variety of factors such as the origin, type of burning (Reta & Mahto, 2019). Coffee husk ash can vary in Blaine fineness depending on the origin, type of burning. Blaine fineness ranges from 30 to 600 $cm^2/g$. The higher the Blaine fineness, the finer the coffee husk ash (Demissew et al., 2019).

### 2.8.2 Chemical Composition of coffee husk ash

According to (Acchar et al., 2013), the main mineral compositions of the CHA are calcium carbonate, calcium silicate, calcium phosphate and potassium sulfate. The various ingredients of coffee husk ash and its chemical composition that is studied by (Reta & Mahto, 2019) are as shown below in table 2.5

Table 2. 4: Chemical composition of Coffee Husk Ash, as Ash studied by (Reta & Mahto, 2019)

| **Constituent** | **Amount of oxide in Coffee Husk Ash by weight (%)** |
|---|---|
| Silica ($SiO_2$) | 14.65 |
| $K_2O$ | 47.45 |
| Alumina ($Al_2O_3$) | 12.07 |
| Lime (CaO) | 13.05 |
| $P_2O_5$ | 3.40 |
| Iron Oxide ($Fe_2O_3$) | 4.5 |
| $Na_2O$ | 0.5 |

### 2.8.3 Effect of Coffee Husk Ash on Concrete

**Effect of Coffee Husk Ash on Workability of Concrete**

The use of CHA as a partial replacement for cement in concrete has been investigated regarding its impact on the workability of the fresh concrete mixture. Research by (Hareru et al., 2022) found that increasing the percentage of CHA in the mix led to a decrease in workability due to the higher specific surface area and water demand of CHA compared to cement. The fine particles of CHA tend to absorb more water, reducing the available water content for lubrication and plasticity. However, (Acchar et al., 2013) demonstrated that by adjusting the water to powder ratio and incorporating high range water reducing superplasticizers, the workability of CHA modified concrete can be improved. These admixtures help optimize the mixture, ensuring the desired flowability and workability of the concrete while utilizing CHA as a sustainable alternative material. Proper mix design and the appropriate use of chemical admixtures can effectively mitigate the challenges associated with reduced workability when incorporating CHA into the concrete mixture (Acchar et al., 2013).

**Effect of Coffee Husk Ash on Compressive Strength of Concrete**

Several studies have examined the dosage at which coffee husk ash incorporation in concrete yields greater compressive strength. (Demissew et al., 2019) conducted laboratory experiments with different percentages of coffee husk ash in concrete mixtures and found that the optimum dosage for achieving higher compressive strength was at a replacement level of 10% by weight of cement. Similarly, (Reta & Mahto, 2019) investigated the influence of coffee husk ash on concrete strength and determined that an optimal replacement dosage of 15% produced the highest compressive strength. These findings suggest that careful selection and control of the dosage of coffee husk ash can lead to enhanced compressive strength in concrete. Future research should focus on optimizing the dosage for specific applications, considering factors such as the desired strength requirements and environmental considerations.

**Effect of Coffee Husk Ash on Split Tensile strength of Concrete.**

Several studies have examined the effect of coffee husk ash on the split tensile strength of concrete, revealing its potential for enhancing this property. In a study by (Demissew et al., 2019), various proportions of coffee husk ash were incorporated as a partial replacement for cement in concrete mixtures. The results demonstrated that the split tensile strength of concrete increased with the addition of coffee husk ash, reaching its peak at an optimal replacement level of 10% by weight of cement. Similarly, research by (Hareru et al., 2022) revealed that the inclusion of coffee husk ash in concrete significantly improved the split tensile strength. These findings suggest that coffee husk ash has the potential to enhance the split tensile strength of concrete, providing a sustainable and cost effective alternative in construction materials.

**Effect of Coffee Husk Ash on Flexural strength of Concrete.**

The utilization of CHA as a supplementary material in concrete has been investigated for its potential to enhance the flexural strength of the material. A study conducted by (Tarekegn et al., 2022) examined the effect of incorporating CHA as a partial replacement of cement on the flexural strength of concrete and the results indicated that the addition of CHA led to an improvement in the flexural strength of concrete specimens. The researchers attributed this enhancement to the pozzolanic reactivity of CHA, which contributed to the formation of additional calcium silicate hydrate (C-S-H) gel. The increased formation of C-S-H gel resulted in denser microstructures and improved bonding between the cement matrix and aggregates, thereby enhancing the flexural strength of the concrete.

Furthermore, a study by (Demissew et al., 2019) also investigated the effect of coffee husk ash on the flexural strength of concrete. The researchers examined various replacement levels of CHA and observed that as the percentage of CHA increased, the flexural strength of the concrete also improved. This improvement was attributed to the presence of reactive silica and alumina in CHA, which contributed to the pozzolanic reaction with calcium hydroxide, resulting in the formation of additional C-S-H gel. The enhanced C-S-H gel formation led to improved densification and reduced porosity of the concrete matrix, ultimately resulting in higher flexural strength. In addition to the formation of additional C-S-H gel, it contributes to the enhancement of flexural strength with the incorporation of CHA is the filler effect. CHA particles act as microfillers within the concrete matrix, effectively filling the voids and reducing the overall porosity. This filling effect improves the packing density of the concrete mixture, resulting in increased interparticle contact and improved load transfer across the matrix. As a result, the presence of CHA as a supplementary material contributes to a more compact and homogeneous concrete microstructure, leading to higher flexural strength (Gedefaw et al., 2022).

**Effect of Coffee Husk Ash on Durability of Concrete.**

The effect of CHA on the durability properties of concrete has been the subject of investigation in recent research. A study conducted by (Reta & Mahto, 2019) examined the impact of incorporating CHA as a partial replacement of cement on the durability performance of concrete. The results revealed that the addition of CHA led to improved durability characteristics of concrete, including enhanced resistance to chloride ion penetration and increased resistance to carbonation. The researchers attributed these improvements to the pozzolanic activity of CHA, which contributed to the formation of additional calcium silicate hydrate (C-S-H) gel. The denser microstructure resulting from the enhanced C-S-H gel formation led to reduced pore connectivity, limiting the entrance of chloride ions and the diffusion of carbon dioxide into the concrete. These findings suggest that the inclusion of CHA in concrete can significantly enhance its durability, making it a promising sustainable alternative in construction applications.

## Research Gap

Although there have been numerous studies on the individual use of RHA or CHA as cement replacements in concrete, there is a noticeable research gap when it comes to the combined application of these ashes as a hybrid mixture. Most of the existing literature focuses on their individual properties, with limited attention given to the potential synergistic effects of blending RHA and CHA. Therefore, there is a need to investigate the properties of fresh and hardened concrete by partially replacing the cement with the hybrid RHA and CHA ashes mixture to fill this research gap.

While the individual benefits of RHA and CHA as cement replacements have been explored, there is a lack of comprehensive understanding regarding their combined application. Understanding the oxide composition of the hybrid ash is crucial to determining the optimal blend ratio and potential advantages of the mixture. Furthermore, there is a need to evaluate the mechanical and physical properties of concrete incorporating the hybrid RHA and CHA ashes, including its Mechanical strength development, workability, and overall performance compared to conventional concrete. Contributing to this knowledge gap will provide valuable insights for engineers and researchers in the field of sustainable construction materials.

# CHAPTER THREE

# 3.METHODS AND MATERIALS

## 3.1 Introduction

The literature review in the previous chapter has discussed various past studies and research gaps in relation to properties of fresh and hardened concrete with Partial Replacement of Cement by Coffee Husk Ash and Rice Husk Ash. Based on the identified research gaps, Chapter 1 outlines the research objectives set for this study. This chapter elucidates the research methodology used to achieve the goals set in Chapter 1. The research identified a gap in understanding the combined use of RHA and CHA as a hybrid mixture in concrete. Previous studies mainly focused on their individual properties, neglecting the potential benefits of blending RHA and CHA together. To fill this gap, the methodology involved investigating the properties of fresh and hardened concrete by partially replacing the cement with the hybrid RHA and CHA ashes. The study included analyzing the oxide composition of the ash, evaluating the concrete's mechanical and physical properties, and comparing its performance to traditional concrete. The outcomes of this research will offer valuable insights for engineers and researchers working with sustainable construction materials.

## 3.2 Study Design

The study aims to investigate the properties of fresh and hardened concrete with partial replacement of cement by a hybrid of coffee husk ash and rice husk ash. Concrete mixtures will be prepared using ordinary Portland cement (OPC) as the control binder and the hybrid of RHA and CHA ashes as a partial replacement. The physical properties of the materials, such as particle size distribution, specific gravity, and fineness, will be determined. The concrete mixtures was prepared with varying percentages of the hybrid ash, and tests was conducted to evaluate the workability, compressive strength, tensile strength and flexural strength properties of the concrete. The obtained results was analyzed to assess the effects of the hybrid ash on the concrete properties and draw conclusions regarding its performance as a cement replacement.

## 3.3 Research Methodology Framework

The following flowchart illustrates the nature of the study, the process of the conducted study, the methodology employed to obtain research results, and the strategies for effectively addressing research issues.

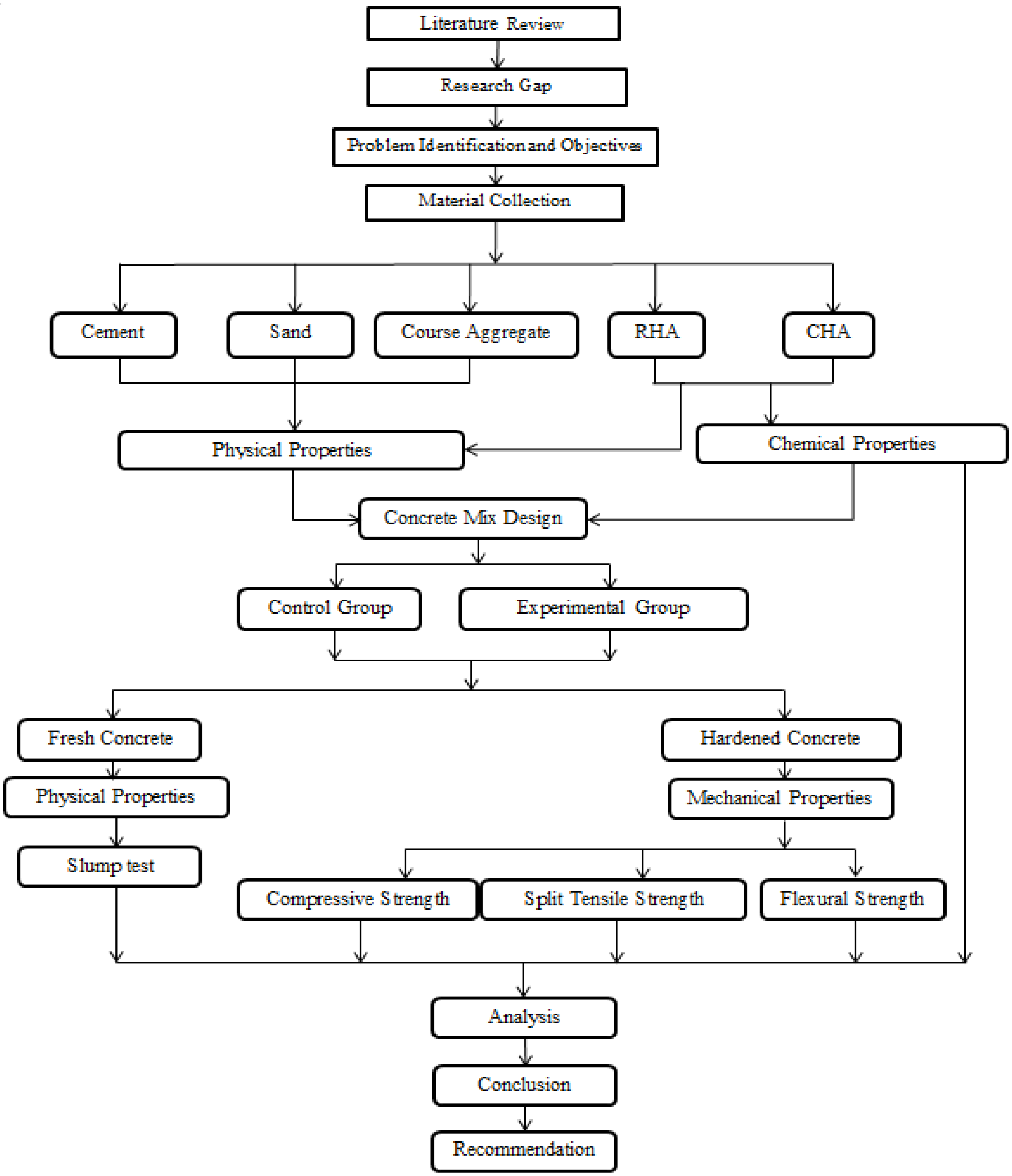


Figure 3-0-1 Representation of Research Framework

## 3.4 Material preparation

The materials used for studying the properties of fresh and hardened concrete with partial replacement of cement by a hybrid of rice husk ash and coffee husk ash were water, coarse aggregate, fine aggregate, cement, rice husk ash, and coffee husk ash. The water served to achieve the desired consistency and workability of the concrete mixtures. Coarse aggregate and fine aggregate were selected based on ASTM C33 designation to provide strength and stability to the concrete. Ordinary Portland cement (OPC) was used as the control binder, while rice husk ash and coffee husk ash were utilized as partial replacements for cement. The precise preparation and combination of these materials were carefully carried out to ensure consistent and accurate experimental results.

### 3.4.1 Water

The potable tap water stored in the central laboratory of the Ethiopian Construction Works Corporation was employed. The use of potable tap water is good for achieving the desired consistency and workability of the concrete mixture.

### 3.4.2 Cement

Ordinary Portland Cement (OPC) with a grade of 42.5, produced by Dangote Cement Factory, was employed. Cement, which is a vital ingredient in concrete, acts as a binding agent for the other materials. The selection of OPC with a grade of 42.5 was made to ensure the desired early strength and performance of the concrete.


Figure 3-0-2 Ordinary Portland Cement

### 3.4.3 River Sand

Washed river sand from Alage, East Shewa, was employed. Sand plays a crucial role in concrete as it fills the gaps between coarse aggregates and adds volume to the mixture. By utilizing washed river sand from Alage, we ensured the sand's cleanliness and high quality. This choice contributed to achieving the desired workability and strength of the concrete mixtures. The use of sand from a specific source helped maintain consistency and minimize variations in the experimental results.

**Figure 3-0-3 River Sand**

### 3.4.4 Course Aggregate

Well graded coarse aggregate with a nominal size of 19mm was utilized. Coarse aggregate refers to the larger particles in the concrete mixture that provide strength and stability. By selecting coarse aggregate with a nominal size of 19mm and maximum aggregate size of 25mm, uniformity in the particle size was ensured, which inturn contributes to the desired characteristics of the concrete. The appropriate size of the coarse aggregate helps achieve optimal workability and structural integrity in the concrete mixtures.

**Figure 3-0-4 Course Aggregate**

### 3.4.5 Rice Husk Ash

The rice husk was collected from Buno Bedele Zone, Gechi woreda. The husk was used after sieving and identifying small particle size of rice from the husk. It was then burned in the laboratory by using burning machine. The rice husk was burnt for 6-7 hours in the burning machine and it is controlled burning process. The temperature was in the range of 500 - 600°C, the temperature is controlled to this interval because, at this interval the ash will have the amorphous form of particle, which has better reactivity than the crystal one (Fapohunda et al., 2017). The ash was left inside the machine to cool down and it takes more time to cool down therefore using some external area to cool the ash with room temperature before collecting it. Finally, the ash was collected, grinded and sieved on a sieve having 75 microns opening, so that the ash have had fineness that is similar to cement.

Figure 3-0-5 Rice Husk Ash preparation

### 3.4.6 Coffee Husk Ash

The coffee husk was collected from Buno Bedele Zone, Gechi woreda. The husk was burned in the laboratory by using burning machine. The coffee husk was burnt in burning machine till the the husk completely changes to black grey color ash. The ash was left inside the machine to cool down and it takes more time to cool down therefore using some external area to cool the ash with room temperature before collecting it. Finally, the ash was collected, grinded and sieved on a sieve having 75 microns opening, so that the ash will have fineness that is similar to cement.

**Figure 3-0-6 Coffee Husk Ash Preparation**

### 3.4.7 Experimental Tests On Materials

The engineering properties of the materials used in this experimental study was tested as follows.

#### 3.4.7.1 Properties Of Coarse Aggregate

**1. Sieve Analysis**

Sieve analysis of coarse aggregate was conducted to determine the particle size distribution of the coarse aggregate, to ensure the quality and suitability of aggregates for the production of concrete used for this experiment. ASTM C136 was used as standardized guidelines for conducting the sieve analysis, specifying the selection of appropriate sieves, shaking duration, and calculation of retained percentages. On the other hand, ASTM C33 was used to observe wether the aggregate satisfies the requirements or not for concrete's aggregates. The grading limits and physical properties written under the ASTM C33 designation was observed for this experiment. The laboratory samples of aggregate for the property test were taken by using quartering method and sample splitter.

Figure 3-0-7 Quartering the Coarse Aggregate

## 1. Specific Gravity & Absorption (ASTM C 127-01 and ASTM C 128-01)

Tests for the specific gravity and absorption characteristics of aggregates have long been used to dtermine batch quantities for concrete. In this test experiment, all material passing 4.75mm sieve have been rejected. Test methods to calculate specific gravity of aggregates are described in ASTM C-127, “Specific Gravity and Absorption of Coarse Aggregate,” are employed test procedures to this experiment. The specific gravity and water absorption are calculated according to the following equation provided in the standard: The bulk specific gravity and bulk specific gravity SSD are calculated as follows;

Bulk Specific Gravity $= \frac{A}{B-C}$ ……………………………………………….Equation 3.1

Bulk Specific Gravity (SSD) $= \frac{B}{B-C}$ ……………………………………..… Equation 3.2

Apparent Specific Gravity $= \frac{A}{A-C}$ ………………………………………….……… Equation 3.3

Absorption,% $= \frac{A}{B-C} \times 100$ ………………………………………………….. Equation 3.4

Where, A = Weight of oven dry sample in air;

B = Weight of Saturated Surface dry mass in air; and

C = Weight of Saturated sample in water.

Figure 3-0-8 Coarse Aggregate Specific Gravity

## 2. Bulk density (Unit Weight)

The bulk density of the aggregate was determined according to ASTM C-29. In the test, a test cylinder of known volume is used and the mass of aggregate required to fill the cylinder is determined from the difference in mass between filled and empty cylinder.

The bulk density, unit weight, of an aggregate is the mass of the aggregate divided by the volume of particles and the voids between particles. The method most commonly used requires placing three layers of oven dry aggregate in a container of known volume, tamping each layer 25 times with a tamping rod, leveling off the surface, and determining the mass of the container and its contents. The mass of the container is subtracted to give the mass of the aggregate, and the bulk density is the aggregate mass divided by the volume of the container. The bulk density is calculated for each test specimen from the equation,

Unit Weight ($Kg/m^3$) = $\frac{B-A}{C}$ ………………………………………………………. Equation 3.5

Where; A = Weight of Container (Kg)

B = Weight of Container + Sample (Kg)

C = Volume of Container

Figure 3-0-9 Coarse Aggregate's bulk density

### 3. Moisture Content

Moisture Content of coarse aggregate was determined in accordance with ASTM C 566, "Total Moisture Content of Aggregate by Drying," by measuring the mass of a sample of the aggregate representative of the moisture content in the supply being tested, drying the sample and obtaining the mass again. In the test, about 2 kg of aggregate sample is oven dried at 105‟C for 24 hours and from the difference in weight before and after drying, the moisture content is determined. The moisture content is calculated from the equation,

Total Moisture Content, % = $\frac{A-B}{B}$ x 100…………………………………………… Equation 3.6

Where A = Weight of the original Sample.

B = Weight of the dry sample.

Figure 3-0-10 Moisture content testing

### 3.4.7.2 Properties of fine Aggregate

**1. Silt Content determination**

For good sand to use in concrete, it must be clean, without any clay, silt, or organic materials, and its sand particles should be of consistent particle size distribution. If the sand you use has a lot of silt or clay in it, it will make the concrete weaker. Impurities in the sand can be either solid particles or substances that can dissolve in water. Solid impurities are very tiny particles that can pass through a small sieve openings. In the case of fine aggregate, anything smaller than 75 micrometers is called silt. In our research, we tested the silt content according to ASTM C117 standard and found it to be 2.8%. According to the ASTM C33-18 standard for concrete aggregates, the maximum silt content that is allowed in fine aggregate used for concrete is 3% by weight, and our fine aggregate meets this requirement.

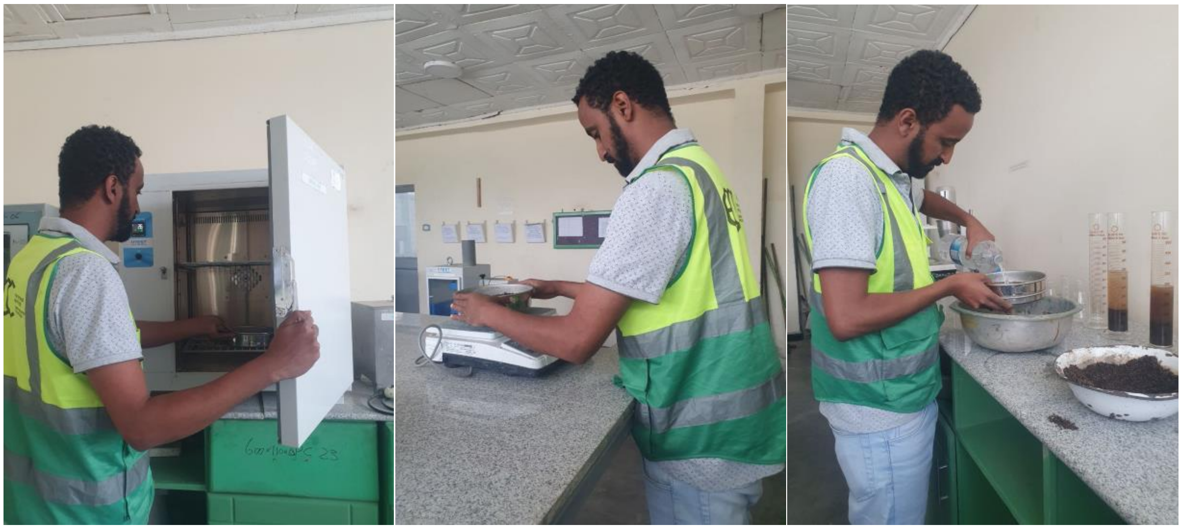

Figure 3-0-11 Silt content determination

### 1. Sieve Analysis

The grading was determined in accordance with ASTM C136/C136M, "Sieve Analysis of Fine and Coarse Aggregates." A representative sample of the aggregate that has been properly prepared is shaken through a series of sieves nested one above the other in order of size, with the sieve having the largest openings on top and the one having the smallest openings at the bottom.

The test results are as shown on Table 3.1,

Table 3. 1: River Sand Gradation test result

| Sieve size (mm) | Weight Retained (gm) | Percentage Retained (%) | Cumulative Coarser (%) | Cumulative Passing (%) | Percent passing | |
|---|---|---|---|---|---|---|
| | | | | | Lower limit | Upper limit |
| 9.75 | **0** | **0.00** | 0.00 | **100.00%** | 100% | 100% |
| 4.75 | **9.5** | **1.94** | 1.94 | **98.06%** | 95% | 100% |
| 2.36 | **29.5** | **6.03** | 7.98 | **92.02%** | 80% | 100% |
| 1.18 | **113.5** | **23.21** | 31.19 | **68.81%** | 50% | 85% |
| 0.6 | **161.5** | **33.03** | 64.21 | **35.79%** | 25% | 60% |
| 0.3 | **107.5** | **21.98** | 86.20 | **13.80%** | 10% | 30% |
| 0.15 | **42.5** | **8.69** | 94.89 | **5.11%** | 2% | 10% |
| Pan | **25** | **5.11** | 100.00 | **0.00%** | | |
| | **489** | | | | | |

As one can understand from above table the gradation of river sand that was used for this research is with in the limit envelop set in ASTM C33. So, the sand is suitable for concrete.

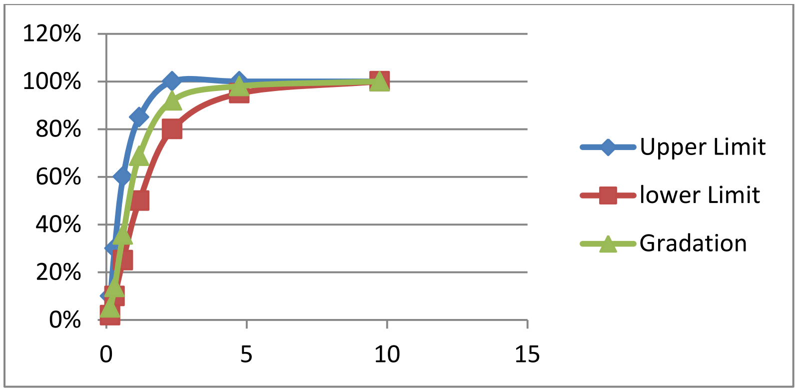


Figure 3-0-12 Graphical representation of fine aggregate's gradation

Figure 3-0-13 Quartering of River Sand

## 2. Fineness Modulus

Fineness modulus is computed using the sieve analysis results. 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 are the 4.75 mm, 2.36 mm, 1.18 mm, 600 μm, 300 μm, and 150 μm (No. 4, 8, 16, 30, 50, and 100). Note that the lower limit of the specified series of sieves is the 150 mm (No. 100) sieve and that the actual size of the openings in each larger sieve is twice that of the sieve in the following. From the following table 3.2, the Fineness Modulus of the river sand used for this research is 2.8. The maximum allowable Fineness Modulus of river sand as per ASTM C33 is 3.2, so the river sand is suitable for concrete use.

$$FM = \sum \frac{\%\ \text{Retained}}{100} \quad \text{.................................. Equation 3.7}$$

Table 3. 2:Fineness Modulus of the river sand

| Sieve size (mm) | Weight Retained (gm) | Percentage Retained (%) | Cumulative Coarser (%) | Cumulative Passing (%) | Percent passing | |
|---|---|---|---|---|---|---|
| | | | | | lower limit | upper limit |
| 9.75 | **0** | **0.00** | 0.00 | **100.00%** | 100% | 100% |
| 4.75 | **9.5** | **1.94** | 1.94 | **98.06%** | 95% | 100% |
| 2.36 | **29.5** | **6.03** | 7.98 | **92.02%** | 80% | 100% |
| 1.18 | **113.5** | **23.21** | 31.19 | **68.81%** | 50% | 85% |
| 600 μm | **161.5** | **33.03** | 64.21 | **35.79%** | 25% | 60% |
| 300 μm | **107.5** | **21.98** | 86.20 | **13.80%** | 10% | 30% |
| 150 μm | **42.5** | **8.69** | 94.89 | **5.11%** | 2% | 10% |
| Pan | **25** | **5.11** | 100 | **0.00%** | | |
| | **489** | **FM** | **2.86** | | | |

**3.Specific gravity**

This test was conducted in accordance with ASTM C128, "Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate." Fine aggregate is dried at a temperature of 100 to 110°C (212 to 230°F), cooled in air, and immersed in water for 24 hours. The sample is stirred frequently until it approaches a free flowing condition and then a portion is placed in a mould and tamped. If surface moisture is still present, the fine aggregate will retain its molded shape after the mould is lifted. Drying is continued with testing at frequent intervals until the tamped fine aggregate slumps slightly upon removal of the mold. This indicates that it has reached a saturated surface dry (SSD) condition. The mass of fine aggregate sample is determined in SSD, oven dry and submerged states. These values are then used to calculate bulk specific gravity, bulk SSD specific gravity, apparent specific gravity and absorption. Relative density (specific gravity) is computed from the equation.

Bulk Relative Specific Gravity = $\frac{A}{B+C-D}$ …………………………………………… Equation 3.8

Bulk Relative Specific Gravity (SSD) = $\frac{A}{B+C-D}$ ……………………….………… Equation 3.9

Where A = is the mass of the oven-dry sample in air

B = is the mass of the SSD sample in air

C = is the mass of the pycnometer + water; and.

D= is the mass of the pycnometer + specimen + water

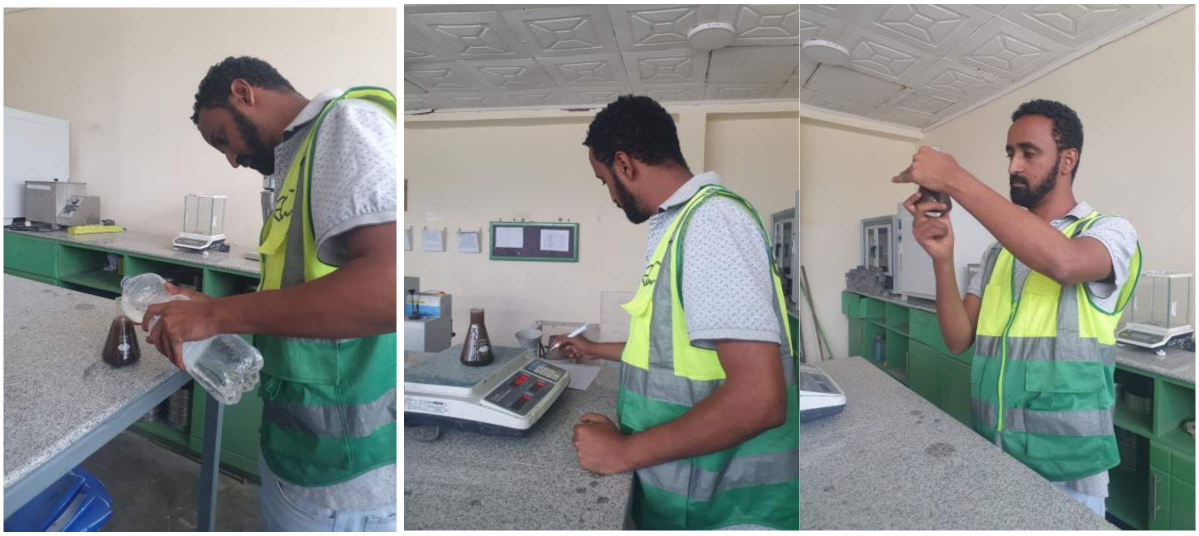

Figure 3-0-14 Specific gravity test

**4.Absorption and surface moisture**

Of the different moisture conditions in which an aggregate may exist, oven dry moisture condition and saturated surface dry moisture condition, are used as the basis for relative density calculations. Aggregates stockpiled on the job, however, are seldom in either of these states. Absorption is a measure of the total pore volume accessible to water and is usually calculated using the results from a relative density determination (ASTM C127; ASTM C128). Absorption was computed as a percentage by subtracting the oven-dry mass from the saturated surface-dry mass, dividing by the oven-dry mass, and multiplying by 100.

Absorption % = $\frac{\text{WSSD(Saturated surface dry mass)} - \text{WOD (Oven dry mass)}}{\text{WOD (oven}-\text{dry mass)}}$ x 100 ……….. Equation 3.10

**5.Total moisture content**

Total moisture content is measured in accordance with ASTM C566, "Total Moisture Content of Aggregate by Drying," by measuring the mass of a sample of the aggregate representative of the moisture content in the supply being tested, drying the sample, and obtaining the mass again.

Total moisture content % = $\frac{A-B}{B}$ x 100 …………………………………………….. Equation 3.11

Where A = Weight of the original sample

B = Weight of the Oven dried sample

### 3.3.7.3 Properties of Cement

**1. Consistency of Cement**

To determine the quantity (percentage) of mixing water required for preparing cement paste of standard consistency (satisfactory workability) test was needed .Cement sets and hardens in to a solid mass up on hydration when mixed with water. It Binds two or more non adhesive aggregates together. It is determined by using vicat apparatus, which measures the resistance of the paste to the penetration of a plunger of 300gm released at the surface of the paste. The determination of the correct amount of water is required for the reason that the rate of hydration and setting of cement are affected by the W/C ratio. The water requirement for various tests of cement depends up on the normal consistency of the cement,which itself depends up on the compound ,composition & fineness of the cement. Percentage of water (P) in the cement paste of standard consistency varies from cement to cement and from batch to batch of cement production. The usual rage of water to cement ratio for normal consistency is between 0.26 to 0.33. The consistency test analysis was conducted as follows;

$$P = \frac{W}{C} \times 100\% \quad \text{.......................................... Equation 3.12}$$

Where C = Weight of cement taken (gm)

W = Weight of water for desired penetration

P = % age of water for normal consistency

Figure 3-0-15 Consistency of cement test

**2. Fineness of cement**

As per ASTM Standards C204, the No. 200 sieve method is a test method that is commonly used to determine the fineness of cement. According to the standard, the sieve must be agitated for a predetermined amount of time after the sample has been dried and weighed. Weighing the residue that remains on the sieve allows us to determine the residue's proportion by weight. The test is used to check proper grinding of cement. And it can be determined by using standard size sieve IS 90 micron (9) sieve. Sieve should be cleaned gently only with bristle brush to avoid damage to the mesh and sieving must be carried out gently and continuously for 15 minutes. The calculation of fineness percentage is;

$$\text{Finennes } \% = \frac{W1}{W2} \times 100 \quad \text{……………………….. Equation 3.13}$$

Where $W_1$ ( gm ) = Weight of the cement before sieving

$W_2$ ( gm ) = Weight of the cement retained after sieving

Figure 3-0-16 Finennes of cement test

### 3.3.7.4 Physical Properties of Rice Husk Ash and Coffee Husk Ash

The Oxide compositions and specific gravities of the rice husk ash coffee husk ash were examined at the Ethiopian Mineralogy & Geotechnical Laboratory of the Ethiopian Geological Survey. The percentages of various oxides that present in the ash were determined by analytical method of $LiBO_2$ FUSION, HF attack, GRAVIMETERIC, COLORIMETRIC and AAS.

## 3.4 Mix Design

In order to ensure the desired properties of concrete, several steps were taken to determine the appropriate mixture proportions. Firstly, the required compressive strength for control was specified to be 25 MPa. Based on this strength requirement, a suitable maximum water to cement ratio of 0.5 was selected for a non air entrained mix. Next, the slump, which indicated the workability of the concrete, needed to be determined. In this case, a slump value of 75 mm was chosen to meet the workability requirements. To calculate the cement content, the water content was multiplied by the water to cement ratio of 0.5. The cement content was then determined as 0.5 times the water content. The aggregate proportions were then determined. The coarse aggregate content was calculated as a percentage of the total aggregate content, based on Finennes Modulus of the fine aggregate and Nominal aggregate size, assuming a coarse aggregate content of 67% based on Table A-1.5.3.6 of ACI 211.1-81. The coarse aggregate content was obtained by subtracting the cement, water, and fine aggregate content from the total weight of the concrete mixture. Accounting for the moisture content of the aggregates was deemed important, and the water content was adjusted accordingly. This adjustment depended on the moisture content of the aggregates and was determined using Table A-1.5.3.6 of ACI 211.1-81. To verify the mixture proportions, the total weight of the concrete mixture was calculated, taking into account the individual weights of cement, water, river sand, and coarse aggregate. Finally, the percentages of cement, water, fine aggregate, and coarse aggregate in the total weight of the mixture were determined to ensure that the proportions met the requirements for a successful concrete mix. Full mix design procedures, calculations and the final mix ratio obtained from the mix design are attached to the appendix.

## 3.5 Sample Preparation

A sample of concrete was prepared following the established procedures outlined in the ASTM C192/C192M standards. Initially, the necessary ingredients, including OPC Cement, Rice Husk Ash, Coffee Husk Ash, Coarse Aggregate, Fine Aggregate, and water, were gathered in the appropriate proportions.

Subsequently, the mixing process started by first combining and thoroughly mixing the dry ingredients, namely Cement, Aggregates (Fine and coarse) and with different percentages of hybrid Rice Husk Ash (RHA) and Coffee Husk Ash (CHA). The hybrid was mixed by creating a matrix of various combinations. This was done to ensure a consistent distribution. Amount of Water content that was calculated during mix design phase was then added gradually while the mixing continued, aiming to achieve the desired consistency of the concrete. The mixing process was carefully carried out for an appropriate duration in accordance with ASTM C305 to facilitate proper hydration and ensure a homogeneous mixture.

After the completion of the mixing process, the freshly mixed concrete was carefully placed into suitable cube molds or forms in line with the requirements of the laboratory experiment, following ASTM C192/C192M. The molds were adequately prepared by cleaning and applying a lubricant to facilitate the subsequent removal of the hardened samples. Before pouring to the cube mold, the workability of the concrete was checked, once the slump cone was filled at 3 layers, the concrete was compacted using tamping, conforming to ASTM C143/C143M to check the Slump, with the objective of eliminating any voids or air pockets. Following the Slump tests and filling the Cube mold of compressive strength test, Cylinder mold of Spilit tensile test and Beam mold for flexural test and compacting well, all of the concrete specimens were subjected to appropriate curing method. As per ASTM C192/C192M curing was conduted in a standard curing tanker of the ECWC's laboratory. This process allowed for proper hydration and the development of strength within the specimens. The duration of the curing period was determined based on ASTM C192/C192M standards, and the specimens were cured for 28 days of age. Upon the completion of the designated curing time, the specimens were ready for subsequent testing in the laboratory experiment to assess their properties and performance accurately, as defined by the relevant standards.

**Figure 3-0-17 Preparation of hybrid RHA**

## 3.6 Laboratory experiments on fresh and hardened concrete with different percentages of hybrid RHA and CHA

After complete examination of the physical properties of fine aggregate, coarse aggregate, and cement conducted, affirming their satisfaction of the required engineering properties. Additionally, the physical and Chemical properties of RHA and CHA were also thoroughly tested. These materials underwent several analysis to evaluate their suitability and influence on concrete performance. Parameters such as specific gravity, chemical composition, and other relevant characteristics were investigated. The results of these tests provided valuable insights into the behavior and potential benefits of incorporating RHA and CHA into concrete mixtures. The results of tests conducted at Ethiopian Geological Survey on RHA and CHA has been attached to the Appendix. Building upon this knowledge, laboratory experiments were then carried out to evaluate the fresh and hardened concrete properties.

The hybrid of RHA and CHA was mixed by creating a matrix of various combinations as shown on Table 3.3.

Table 3.3 The Matrix of various combinations of RHA and CHA in %

| | | | |
|---|---|---|---|
| (0,0) | (0,2.5) | (0,3.5) | (0,5) |
| (5,0) | (5,2.5) | (5,3.5) | (5,5) |
| (10,0) | (10,2.5) | (10,3.5) | (10,5) |
| (15,0) | (15,2.5) | (15,3.5) | (15,5) |
| (20,0) | (20,2.5) | (20,3.5) | (20,5) |
| (25,0) | (25,2.5) | (25,3.5) | (25,5) |

### 3.6.1 Workability of Concrete

A slump test was undertaken to assess the workability of concrete by incorporating varying percentages of hybrid RHA and CHA. The primary objective of these experiments was to investigate the influence of different proportions of RHA and CHA on the workability of fresh concrete, specifically focusing on its flowability and ease of placement. The workability was evaluated through the ASTM C143/C143M standard, commonly known as the Slump test. Concrete mixtures were very thoroughly prepared by replacing a portion of the cement with the hybrid RHA and CHA, and the Slump test was conducted following the specified ASTM guidelines.

Figure 3-0-18 Workability test

### 3.6.2 Compressive Strength of Concrete

Compressive strength tests were conducted in accordance with ASTM C39/C39M-09 standard to evaluate the compressive strength of hardened concrete with a cement replaced partially with different percentages of hybrid RHA and CHA. The results obtained showed valuable insights into the impact of different percentages of RHA and CHA on the compressive strength of the concrete. These findings contribute to the understanding of the optimal combinations of RHA and CHA for enhancing the compressive strength of concrete. Concrete samples were prepared for age of 28$^{th}$ days to find the optimum replacement of hybrid RHA and CHA that can achieve maximum compressive strength. The concrete specimens was prepared according to ASTM C192/C192M-00 Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory. After the test specimens are made, their locations for identification were marked, and stored them in a laboratory environment for 28 days in accordance with ASTM C39/C39M-09 Standard Test Method for Compressive Strength of Cubic Concrete Specimens. On the testing day by using compression machine, compressive force was applied at the rate of 0.3Mpa/sec until the specimen fails, and record the maximum load attained. compressive strength was calculated by dividing the maximum load attained by the crosssectional area of the specimen. Finally, compressive strength results were reported according to ASTM C39/C39M-09.

Figure 3-0-19 Compressive Strength test

### 3.6.3 Spilit Tensile Strength of Concrete

Tensile split strength tests were conducted According to ASTM C496 standard for concrete tensile split testing. The procedure involves the following steps, cylindrical concrete specimen with a diameter of 150 mm and a height of 300 mm was used for sampling the specimen. Tensile splitting strength also was conducted for the age of $28^{th}$ days using the same machine used for compressive strength test. The concrete was surface dried for two hours to be tested in the moist condition according to ASTM C39 The cylindrical specimen was Placed under a compression testing machine with a loading rate of 0.3Mpa/sec and capacity of 3000KN, with the axis of the cylinder parallel to the direction of the applied load. tensile load was applied to the specimen at a constant rate of deformation until the specimen fails. the maximum load applied to the specimen was recorded, and the splitting tensile strength of the concrete was calculate by using the following formula.

$$\text{Splitting Tensile Strength} = \frac{\mathbf{2P}}{\mathbf{\pi D * h}} \quad \text{………………..} \text{ Equation 3.14}$$

Where P is maximum load in (KN)

D is diameter of cylinder (mm)

H is height of the cylinder (mm)

Figure 3-0-20 Spilit tensile strength test

### 3.6.4 Flexural Strength of Concrete

An experimental investigation was carried out to evaluate the flexural strength of concrete with varying percentages of hybrid RHA and CHA. Concrete specimens were prepared in accordance with standard practices, and flexural strength testing was performed following ASTM C78/C78M. The obtained results provided valuable insights into the influence of different percentages of hybrid RHA and CHA on the flexural strength of concrete. This research contributes to the knowledge of optimal RHA and CHA combinations for enhancing the flexural strength of concrete, enabling their potential application in various structural and construction projects.

$$fb = \frac{3PL}{2bd*d} \qquad \text{………………………….. Equation 3.15}$$

Where: $fb$ = flexural strength Mpa

L = the distance between the lower supporting rollers mm

P= maximum applied load N

b =width of the beam mm

d = depth of the beam mm

Figure 3-0-21 Flexural strength test

### 3.6.5 Curing Of Concrete Specimens

In the conducted laboratory experiment, curing of the concrete specimens was a crucial step to promote hydration and ensure the development of strength. The curing process followed the guidelines outlined in the ASTM standards. After the freshly mixed concrete was placed into suitable molds or forms as per ASTM C192/C192M, the specimens were subjected to a curing regimen. Curing involved protecting the specimens from excessive moisture loss, which is crucial for optimal hydration and strength gain. The duration of the curing period was determined based on the requirements outlined in ASTM C192/C192M. Specifically in this research, the specimens were cured for 28 days of age to allow sufficient time for hydration and the desired level of strength development. Proper curing played a significant role in enhancing the properties of the concrete specimens. It helped to minimize the risk of surface drying and shrinkage, ensuring a more uniform and robust concrete matrix.

Figure 3-22 Curing of specimens

## 3.7 Summary

In this chapter, the research methodology is discussed. The chapter presents an overview of the overall research methodology employed in the study, followed by a detailed discussion of the methodologies adopted to achieve each objective. Various physical property tests were conducted for fine aggregate, coarse aggregate, rice husk ash, coffee husk ash, and cement. After testing the physical properties of the aggregates and cement and physical and chemical tests were conducted on the CHA and RHA. Physical and Mechanical tests was conducted on the fresh and hardened concrete. Each material underwent thorough examination to determine its specific physical properties relevant to the study. The methodology chapter provides a comprehensive outline of the steps taken to conduct the experiments and obtain precise data for further analysis in the research.

# CHAPTER FOUR

# 4. RESULTS AND DISCUSSION

## 4.1 Introduction

The previous chapter discussed the research methodology adopted in this study. This chapter presents the results and discussions obtained from an experimental investigation conducted to examine the properties of fresh and hardened concrete with the partial replacement of cement by a hybrid of coffee husk ash and rice husk ash.

The objective of this chapter is to analyze and interpret the data gathered through a comprehensive set of physical and chemical properties tests performed on the materials used in the study. Slump was conducted to evaluate the properties of the fresh concrete. Slump test provides insights into the ease of handling and placing the concrete mixture. Furthermore, various tests were carried out on the hardened concrete specimens to assess their mechanical properties. These tests include compressive strength, tensile strength and flexural strength. The results obtained from these tests will be discussed in detail, highlighting any notable observations, trends, and variations in comparison to the control samples.

## 4.2 The Oxide Compositions of RHA and CHA

Table 4.1 shows the oxide composition of rice husk ash and coffee husk ash that were tested during the study. The results of oxide composition of RHA and CHA were collected from the result conducted at Ethiopian Mineralogy & Geotechnical Laboratory of the Ethiopian Geological Survey. The official test result is attached to Appendix - 3

Table 4. 1: The Oxide Compositions of RHA and CHA

| No. | Parameters | RHA Oxide Composition (%) | CHA Oxide Composition (%) |
|---|---|---|---|
| **1** | $SiO_2$ | 75.22 | 59.15 |
| **2** | $Al_2O_3$ | 1.16 | 7.4 |
| **3** | $Fe_2O_3$ | 0.6 | 3.5 |
| **4** | CaO | 1.44 | 8.2 |
| **5** | MgO | 1.68 | 1.2 |

| | | | |
|---|---|---|---|
| **6** | $Na_2O$ | 1.04 | 1.3 |
| **7** | $K_2O$ | 2 | 6.5 |
| **8** | MnO | 0.08 | 0.05 |
| **9** | $P_2O_5$ | 3.83 | 3.4 |
| **10** | $TiO_2$ | 0.04 | 0.06 |
| **11** | $H_2O$ | 5 | 4 |
| **12** | LOI | 8 | 6 |
| $SiO_2 + Fe_2O_3 + Al_2O_3$ | | 76.98 | 70.05 |

RHA and CHA must meet ASTM C618 requirements to be used as a pozzolan in concrete production. The chemical composition of RHA and CHA should have a combined proportion of silicon dioxide ($SiO_2$), aluminum oxide ($Al_2O_3$), and iron oxide ($Fe_2O_3$) of at least 70%. The loss on ignition (LOI) should not exceed 10% as per ASTM standards. Class F pozzolan, which contains up to 12% LOI, is commonly used. The available alkalis, specifically $Na_2O$, should not exceed 1.5% according to ASTM C618. The MgO percentage in cement, originating from magnesia compounds in raw materials, typically ranges from 0.1% to 4%, with 5% being the maximum to control expansion in hardened concrete. The laboratory report indicated that the MgO content was within the acceptable limit. The LOI of both ashes revealed a result of less than 12%, which is lower than the maximum limit of 12% set by ASTM.

## 4.3 Properties of fresh and hardened concrete with partial replacement of hybrid Rice husk ash (RHA) and Coffee husk ash (CHA)

The study investigated the properties of fresh and hardened concrete with partial replacement of hybrid RHA and CHA. For fresh concrete, an increase in the proportion of RHA and CHA led to a decrease in slump value, indicating reduced workability. In hardened concrete, optimized hybrid proportions of RHA and CHA resulted in increased compressive strength, split tensile strength, and flexural strength compared to the control mix. However, proportions beyond the optimized range showed a decline in strength properties, highlighting the importance of careful selection for enhanced strength characteristics.

### 4.3.1 Workability

In the study, the slump value of fresh concrete was investigated and observed to decrease as the proportion of hybrid RHA and CHA increased. This reduction in slump indicated a decrease in the workability of the fresh concrete mix. The slump value, which measures the ease of handling and placing of concrete, was found to be lower when conventional materials were partially replaced with RHA and CHA. The decrease in slump value suggested that the substitution of materials had an impact on the ability to pour and shape the concrete mix.

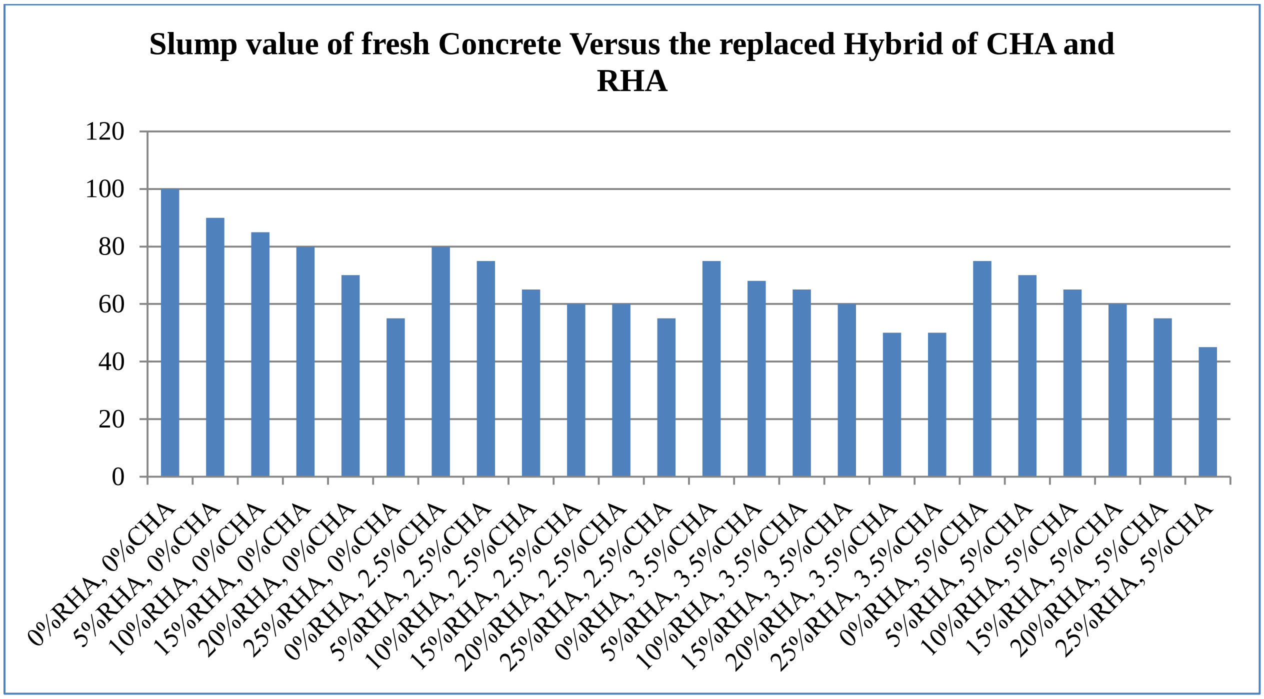


**Figure 4. 1: Slump Value**

### 4.3.2 Compressive Strength

This study investigated the properties of hardened concrete with partial replacement of hybrid RHA and CHA. The compressive strength showed interesting developments. Some hybrid proportions derived from RHA and CHA showed increased compressive strength compared to the control mix. However, in certain proportions beyond the optimized range, the compressive strength showed a decline. This highlights the importance of careful selection of the hybrid proportions of RHA and CHA to achieve enhanced compressive strength in hardened concrete.

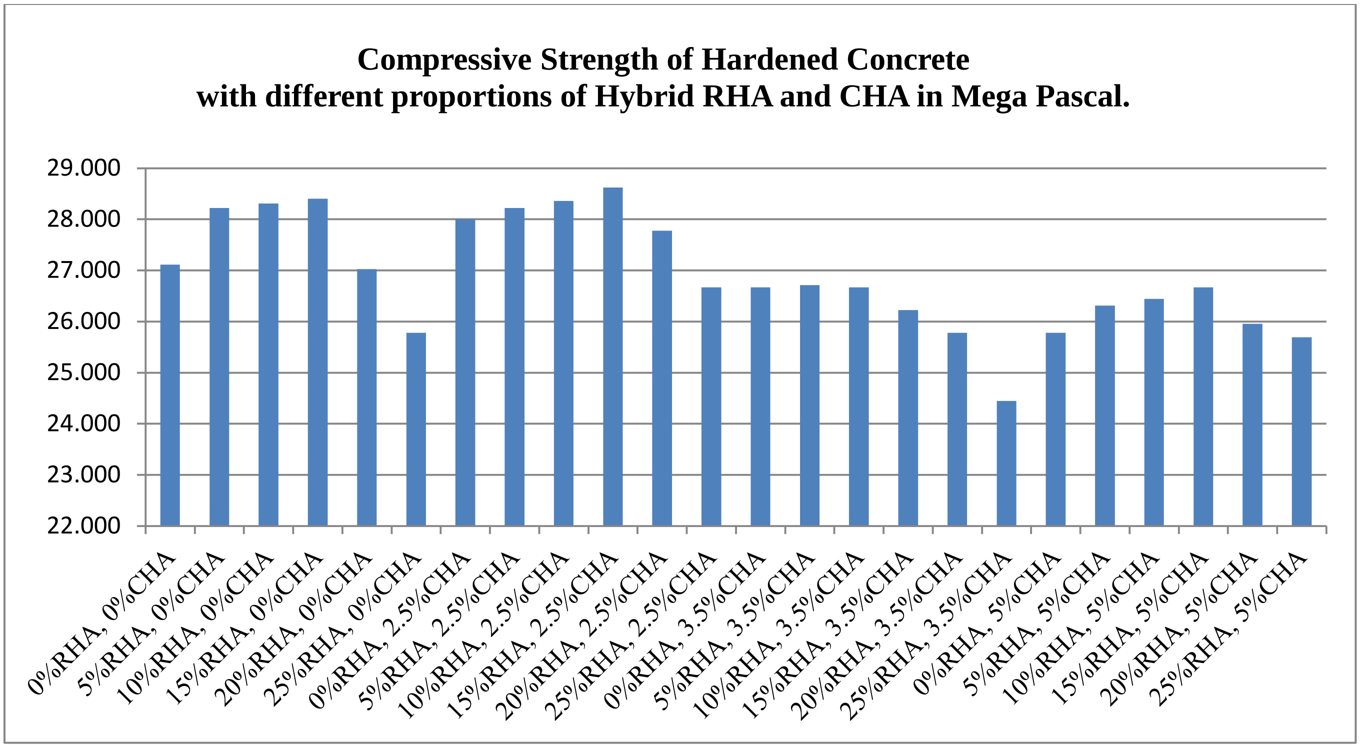


**Figure 4. 2: Compressive Strength**

As it can be observed from Figure 4.2, The study involved mixing a matrix of various combinations of hybrid RHA and CHA to investigate their impact on the compressive strength of hardened concrete. The combinations included different proportions of RHA and CHA, ranging from 0% to 25% RHA and 0% to 5% CHA. Notably, it was observed that within the range of 2.5% CHA, the compressive strength of the hardened concrete increased with different proportions of RHA. The maximum compressive strength was achieved at the combination of 15% RHA and 2.5% CHA.

### 4.3.3 Split Tensile Strength

The investigation of hardened concrete properties with partial replacement of hybrid RHA and CHA revealed interesting inclinations in split tensile strength. Optimized hybrid proportions, obtained from RHA and CHA, showed an increase in split tensile strength compared to the control mix. However, proportions exceeding the optimized range revealed a decline in split tensile strength. The findings highlight the importance of attentive selection when determining the hybrid proportions of RHA and CHA to achieve enhanced split tensile strength in hardened concrete.

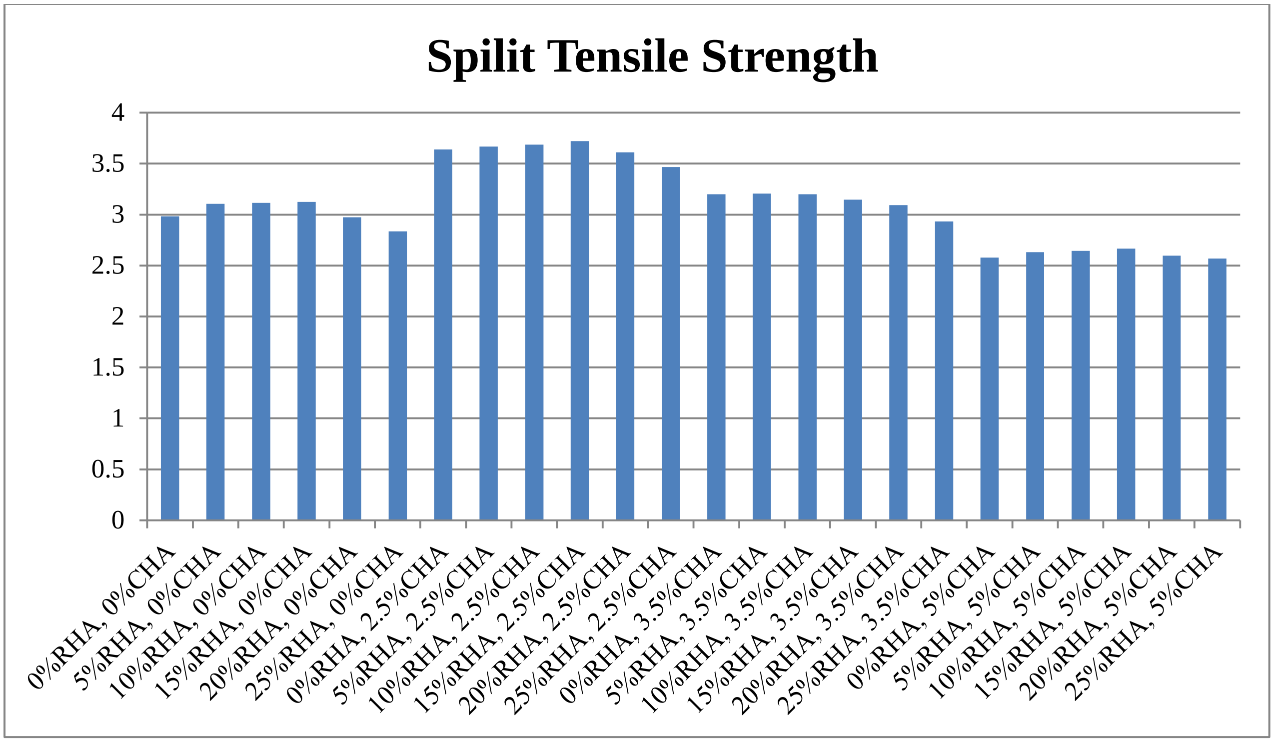


**Figure 4. 3: Spilit Tensile Strength**

As shown in Figure 4.3, the study focused on blending hybrid RHA and CHA to assess their effect on the split tensile strength of hardened concrete. Various mixtures were tested, covering different ratios of RHA and CHA, ranging from 0% to 25% RHA and 0% to 5% CHA. Notably, it was found that within the range of 2.5% CHA, the split tensile strength of the concrete increased across different RHA proportions. The highest split tensile strength was recorded with a blend containing 15% RHA and 2.5% CHA.

### 4.4.4 Flexural Strength

The flexural strength of the concrete specimens was evaluated using the one-point method to assess the ability of the hardened concrete that its cemen has been partially replaced by optimized hybrid proportions of RHA and CHA to resist bending forces. The results indicated a significant enhancement in flexural strength for the specimens. This improvement can be attributed to the pozzolanic reactivity and microfiller effect provided by RHA and CHA, resulting in improved interfacial bonding and reduced microcracks within the hardened concrete matrix.

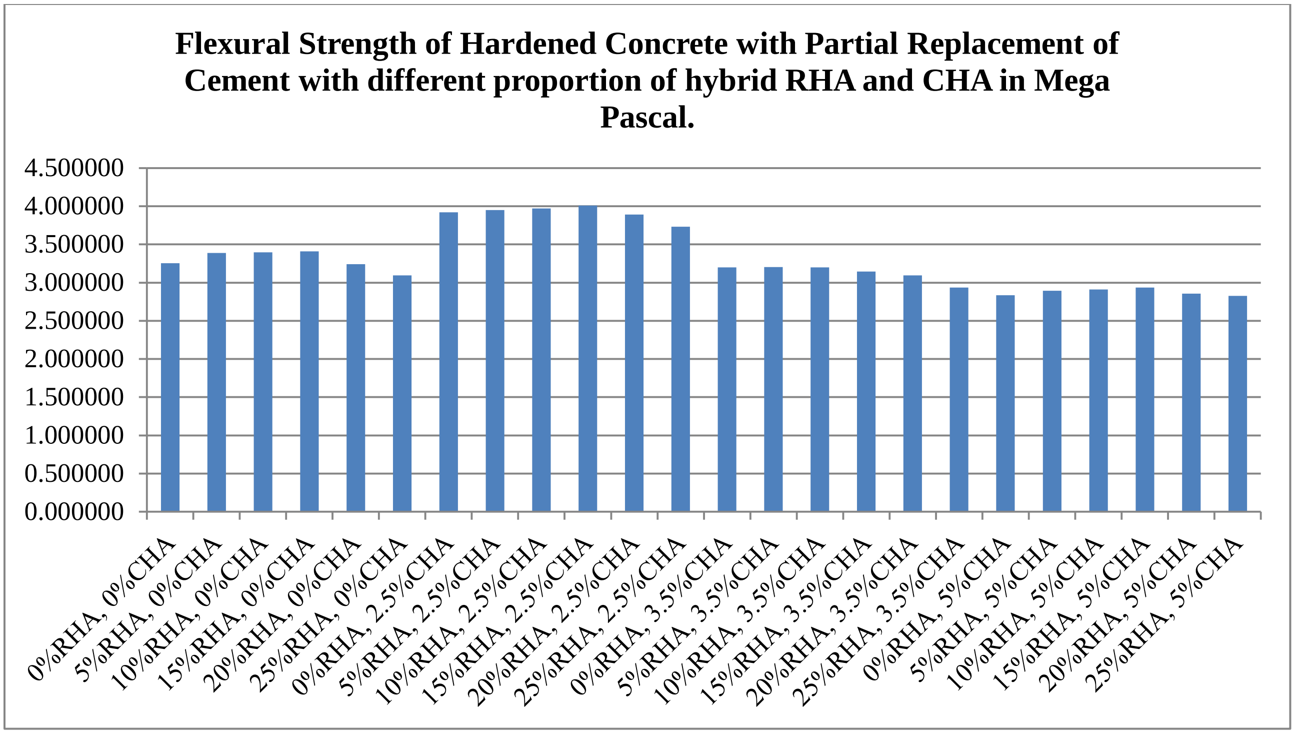


**Figure 4. 4: Flexural Strength**

As depicted in Figure 4.4, the study aimed to assess the influence of hybrid rice RHA and CHA combinations on the flexural strength of hardened concrete. Various mixes were tested, encompassing different ratios of RHA and CHA, ranging from 0% to 25% RHA and 0% to 5% CHA. Notably, it was found that within the range of 2.5% CHA, the flexural strength of the concrete increased across different RHA proportions. The highest flexural strength was achieved with a blend containing 15% RHA and 2.5% CHA.

# CHAPTER FIVE
# 5.CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

In conclusion, this study aimed to explore the properties of rice husk ash and coffee husk ash, the effects of using a combination of RHA and CHA to partially replace cement in workability of fresh concrete and mechanical properties of hardened concrete made from a cement partially replaced by hybrid of RHA and CHA.

RHA and CHA need to fulfill the ASTM C618 standards for their utilization as pozzolans in concrete manufacturing. The chemical composition of RHA and CHA should consist of a minimum of 70% combined Silicon Dioxide ($SiO_2$), aluminum oxide ($Al_2O_3$), and iron oxide ($Fe_2O_3$) from the result obtained, both ashes have satisfied the requirement. According to ASTM, the loss on ignition (LOI) must not surpass 10%. Typically, Class F pozzolans, with an LOI of up to 12%, are commonly employed and the loss on ignition observed on both ashes were less than 10%. The alkali content, specifically $Na_2O$, should not exceed 1.5% in accordance with ASTM C618 and both ashes have satisfied it. In cement, the magnesium oxide (MgO) content, derived from magnesia compounds in raw materials, typically ranges from 0.1% to 4%, with 5% being the upper limit to prevent expansion in hardened concrete and both RHA and CHA satisfies this requirement.

Among the various combinations tested, the highest performance of compressive strength, flexural strength and spilitting tensile strength was observed with a mixture containing 15% RHA and 2.5% CHA.

Although the partial replacement of cement with hybrid of RHA and CHA improved the results of mechanical properties of hardened concrete, the workability of the fresh concrete has reduced while replacing the cement with the hybrid ash.

Moreover, these findings provide valuable insights for future research and advancements in the field of sustainable construction materials.

In conclusion, this study demonstrates the potential benefits of incorporating RHA and CHA as partial replacements for cement in concrete.

## 5.2 Recommendations Of The Study

Based on the findings of this study, the following recommendations has been set to enhance the use of RHA and CHA in concrete.

1. Further research is needed to explore the optimal proportions of RHA and CHA for different concrete applications. This research should focus on understanding their effects on concrete properties and improving overall concrete performance. By investigating a wider range of proportions and their impact on various concrete properties, a more comprehensive understanding can be gained.
2. Standardization is crucial to ensure consistent and reliable use of RHA and CHA as cement replacements in concrete. Developing guidelines or specifications for their application will provide clear instructions for construction professionals, making it easier for them to incorporate RHA and CHA into concrete mixtures effectively.
3. Field testing and durability studies should be conducted to assess the long term performance of concrete mixtures containing RHA and CHA. By subjecting these mixtures to real world conditions, their ability to withstand environmental factors and ensure long lasting durability can be evaluated. This will provide valuable insights for their practical use in sustainable construction practices.
4. Disseminating the findings of this study to industry professionals, engineers, and researchers is crucial. Sharing the benefits and potential applications of RHA and CHA through conferences, publications, and workshops will raise awareness and encourage their adoption in the construction industry.

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# APPENDIX-1

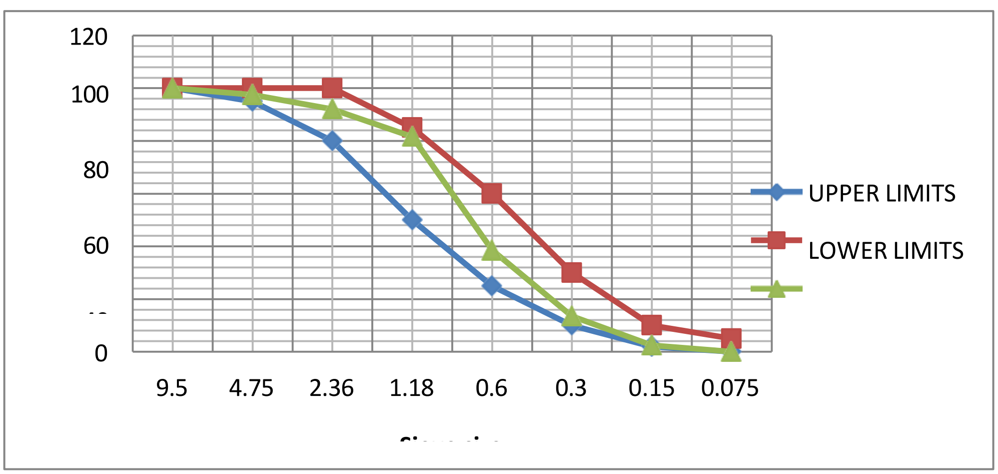
**Laboratory data sheet for material property**

**Test Place: ECWC Production center's Lab**

## 1. Fine aggregate

### I. Sieve analysis

| Sieve sample | Sieve Dia | Mass of retaining(Kg) | % of retaining | Cumulative retaining | Cumulative % passing | ASTM C 33 standard upper and lower limit | Remark |
|---|---|---|---|---|---|---|---|
| | 9.5 | 0 | 0 | 0 | 100 | 100 | ok |
| 4 | 4.75 | 0.05 | 2.5 | 2.5 | 97.5 | 95 - 100 | ok |
| 8 | 2.36 | 0.109 | 5.45 | 7.95 | 92.05 | 80 - 100 | ok |
| 16 | 1.18 | 0.209 | 10.45 | 18.4 | 81.6 | 50 - 85 | ok |
| 30 | 0.6 | 0.861 | 43.05 | 61.45 | 38.55 | 25 - 60 | ok |
| 50 | 0.3 | 0.509 | 25.45 | 86.9 | 13.1 | 10- 30 | ok |
| 100 | 0.15 | 0.212 | 10.6 | 97.5 | 2.5 | 2 -10 | ok |
| 200 | 0.075 | 0.05 | 2.5 | 100 | 0 | 0-5 | ok |
| pan | | 0 | 0 | | | | |



II. **Specific gravity and absorption test result for Fine Aggregate**

| **Description** | **Measurement in (kg)** | | | **Mean of the result** |
|---|---|---|---|---|
| | **sample 1** | **sample 2** | **sample 3** | |
| D. Mass of Oven Dry Sample in Air | 0.492 | 0.489 | 0.492 | _ |
| A .Mass of Saturated Surface dry sample in air | 0.5 | 0.5 | 0.5 | _ |
| B. Mass of Flask + Water | 1.5 | 1.5 | 1.5 | _ |
| C. Mass of Flask + Water + Sample | 1.82 | 1.83 | 1.79 | _ |
| **Absorption** = (0.5-D)/D)*100 | 1.63 | 2.25 | 1.63 | 1.83 |
| **Apparent Specific Gravity** =D/(B+D-C) | 2.86 | 3.08 | 2.44 | 2.79 |
| **Bulk Specific Gravity** = D/B+0.5-C | 2.73 | 2.88 | 2.34 | 2.65 |
| **Bulk Specific Gravity** ( Saturated surface dry basis ) = 0.5/B+0.5-C | 2.78 | 2.94 | 2.38 | 2.6 |

**III. Silt content of Fine Aggregate**

| **Description** | **Measurement (Kg)** | | |
|---|---|---|---|
| | **sample 1** | **sample 2** | **sample 3** |
| A. Weight of sample | 1 | 1 | 1 |
| B. weight of oven dry sample after washing | 0.973 | 0.968 | 0.97 |
| Silt content % = ( A-B)/A*100 | 2.7 | 3.2 | 3 |
| **MEAN OF SILT CONTENT** | **2.97** | | |

### IV. Moisture content

| Description | Measurement ( Kg) | | |
|---|---|---|---|
| | sample 1 | sample 2 | sample 3 |
| A. weight of original sample | 0.5 | 0.5 | 0.5 |
| B. weight of oven dry sample | 0.482 | 0.491 | 0.498 |
| moisture content % (w%)= ( ( A-B)/B)*100 | 3.73 | 1.83 | 0.40 |
| **MEAN MOISTURE CONTENT** | **1.99** | | |

### V. Bulk unit weight test result for fine aggregate

| Description | Measurement | | |
|---|---|---|---|
| | sample 1 | sample 2 | sample 3 |
| D. Weight of sample = B-A (Kg) | 7.219 | 7.23 | 7.055 |
| A. Weight of container | 1.6 | 1.6 | 1.6 |
| B. Weight of container + sample | 8.819 | 8.83 | 8.655 |
| C Volume of container ($m^3$) | 0.005 | 0.005 | 0.005 |
| Unit weight = D/C | 1443.8 | 1446.0 | 1411.0 |
| **Mean unit weight ( $Kg/m^3$ )** | **1433.60** | | |

### VI. Fineness Modulas of sand

| Sieve size Total | Percent retained (X) | Y =100-X |
|---|---|---|
| 9.5 mm (3/8 in.) | 0 | |
| 4.75 mm (No. 4) | 98 | 2 |
| 2.36 mm (No. 8) | 89.65 | 10.35 |
| 1.18 mm (No. 16) | 69.15 | 30.85 |
| 600 mm (No. 30) | 52.65 | 47.35 |
| 300 mm (No. 50) | 17.6 | 82.4 |
| 150 mm (No. 100) | 2.7 | 97.3 |
| Sum = ∑ Y | | 270.25 |
| FM= ∑ Y /100 = 2.7 | | |

2. **Coarse Aggregate**

**I. Specific gravity and absorption test result for course aggregate**

| Description | variable | weight of sample in kg | | | Mean |
|---|---|---|---|---|---|
| | | sample 1 | sample 2 | sample 3 | |
| Weight in water of the saturated aggregate (Ww) = Wa-Wb | Mw | 1.2 | 1.3 | 1.3 | |
| weight in air of the saturated surface dry aggregate | MSSD | 2 | 1.99 | 1.99 | |
| weight in air of oven dried aggregate | MD | 1.988 | 1.979 | 1.985 | |
| Apparent specific gravity | MD /(MD-MW) | 2.52 | 2.91 | 2.90 | 2.78 |
| Bulk specific gravity (oven dry basis ) | MD/(MSSD-Mw) | 2.49 | 2.87 | 2.88 | 2.74 |
| Bulk specific gravity (sat. surf, dry basis ) | MSSD/(MSSD-Mw) | 2.50 | 2.88 | 2.88 | 2.76 |
| % water Absorption | ((MSSD-MD)/MD)*100 | 0.60 | 0.56 | 0.25 | 0.47 |

II. **Moisture content test result for course aggregate**

| **Description** | **Measurement** | | |
|---|---|---|---|
| | **sample 1** | **sample 2** | **sample 3** |
| A. weight of original sample | 2 | 2 | 2 |
| B .weight of oven dry sample | 1.985 | 1.98 | 1.985 |
| moisture content % (w%)= ( ( A-B) / B) *100 | 0.76 | 1.01 | 0.76 |
| **MEAN MOISTURE CONTENT** | **0.84** | | |

III. **Bulk unit weight test result for course aggregate**

| **Description** | **weight of sample in kg** | | |
|---|---|---|---|
| | **sample 1** | **sample 2** | **sample 3** |
| A .weight of container | 1.695 | 1.695 | 1.695 |
| B. weight of container + weight of sample | 16.1 | 16.31 | 16.01 |
| Weight of sample = B - A | 14.405 | 14.615 | 14.315 |
| C. volume of container m3 | 0.01 | 0.01 | 0.01 |
| unit weight (kg/m3) = (B-A)/c | 1440.5 | 1461.5 | 1431.5 |
| **Mean unit weight** | **1444.5** | | |

# APPENDIX-2

**Laboratory Test Result for Slump, Compressive Strength, Flexural Strength, and Spilitting Tensile Strength**

**Test Place: ECWC Central Laboratory**

1. **Test Results of Compressive Strength Tests**

| | | |
|---|---|---|
| ECWC ENGINEERING CENTRAL LABORATORY | Company Name: የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን ETHIOPIAN CONSTRUCTION WORKS CORPORATION | Document No: OF/ECWC/LAB/016 |
| ISSUE No:1 | Document title: Concrete Compressive strength Test Result | Page No.: 1 of1 |

PROJECT : Final Research
CLIENT Naol Bekele Amente
SAMPLE OF: Concrete Cube Samples
DATE SAMPLE : 09/06/2023
TEST REQUESTED: C-25 Compressive Strength Test
Date Reported: 07/07/2023

ASTM C-39

| | |
|---|---|
| SPECIMEN CODE | CSp-1 |
| RHA | 0% |
| CHA | 0% |
| Slump value (mm) | 100 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, Kg/m$^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 07/07/2023 | 28 | 0.15 | 0.15 | 0.15 | 2430 | 25.50 | 3698 |
| 2 | 09/06/2023 | 07/07/2023 | 28 | 0.15 | 0.15 | 0.15 | 2430 | 25.59 | 3711 |
| 3 | 09/06/2023 | 07/07/2023 | 28 | 0.15 | 0.15 | 0.15 | 2430 | 25.63 | 3717 |
| | | | | | | AVG. | **2430** | **25.58** | **3708** |

Reported by:
Sign.
Date. 20-07-2023
Wossen Tadesse
Crew Head

Checked by:
Sign.
Date. 20-07-23
Behayilu Kebede
Team Leader (ME)

Approved by:
Sign.

| ECWC ENGINEERING CENTRAL LABORATORY | Company Name: የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን ETHIOPIAN CONSTRUCTION WORKS CORPORATION | Document No: OF/ECWC/LAB/016 |
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| | |
|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| | Date Reported: 21/07/2023 |

ASTM C-39

| | |
|---|---|
| SPECIMEN CODE | CSp-2 |
| RHA | 5% |
| CHA | 0% |
| Slump value (mm) | 90 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, Kg/m³ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 28.31 | 4106 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 28.24 | 4094 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 28.10 | 4074 |
| | | | | | | AVG. | **2400** | **28.22** | **4091** |

| | |
|---|---|
| SPECIMEN CODE | CSp-3 |
| RHA | 10% |
| CHA | 0% |
| Slump value (mm) | 85 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, Kg/m³ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2409 | 28.36 | 4112 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2406 | 28.27 | 4099 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2406 | 28.31 | 4106 |
| | | | | | | AVG. | **2407** | **28.31** | **4106** |

Reported by:

Sign.

Date. 21/07/2023

Wossen Tadesse
Crew Head

Checked by:

Sign.

Date. 20-07-23

Behayilu Kebede
Team Leader (ME)

Engineering Central Laboratory ECL

Approved by:

Construction Works & Materials Laboratory Service Head

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| | |
|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| | Date Reported: 21/07/2023 |

ASTM C-39

| | |
|---|---|
| SPECIMEN CODE | CSp-4 |
| RHA | 15% |
| CHA | 0% |
| Slump value (mm) | 80 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2409 | 28.36 | 4112 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2410 | 28.40 | 4118 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2409 | 28.44 | 4124 |
| | | | | | | AVG. | **2409** | **28.40** | **4118** |

| | |
|---|---|
| SPECIMEN CODE | CSp-5 |
| RHA | 20% |
| CHA | 0% |
| Slump value (mm) | 70 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2406 | 27.02 | 3917 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2409 | 27.06 | 3924 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2409 | 26.97 | 3911 |
| | | | | | | AVG. | **2408** | **27.02** | **3917** |

Reported by:
Sign.
Date 21/07/2024
Wossen Tadesse
Crew Head

Checked by:
Sign.
Date. 20-07-23
Behayilu Kebede
Team Leader (ME)

Approved by:
Engineering Central Laboratory ECL
Behailu Melaku
Construction Works & Materials Laboratory Service Head

| | Company Name: | Document No: |
|---|---|---|
| ECWC ENGINEERING CENTRAL LABORATORY | የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን<br>ETHIOPIAN CONSTRUCTION WORKS CORPORATION | OF/ECWC/LAB/016 |
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| | |
|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| | Date Reported: 21/07/2023 |

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ASTM C-39

| | |
|---|---|
| SPECIMEN CODE | CSp-6 |
| RHA | 25% |
| CHA | 0% |
| Slump value (mm) | 55 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2409 | 25.76 | 3736 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2410 | 25.76 | 3736 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2409 | 25.81 | 3742 |
| | | | | | | AVG. | **2409** | **25.78** | **3738** |

| | |
|---|---|
| SPECIMEN CODE | CSp-7 |
| RHA | 0% |
| CHA | 2.50% |
| Slump value (mm) | 80 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2415 | 28.01 | 4062 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2415 | 27.97 | 4055 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2415 | 28.01 | 4062 |
| | | | | | | AVG. | **2415** | **28.00** | **4060** |

| Reported by: | Checked by: | Approved by: |
|---|---|---|
| Sign. | Sign. | |
| Date. 21/07/2023 | Date. 21-07-23 | |
| Wossen Tadesse | Behayilu Kebede | Behailu Melaku |

Engineering Central Laboratory ECL

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|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| | Date Reported: 21/07/2023 |

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| | |
|---|---|
| SPECIMEN CODE | CSp-8 |
| RHA | 5% |
| CHA | 2.50% |
| Slump value (mm) | 75 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2418 | 28.24 | 4094 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2418 | 28.18 | 4087 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2421 | 28.23 | 4093 |
| | | | | | | AVG. | **2419** | **28.22** | **4091** |

| | |
|---|---|
| SPECIMEN CODE | CSp-9 |
| RHA | 10% |
| CHA | 2.50% |
| Slump value (mm) | 65 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2424 | 28.36 | 4112 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2424 | 28.36 | 4112 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2424 | 28.23 | 4093 |
| | | | | | | AVG. | **2424** | **28.31** | **4106** |

Reported by:
Sign.
Date. 21/07/2023
Wossen Tadesse

Checked by:
Sign.
Date. 21-07-23
Behayilu Kebede

Approved by:
Engineering Central Laboratory ECL
Behailu Melaku
Construction Works & Materials Laboratory Service Head

| | Company Name: | Document No: |
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| | |
|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| | Date Reported: 21/07/2023 |

ASTM C-39

| | |
|---|---|
| SPECIMEN CODE | CSp-10 |
| RHA | 15% |
| CHA | 2.50% |
| Slump value (mm) | 60 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2412 | 28.66 | 4156 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2412 | 28.66 | 4156 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2412 | 28.53 | 4137 |
| | | | | | | AVG. | **2412** | **28.62** | **4150** |

| | |
|---|---|
| SPECIMEN CODE | CSp-11 |
| RHA | 20% |
| CHA | 2.50% |
| Slump value (mm) | 60 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2427 | 27.75 | 4024 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2424 | 27.80 | 4030 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2424 | 27.80 | 4030 |
| | | | | | | AVG. | **2425** | **27.78** | **4028** |

Reported by:
Sign.
Date. 21/07/2023
Wossen Tadesse
Crew Head

Checked by:
Sign.
Date. 21-07-23
Behayilu Kebede
Team Leader (ME)

Engineering Central Laboratory
ECL

Approved by:
Behailu Meleku

6

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|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| Date Reported: | 21/07/2023 |

ASTM C-39

| | |
|---|---|
| SPECIMEN CODE | CSp-12 |
| RHA | 25% |
| CHA | 2.50% |
| Slump value (mm) | 55 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 26.71 | 3874 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 26.71 | 3874 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 26.58 | 3855 |
| | | | | | | AVG. | **2400** | **26.67** | **3867** |

| | |
|---|---|
| SPECIMEN CODE | CSp-13 |
| RHA | 0% |
| CHA | 3.50% |
| Slump value (mm) | 75 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 26.58 | 3855 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 26.71 | 3874 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 26.71 | 3874 |
| | | | | | | AVG. | **2400** | **26.67** | **3867** |

Reported by:
Sign.
Date. 21-07-2023
Wossen Tadesse
Crew Head

Checked by:
Sign.
Date. 21-07-23
Behayilu Kebede
Team Leader (ME)

Engineering Central Laboratory ECL

Approved by:

| ECWC ENGINEERING CENTRAL LABORATORY | Company Name: የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን ETHIOPIAN CONSTRUCTION WORKS CORPORATION | Document No: OF/ECWC/LAB/016 |
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|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| | Date Reported: 21/07/2023 |

ASTM C-39

| | |
|---|---|
| SPECIMEN CODE | CSp-14 |
| RHA | 5% |
| CHA | 3.50% |
| Slump value (mm) | 68 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2403 | 26.50 | 3842 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2403 | 26.80 | 3886 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2403 | 26.84 | 3892 |
| | | | | | | AVG. | **2403** | **26.71** | **3874** |

| | |
|---|---|
| SPECIMEN CODE | CSp-15 |
| RHA | 10% |
| CHA | 3.50% |
| Slump value (mm) | 65 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2403 | 26.71 | 3874 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 26.67 | 3867 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 26.63 | 3861 |
| | | | | | | AVG. | **2401** | **26.67** | **3867** |

8

Reported by:
Sign.
Date. 21/07/2023
Wossen Tadesse
Crew Head

Checked by:
Sign.
Date. 21-07-23
Behayilu Kebede
Team Leader (ME)

Engineering Central Laboratory
ECL

Approved by:

| ECWC ENGINEERING CENTRAL LABORATORY | Company Name: የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን ETHIOPIAN CONSTRUCTION WORKS CORPORATION | Document No: OF/ECWC/LAB/016 |
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|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| | Date Reported: 21/07/2023 |

ASTM C-39

| | |
|---|---|
| SPECIMEN CODE | CSp-16 |
| RHA | 15% |
| CHA | 3.50% |
| Slump value (mm) | 60 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2418 | 26.20 | 3798 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2418 | 26.20 | 3798 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2418 | 26.28 | 3811 |
| | | | | | | AVG. | **2418** | **26.22** | **3803** |

| | |
|---|---|
| SPECIMEN CODE | CSp-17 |
| RHA | 20% |
| CHA | 3.50% |
| Slump value (mm) | 50 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 25.63 | 3717 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 25.85 | 3748 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 25.85 | 3748 |
| | | | | | | AVG. | **2400** | **25.78** | **3738** |

9

Reported by:

Sign.

Date. 21/07/2023

Wossen Tadesse
Crew Head

Checked by:

Sign.

Date. 21-07-23

Behayilu Kebede
Team Leader (ME)

Engineering Central Laboratory ECL

Approved by:

Behailu Melaku
Construction Works & Materials Laboratory Service Head

| | Company Name: | Document No: |
|---|---|---|
| ECWC<br>ENGINEERING CENTRAL LABORATORY | የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን<br>ETHIOPIAN CONSTRUCTION WORKS CORPORATION | OF/ECWC/LAB/016 |
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|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| | Date Reported: 21/07/2023 |

ASTM C-39

| | |
|---|---|
| SPECIMEN CODE | CSp-18 |
| RHA | 25% |
| CHA | 3.50% |
| Slump value (mm) | 50 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, Kg/m$^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2370 | 24.47 | 3547 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2370 | 24.47 | 3547 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2370 | 24.38 | 3535 |
| | | | | | | AVG. | **2370** | **24.44** | **3543** |

| | |
|---|---|
| SPECIMEN CODE | CSp-19 |
| RHA | 0% |
| CHA | 5.00% |
| Slump value (mm) | 75 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, Kg/m$^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 25.85 | 3748 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 25.85 | 3748 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 25.63 | 3717 |
| | | | | | | AVG. | **2400** | **25.78** | **3738** |

Reported by:

Sign.

Date. 21/07/2023

Wossen Tadesse
Crew Head

Checked by:

Sign.

Date. 21-07-23

Behayilu Kebede
Team Leader (ME)

Engineering Central Laboratory
ECL

Approved by:

10

| ECWC ENGINEERING CENTRAL LABORATORY | Company Name: የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን ETHIOPIAN CONSTRUCTION WORKS CORPORATION | Document No: OF/ECWC/LAB/016 |
|---|---|---|
| ISSUE No:1 | Document title: **Concrete Compressive strength Test Result** | Page No.: 1 of1 |

| | |
|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| | Date Reported: 21/07/2023 |

ASTM C-39

| SPECIMEN CODE | CSp-20 |
|---|---|
| RHA | 5% |
| CHA | 5.00% |
| Slump value (mm) | 70 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2415 | 26.28 | 3811 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2415 | 26.37 | 3823 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2415 | 26.28 | 3811 |
| | | | | | | AVG. | **2415** | **26.31** | **3815** |

| SPECIMEN CODE | CSp-21 |
|---|---|
| RHA | 10% |
| CHA | 5.00% |
| Slump value (mm) | 65 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2415 | 26.41 | 3830 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2415 | 26.45 | 3836 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2415 | 26.45 | 3836 |
| | | | | | | AVG. | **2415** | **26.44** | **3834** |

Reported by:

Sign.

Date. 21/07/2023

Wossen Tadesse
Crew Head

Checked by:

Sign.

Date. 21-07-23

Behayilu Kebede
Team Leader (ME)

Engineering Central Laboratory ECL

Approved by:

Behailu Melaku
Construction Works & Materials Laboratory Service Head

| | Company Name: | Document No: |
|---|---|---|
| ECWC ENGINEERING CENTRAL LABORATORY | የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን<br>ETHIOPIAN CONSTRUCTION WORKS CORPORATION | OF/ECWC/LAB/016 |
| | Document title: | Page No.: |
| ISSUE No:1 | **Concrete Compressive strength Test Result** | 1 of1 |

| | |
|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| | Date Reported: 21/07/2023 |

ASTM C-39

| | |
|---|---|
| SPECIMEN CODE | CSp-22 |
| RHA | 15% |
| CHA | 5.00% |
| Slump value (mm) | 60 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2418 | 26.71 | 3874 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2418 | 26.63 | 3861 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2418 | 26.67 | 3867 |
| | | | | | | AVG. | **2418** | **26.67** | **3867** |

| | |
|---|---|
| SPECIMEN CODE | CSp-23 |
| RHA | 20% |
| CHA | 5.00% |
| Slump value (mm) | 55 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2412 | 25.98 | 3767 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2412 | 25.98 | 3767 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2412 | 25.94 | 3761 |
| | | | | | | AVG. | **2412** | **25.96** | **3765** |

Reported by:

Sign. 21/07/2023

Date.

Wossen Tadesse
Crew Head

Checked by:

Sign.

Date. 21-07-23

Behayilu Kebede
Team Leader (ME)

Engineering Central Laboratory ECL

Approved by:

Behailu Melaku
Construction Works & Materials Laboratory Service Head

| | Company Name: | Document No: |
|---|---|---|
| ECWC ENGINEERING CENTRAL LABORATORY | የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን<br>ETHIOPIAN CONSTRUCTION WORKS CORPORATION | OF/ECWC/LAB/016 |
| | Document title: | Page No.: |
| ISSUE No:1 | Concrete Compressive strength Test Result | 1 of1 |

| | |
|---|---|
| PROJECT : | Final Research |
| CLIENT | Naol Bekele Amente |
| SAMPLE OF: | Concrete Cube Samples |
| DATE SAMPLE : | 09/06/2023 |
| TEST REQUESTED: | C-25 Compressive Strength Test |
| | Date Reported: 07/07/2023 |

ASTM C-39

| | |
|---|---|
| SPECIMEN CODE | CSp-24 |
| RHA | 25% |
| CHA | 5% |
| Slump value (mm) | 45 |

| Marking | Date | | Age in Days | Dimension - m | | | Unit Weight, $Kg/m^3$ | Compressive Strength | |
|---|---|---|---|---|---|---|---|---|---|
| | Poured | Tested | | L | W | H | | Mpa | PSI |
| 1 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 25.76 | 3736 |
| 2 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 25.68 | 3723 |
| 3 | 09/06/2023 | 21/07/2023 | 45 | 0.15 | 0.15 | 0.15 | 2400 | 25.63 | 3717 |
| | | | | | | AVG. | **2400** | **25.69** | **3725** |

Reported by:

Sign.

Date. 21/07/2023

Wossen Tadesse
Crew Head

Checked by:

Sign.

Date. 21-07-23

Behayilu Kebede
Team Leader (ME)

Engineering Central Laboratory
ECL

Approved by:

Behailu Melaku
Construction Works & Materials Laboratory Service Head

## 2. Test Results of Flexural Strength Tests

| ECWC ENGINEERING CENTRAL LABORATORY | Company Name: | Document No: |
|---|---|---|
| | የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን<br>ETHIOPIAN CONSTRUCTION WORKS CORPORATION | OF/ECWC/LAB/017 |
| ISSUE NO:1 | Document title | Page No |
| | Flexural Strength Test | 1 of 3 |

Project: Final Research

Client: Naol Bekele Amente

Material Type: Concrete Beam (45cmx10cmx10cm)

Test Requested: Flexural Strength Test (Test Method : ( ASTM C78 )

Reported On: 20/07/2023

| Code | RHA | CHA | Poured Date | Test Date | Age | Dimensions - mm | | | Flexural Strength | | AVERAGE ( MPA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | L | W | H | MPA | PSI | |
| Fb-1 | 0% | 0% | 08/06/2023 | 06/07/2023 | 28 | 450 | 100 | 100 | 3.25 | 471.25 | 3.25 |
| | | | | | | | | | 3.23 | 468.35 | |
| | | | | | | | | | 3.26 | 472.70 | |
| Fb-2 | 5% | 0% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.39 | 491.55 | 3.39 |
| | | | | | | | | | 3.41 | 494.45 | |
| | | | | | | | | | 3.38 | 490.10 | |
| Fb-3 | 10% | 0% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.40 | 493.00 | 3.40 |
| | | | | | | | | | 3.39 | 491.55 | |
| | | | | | | | | | 3.41 | 494.45 | |
| Fb-4 | 15% | 0% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.41 | 494.45 | 3.41 |
| | | | | | | | | | 3.43 | 497.35 | |
| | | | | | | | | | 3.39 | 491.55 | |
| Fb-5 | 20% | 0% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.24 | 469.80 | 3.24 |
| | | | | | | | | | 3.22 | 466.90 | |
| | | | | | | | | | 3.25 | 471.25 | |
| Fb-6 | 25% | 0% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.09 | 448.05 | 3.10 |
| | | | | | | | | | 3.09 | 448.05 | |
| | | | | | | | | | 3.11 | 450.95 | |
| Fb-7 | 0% | 2.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.92 | 568.40 | 3.92 |
| | | | | | | | | | 3.93 | 569.85 | |
| | | | | | | | | | 3.90 | 565.50 | |
| Fb-8 | 5% | 2.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.95 | 572.75 | 3.95 |
| | | | | | | | | | 3.93 | 569.85 | |
| | | | | | | | | | 3.96 | 574.20 | |

Reported by:

Sign.

Date.

Wossen Tadesse
Crew Head

Checked by:

Sign.

Date. 21-07-23

Behayilu Kebede
Team Leader (ME)

Approved by:

| ECWC ENGINEERING CENTRAL LABORATORY | Company Name: የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን ETHIOPIAN CONSTRUCTION WORKS CORPORATION | Document No; OF/ECWC/LAB/017 |
|---|---|---|
| ISSUE NO:1 | Document title: Flexural Strength Test | Page No 2 of 3 |

Project: Final Research
Client: Naol Bekele Amente
Material Type: Concrete Beam (45cmx10cmx10cm)
Test Requested: Flexural Strength Test (Test Method : ( ASTM C78 )

Reported On: 20/07/2023

| Code | RHA | CHA | Poured Date | Test Date | Age | Dimensions - mm | | | Flexural Strength | | AVERAGE (MPA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | L | W | H | MPA | PSI | |
| Fb-9 | 10% | 2.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.97 | 575.65 | 3.97 |
| | | | | | | | | | 3.95 | 572.75 | |
| | | | | | | | | | 3.98 | 577.10 | |
| Fb-10 | 15% | 2.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 4.01 | 581.45 | 4.01 |
| | | | | | | | | | 4.02 | 582.90 | |
| | | | | | | | | | 4.01 | 581.45 | |
| Fb-11 | 20% | 2.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.89 | 564.05 | 3.89 |
| | | | | | | | | | 3.91 | 566.95 | |
| | | | | | | | | | 3.87 | 561.15 | |
| Fb-12 | 25% | 2.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.73 | 540.85 | 3.73 |
| | | | | | | | | | 3.72 | 539.40 | |
| | | | | | | | | | 3.75 | 543.75 | |
| Fb-13 | 0% | 3.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.20 | 464.00 | 3.20 |
| | | | | | | | | | 3.20 | 464.00 | |
| | | | | | | | | | 3.21 | 465.45 | |
| Fb-14 | 5% | 3.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.21 | 465.45 | 3.20 |
| | | | | | | | | | 3.21 | 465.45 | |
| | | | | | | | | | 3.19 | 462.55 | |
| Fb-15 | 10% | 3.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.20 | 464.00 | 3.20 |
| | | | | | | | | | 3.18 | 461.10 | |
| | | | | | | | | | 3.21 | 465.45 | |
| Fb-16 | 15% | 3.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.15 | 456.75 | 3.15 |
| | | | | | | | | | 3.18 | 461.10 | |
| | | | | | | | | | 3.13 | 453.85 | |

Reported by:
Sign.
Date.
Wossen Tadesse
Crew Head

Checked by:
Sign.
Date. 21-07-23
Behayilu Kebede
Team Leader (ME)

Approved by:

| ECWC ENGINEERING CENTRAL LABORATORY | Company Name: ዮኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን ETHIOPIAN CONSTRUCTION WORKS CORPORATION | Document No; OF/ECWC/LAB/017 |
|---|---|---|
| ISSUE NO:1 | Document title: Flexural Strength Test | Page No 3 of 3 |

Project: Final Research
Client: Naol Bekele Amente
Material Type: Concrete Beam (45cmx10cmx10cm)
Test Requested: Flexural Strength Test (Test Method : ( ASTM C78 )

Reported On: 20/07/2023

| Code | RHA | CHA | Poured Date | Test Date | Age | Dimensions - mm | | | Flexural Strength | | AVERAGE (MPA) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | L | W | H | MPA | PSI | |
| Fb-17 | 20% | 3.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 3.10 | 449.50 | 3.09 |
| | | | | | | | | | 3.08 | 446.60 | |
| | | | | | | | | | 3.10 | 449.50 | |
| Fb-18 | 25% | 3.50% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 2.93 | 424.85 | 2.93 |
| | | | | | | | | | 2.90 | 420.50 | |
| | | | | | | | | | 2.95 | 427.75 | |
| Fb-19 | 0% | 5% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 2.86 | 414.70 | 2.84 |
| | | | | | | | | | 2.84 | 411.80 | |
| | | | | | | | | | 2.83 | 410.35 | |
| Fb-20 | 5% | 5% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 2.89 | 419.05 | 2.89 |
| | | | | | | | | | 2.92 | 423.40 | |
| | | | | | | | | | 2.87 | 416.15 | |
| Fb-21 | 10% | 5% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 2.90 | 420.50 | 2.91 |
| | | | | | | | | | 2.90 | 420.50 | |
| | | | | | | | | | 2.92 | 423.40 | |
| Fb-22 | 15% | 5% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 2.95 | 427.75 | 2.93 |
| | | | | | | | | | 2.93 | 424.85 | |
| | | | | | | | | | 2.90 | 420.50 | |
| Fb-23 | 20% | 5% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 2.86 | 414.70 | 2.86 |
| | | | | | | | | | 2.85 | 413.25 | |
| | | | | | | | | | 2.87 | 416.15 | |
| Fb-24 | 25% | 5% | 08/06/2023 | 20/07/2023 | 45 | 450 | 100 | 100 | 2.85 | 413.25 | 2.83 |
| | | | | | | | | | 2.83 | 410.35 | |
| | | | | | | | | | 2.80 | 406.00 | |

Reported by:
Sign.
Date.
Wossen Tadesse
Crew Head

Checked by:
Sign.
Date. 21-07-23
Behayilu Kebede
Team Leader (ME)

Engineering Central Laboratory ECL

Approved by:

## 3. Test Results for Spilitting Tensile Strength and Slump Tests

| ECWC | Company Name: የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን ETHIOPIAN CONSTRUCTION WORKS CORPORATION | Document No: OF/ECWC/LAB/017 |
|---|---|---|
| ISSUE NO:1 | Document title: Splitting Tensile Strength Test | Page No 1 of 3 |

| | |
|---|---|
| Project | Final Research |
| Client | Naol Bekele Amente |
| Material Type | Concrete Cylinderical (15cmx30cm) |
| Test Requested | Splitting Tensile Strength Test (Test Method : ( ASTM C496 ) |
| | Reported On: 20/07/2023 |

| Code | RHA | CHA | Poured Date | Test Date | Age | Dimensions - mm | | Splitting Tensile Strength | | AVERAGE (MPA) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ø | H | MPA | PSI | |
| SC-1 | 0% | 0% | 07/06/2023 | 05/07/2023 | 28 | 150 | 300 | 2.96 | 429.20 | 2.98 |
| | | | | | | | | 2.98 | 432.10 | |
| | | | | | | | | 2.99 | 433.55 | |
| SC-2 | 5% | 0% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.13 | 453.85 | 3.10 |
| | | | | | | | | 3.10 | 449.50 | |
| | | | | | | | | 3.08 | 446.60 | |
| SC-3 | 10% | 0% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.10 | 449.50 | 3.10 |
| | | | | | | | | 3.11 | 450.95 | |
| | | | | | | | | 3.10 | 449.50 | |
| SC-4 | 15% | 0% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.13 | 453.85 | 3.12 |
| | | | | | | | | 3.12 | 452.40 | |
| | | | | | | | | 3.10 | 449.50 | |
| SC-5 | 20% | 0% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 2.98 | 432.10 | 2.98 |
| | | | | | | | | 2.97 | 430.65 | |
| | | | | | | | | 2.98 | 432.10 | |
| SC-6 | 25% | 0% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 2.86 | 414.70 | 2.84 |
| | | | | | | | | 2.84 | 411.80 | |
| | | | | | | | | 2.83 | 410.35 | |
| SC-7 | 0% | 2.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.65 | 529.25 | 3.64 |
| | | | | | | | | 3.64 | 527.80 | |
| | | | | | | | | 3.62 | 524.90 | |
| SC-8 | 5% | 2.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.68 | 533.60 | 3.68 |
| | | | | | | | | 3.67 | 532.15 | |
| | | | | | | | | 3.70 | 536.50 | |

Reported by:

Sign.

Date. 19-07-2023

Wossen Tadesse
Crew Head

Checked by:

Sign.

Date.

Behailu Kebede
Team Leader (ME)

Approved by:

Behailu Melaku
Construction Works & Materials Laboratory
Service Head

Engineering Central Laboratory
ECL
ማዕከላዊ ምህንድስና ላቦራቶሪ

| | Company Name: | Document No; |
|---|---|---|
| ECWC | የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን<br>ETHIOPIAN CONSTRUCTION WORKS CORPORATION | OF/ECWC/LAB/017 |
| ISSUE NO:1 | Document title<br>Splitting Tensile Strength Test | Page No<br>2 of 3 |

Project: Final Research
Client: Naol Bekele Amente
Material Type: Concrete Cylinderical (15cmx30cm)
Test Requested: Splitting Tensile Strength Test (Test Method : ( ASTM C496 )

Reported On: 20/07/2023

| Code | RHA | CHA | Poured Date | Test Date | Age | Dimensions - mm | | Splitting Tensile Strength | | AVERAGE (MPA) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ø | H | MPA | PSI | |
| SC-9 | 10% | 2.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.70 | 536.50 | 3.69 |
| | | | | | | | | 3.69 | 535.05 | |
| | | | | | | | | 3.68 | 533.60 | |
| SC-10 | 15% | 2.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.75 | 543.75 | 3.72 |
| | | | | | | | | 3.72 | 539.40 | |
| | | | | | | | | 3.70 | 536.50 | |
| SC-11 | 20% | 2.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.62 | 524.90 | 3.61 |
| | | | | | | | | 3.61 | 523.45 | |
| | | | | | | | | 3.59 | 520.55 | |
| SC-12 | 25% | 2.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.50 | 507.50 | 3.47 |
| | | | | | | | | 3.47 | 503.15 | |
| | | | | | | | | 3.45 | 500.25 | |
| SC-13 | 0% | 3.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.22 | 466.90 | 3.20 |
| | | | | | | | | 3.20 | 464.00 | |
| | | | | | | | | 3.19 | 462.55 | |
| SC-14 | 5% | 3.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.23 | 468.35 | 3.21 |
| | | | | | | | | 3.21 | 465.45 | |
| | | | | | | | | 3.20 | 464.00 | |
| SC-15 | 10% | 3.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.22 | 466.90 | 3.20 |
| | | | | | | | | 3.20 | 464.00 | |
| | | | | | | | | 3.19 | 462.55 | |
| SC-16 | 15% | 3.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.17 | 459.65 | 3.15 |
| | | | | | | | | 3.15 | 456.75 | |
| | | | | | | | | 3.14 | 455.30 | |

Reported by:
Sign.
Date. 19-07-2023
Wossen Tadesse
Crew Head

Checked by:
Sign.
Date.
Behaylu Kebede
Team Leader (ME)

Approved by:
Behailu Melaku
Construction Works & Materials Laboratory Service Head

Engineering Central Laboratory
ECL

| | Company Name: | Document No; |
|---|---|---|
| ECWC | የኢትዮጵያ ኮንስትራክሽን ሥራዎች ኮርፖሬሽን<br>ETHIOPIAN CONSTRUCTION WORKS CORPORATION | OF/ECWC/LAB/017 |
| ISSUE NO:1 | Document title<br>Splitting Tensile Strength Test | Page No<br>3 of 3 |

Project: Final Research
Client: Naol Bekele Amente
Material Type: Concrete Cylinderical (15cmx30cm)
Test Requested: Splitting Tensile Strength Test (Test Method : ( ASTM C496 )

Reported On: 19/07/2023

| Code | RHA | CHA | Poured Date | Test Date | Age | Dimensions - mm | | Splitting Tensile Strength | | AVERAGE ( MPA) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ø | H | MPA | PSI | |
| SC-17 | 20% | 3.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 3.13 | 453.85 | 3.09 |
| | | | | | | | | 3.09 | 448.05 | |
| | | | | | | | | 3.06 | 443.70 | |
| SC-18 | 25% | 3.50% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 2.96 | 429.20 | 2.93 |
| | | | | | | | | 2.93 | 424.85 | |
| | | | | | | | | 2.90 | 420.50 | |
| SC-19 | 0% | 5% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 2.60 | 377.00 | 2.58 |
| | | | | | | | | 2.58 | 374.10 | |
| | | | | | | | | 2.56 | 371.20 | |
| SC-20 | 5% | 5% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 2.62 | 379.90 | 2.63 |
| | | | | | | | | 2.63 | 381.35 | |
| | | | | | | | | 2.65 | 384.25 | |
| SC-21 | 10% | 5% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 2.62 | 379.90 | 2.64 |
| | | | | | | | | 2.64 | 382.80 | |
| | | | | | | | | 2.65 | 384.25 | |
| SC-22 | 15% | 5% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 2.70 | 391.50 | 2.67 |
| | | | | | | | | 2.67 | 387.15 | |
| | | | | | | | | 2.65 | 384.25 | |
| SC-23 | 20% | 5% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 2.63 | 381.35 | 2.60 |
| | | | | | | | | 2.60 | 377.00 | |
| | | | | | | | | 2.57 | 372.65 | |
| SC-24 | 25% | 5% | 07/06/2023 | 19/07/2023 | 45 | 150 | 300 | 2.55 | 369.75 | 2.57 |
| | | | | | | | | 2.57 | 372.65 | |
| | | | | | | | | 2.58 | 374.10 | |

Reported by:
Sign.
Date. 19-07-2023
Wossen Tadesse
Crew Head

Checked by:
Sign.
Date.
Behayilu Kebede
Team Leader (ME)

Approved by:
Sohailu Melaku
Construction Works & Materials Laboratory Service Head

Engineering Central Laboratory
ECL
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# APPENDIX-3

**Laboratory Test Result for Oxide Combination of RHA and CHA /Complete Silicate Analysis Report**

**Test Place: Ethiopian Mineralogy & Geotechnical Laboratory of the Ethiopian Geological Survey**

## I. Test Result for Rice Husk Ash

| | GEOLOGICAL INSTITUTE OF ETHIOPIA | Doc. Number: GLD/F5.10.2 | Version No: 1 |
|---|---|---|---|
| | Geochemical Laboratory Desk | | Page 1of 1 |
| Document Title:- | Complete Silicate Analysis Report | Effective date: | Nov. 2022 |

Customer Name:- Naol Bekel A

Sample type :- Rice hask Ash

Sample Preparation: -200 Mesh

Date Submitted:- 18/07/2023

Issue Date:-07/09/2023

Request No:- GLD/RQ/1593/23

Report No:- GLD/RN/2248/23

Number of Sample:- One (01)

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

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

| Collector's code | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | MnO | $P_2O_5$ | $TiO_2$ | $H_2O$ | LOI | Weight of Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rice hask Ash | 75.22 | 1.16 | 0.06 | 1.44 | 1.68 | 1.04 | 2 | 0.08 | 3.83 | 0.04 | 5 | 8 | 1000 gm |

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

- LOI = Loss on Ignition

| Analysts | Checked By | Approved By | Quality Control |
|---|---|---|---|
| Haimanot Bayeh<br>Gadisa Wakuma<br>Nigist Fikadu | for Lidet Endeshaw | for Yohannes Getachew | Negash Worku |

Geochemical Laboratory Desk Page 1

## II. Test Result for Coffee Husk Ash

| GEOLOGICAL INSTITUTE OF ETHIOPIA | | Doc. Number: GLD/F5.10.2 | Version No: 1 |
|---|---|---|---|
| | Geochemical Laboratory Desk | | Page 1of 1 |
| Document Title:- | Complete Silicate Analysis Report | Effective date: | Nov. 2022 |

Customer Name:- Naol Bekel Amente

Sample type :- Coffee hask Ash

Sample Preparation: -200 Mesh

Date Submitted:- 18/07/2023

Issue Date:-07/09/2023

Request No:- GLD/RQ/1592/23

Report No:- GLD/RN/2247/23

Number of Sample:- One (01)

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

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

| Collector's code | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | MnO | $P_2O_5$ | $TiO_2$ | $H_2O$ | LOI | Weight of Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coffee hask Ash | 59.15 | 7.4 | 3.5 | 8.2 | 1.2 | 1.3 | 6.5 | 0.05 | 3.4 | 0.06 | 4 | 6 | 1000 gm |

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

- LOI = Loss on Ignition

| Analysts | Checked By | Approved By | Quality Control |
|---|---|---|---|
| Haimanot Bayeh | | | |
| Gadisa Wakuma | | | |
| Nigist Fikadu | for Lidet Endeshaw | for Yohannes Getachew | Negash Worku |