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INVESTIGATION ON PARTIAL REPLACEMENT OF CEMENT WITH SUGARCANE BAGASSE AND CATTLE BONE ASH FOR NORMAL STRENGTH CONCRETE

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BY

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By

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Construction Technology and Management

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Approval of thesis for defense result

I hereby confirm that the changes required by the examiners have been carried out and incorporated in the final thesis.

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This thesis work is dedicated

To

My Grandfather, Mr. Godebo Bololo (RIP)

My Uncle, Mr. Bekele Godebo (RIP)

And

My Son, Amen Temesgen

(2022)

DECLARATION

This is to certify that the thesis entitled " **Investigation on partial replacement of cement with sugarcane bagasse and cattle bone ash for normal strength concrete**" was Submitted in partial fulfilment of the requirements for the degree of Master of Science in Construction Technology and Management under the Faculty of Civil and Water Resource Engineering, Bahir Dar Institute of Technology is a record of original work carried out by me and has never been submitted to this or any other institution to get any other degree or certificates. The assistance and help I received during the course of this investigation have been duly acknowledged.

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i

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ABBREVIATIONS

ACI	American Concrete Institute
ASTM	American Standard Testing for Materials
CB	Cattle Bone
CBA	Cattle Bone Ash
CCW	Clock wise
CW	Counter clock wise
DTA	Differential Thermal Analysis
BCBA	Bagasse and Cattle Bone Ash
CSA	Complete Silicate Analysis
FDRE	Federal Democratic Republic of Ethiopia
FWHM	Full width at half maximum
FT-IR	Fourier Transform Infrared Spectroscopy
OD	Oven Dry
OPC	Ordinary Portland Cement
PPC	Pozzolana Portland Cement
SBA	Sugarcane Bagasse Ashe
SEM	Scanning Electron Microscope
SPSS	Statistical Package for Social Science
SSD	Saturated Surface Dry
TGA	Thermogravimetric Analysis
XRD	X-Ray Diffraction

LIST OF SYMBOLS

CO_2	Carbon di Oxide
C_2S	Dicalcium silicate
C_3S	Tricalcium Silicate
C_3A	Tricalcium aluminate
C_4AF	Tetra calcium aluminoferrite
MPa	Mega Pascal
℃	Degree Celsius
^oF	Degree Fahrenheit
θ	Theta (degree measurement)
β	Betha (degree measurement)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Cement is the primary ingredient in concrete, used to create pastes that strengthen the bond. The emission of CO_2 into the atmosphere has been considerably impacted by the manufacture of cement. Additionally, a lot of energy is required for production. On the other hand, wastes like sugarcane bagasse ash and cattle bones seriously harm the environment. Cattle bone wastes from slaughterhouses and sugarcane bagasse ash wastes collected from Wunji sugar factory have been used in this study. The main objective of the study was to use these waste products as a partial replacement for cement. The cattle bone was burned at a temperature of 900°c to produce the appropriate cementitious property of cattle bone ash. The temperature at which sugarcane bagasse ash burned was $700^o{}_C$. In this study, a qualitative research methodology was applied. Characterization of the SBA and CBA materials has been done using x-ray florescence (XRF). Since several researches consistently employed the same percentage, this research tends to use an equal amount of bagasse and cattle bone ash was added to the regular concrete mix after carrying out trial mixes for the amount of SBA and CBA and applied to the replacement percentages of 5%, 10%, 15%, and 20% by weight of cement. The results of compressive and tensile strength of cured concrete demonstrate that it is stronger when up to 10% of the cement is replaced with a mixture of bagasse and cattle bone ash. Concrete strength can be increased by adding combined bagasse and cattle bone ash to concrete. Additionally, using combined SBA and CBA in the cement will enhance the early strength attainment as a result of increasing the tricalcium silicate (C_3S) as the percentage increases from 0 to 20, while the compound dicalcium silicate (C_2S) which is responsible for the long-term strength of concrete decreases which results in the almost small change of concrete strength as the age of concrete increases. Micro-structural of concrete using XRD, SEM, FT-IR, TGA and DTA has been analyzed for a curing age of 28 days. The microstructural analysis of cement paste at 28 curing ages of concrete of BCBA-10 shows improved (C-S-H gel) which enhances and improved the compressive and tensile strength of concrete.

Key words: Cattle Bone Ash, Sugarcane Bagasse, Cement, Micro-Structural Property

CHAPTER ONE

1. INTRODUCTION

A significant sector of the economy that benefits developing, developed, and underdeveloped nations is the construction industry. In the modern world, this industry makes the best use of resources by utilizing a variety of resources to wear these aesthetic appearances. These days, the fundamental feature of managing building projects is thought to be the usage of these resources. The world's construction sector has advanced significantly, which is advantageous for everyone working in it and related fields every day. Utilizing resources effectively is necessary for building projects to be cost-effective. Although there are many other resources utilized in construction projects, the primary resources include materials like cement, steel, wood, plastic, etc.

1.1. Background of Study

Concrete is made up of composite materials including water, cement, coarse aggregate, and fine aggregate. Due to its role as a binding agent, cement is becoming more important in the production of concrete buildings. To achieve the desired quality, cement manufacture alone requires a significant quantity of energy. It is advisable to look for alternative materials that can either partially or completely replace it because cement businesses are expanding all over the world and CO_2 emissions are also increasing. One ton of CO_2 released for every ton of cement production. This indicates 3 to 4 giga tons of cement production in the world and increases in the coming years (Ellis, etal., 2021). Cement is not produced in Ethiopia at the same rate as what is required by the building industry in the country. As a result, it is currently difficult to supply cement to the nation, and its price is always changing and rising. The government made an effort to import cement from other nations in the interim to make up for the shortage. However, this is not the country's long-term solution. The cement industry is one of the rapidly growing industries in Ethiopia. The average per capita cement consumption of the country has increased from 39kg to 62kg. However, this is still way below than the global average per capita consumption of 500kg. The Ethiopian government is planning to expand its cement industry by upgrading the current cement plants and also opening of new cement plants in order to meet the future demand of the country. Currently, the number of cement plants in Ethiopia has reached to 20. By the year 2025, per capita cement consumption is expected to increase to 179kg (Habte, etal., 2018).

Re-using waste materials in current world is significant in creating sustainable environment to the living things. SBA waste is agro-industrial waste which extracted from the sugar industries. It used in the sugar industry as fuel in the production process of sugar (Balakrishnan & Batra, 2011). SBA can be considered as pozzolanic material due to its high amount compositions of silica. Different researches demonstrate that SBA possess pozzolanic reaction to the cement hydration decreasing porosity and creating more C-S-H gel (Mangi, et al.,2017). CB waste is agro waste in which extracted from slaughterhouses. CBA is calcareous material don't possess the pozzolanic property (Gill, et al., 2011). Due to its high amount content of CaO within it can be considered as filler material for cement. CB waste highly pollutes the environment (Getahun and Bewket, 2020).

The chemical compositions of ordinary Portland cement (OPC) indicate major chemical oxides of cement is calcareous and silicious material due to (60% to 68%) of CaO and (20% to 26%) SiO_2 (Abate, D. & Asteray, B. 2020). Researches shows that adopting waste materials rich in calcareous and siliceous as partial replacement of cement gives better improvement in compressive strength of concrete. According to (Adero, 2017), (Tsegihana, 2019), and SBA improves the strength concrete up to 5% replacement. according to (Getahun and Bewket, 2020), (Olutaiwo et al., 2018) and (Okeyinka et al., 2018) CBA can be replaced up to 10% have significant improvement on the compressive strength of concrete. Thus, researches don't indicate the microstructural property of SBA and CBA. Researches don't used SBA siliceous and CBA calcareous materials in combination to study the effects in mechanical and microstructural property. Therefore, this study intends to investigate the effects of using SBA and CBA in strength and microstructural property of concrete.

1.2. Statement of the Problem

The construction industry is a very vast industry that uses different materials in the intended specialities of construction works. Cement is one of the most used materials in concrete and its production needed an extensive high amount of energy. This energy enables potential greenhouse gas emission (GHG) emissions which is CO_2. The amount of GHG emission has been expected to grow due to the development of construction works all over the world. The hunt for cement substitutes has been made possible by the environmental impact and the energy consumption of cement manufacture. In Ethiopia, the production rate (demand and supply) within the country is considered another recent problem associated with cement. The price of cement fluctuation is another recent scouted problem in Ethiopia.

Since SBA is a byproduct, the bulk of it is useless and has a significant impact on the environment. However, some bagasse ash has been utilized as a fertilizer for the soil in small amounts for sugarcane production. On the other hand, the disposal of bone wastes severely pollutes the environment, has a harmful smell initially, and produces hazardous compounds (methane gas) that can contaminate rivers, soil, and plant life and also the life of humans. Both SBA and CBA wastes contaminate the environment and create hazards for the living environment. SBA has more amount of silica and CBA has a high amount of calcium oxide. SBA can be considered as pozzolana material which possesses the pozzolanic property. The pozzolanic property of SBA is due to the availability of a high amount of silica with in it. CBA as a filler can be used for the production of concrete Therefore, combining these two wastes improved material to be expected to replace partially cement. To compensate for the low silicate content of bone ash, the addition of silicate-containing materials expected to improve the strength of concrete containing CBA. To reduce the aforementioned issues, using these wastes is important. This study aims the use of SBA and CBA in partial replacement of cement to determine the mechanical property and micro-structural properties of normal strength concrete.

1.3. Research Questions

The above problems were the initial points to be addressed in the research. The researcher aims to answer the aforementioned questions.

1) What are the physical properties of sugarcane bagasse and cattle bone ash?

2) What effects do sugarcane bagasse and cow bone ash have when combined on the characteristics of fresh and hardened concrete?
3) What influence do sugarcane bagasse and cattle bone ash have on the micro-structural properties of concrete?
4) What effect do SBA and CBA have on the cost of concrete production compared to the traditional?

1.4. Objectives of the Study

1.4.1. General Objective

The general objective of the study is an investigation on partial replacement of Cement by sugarcane bagasse and cattle bone ash for normal strength concrete.

1.4.2. Specific Objective

The specific objective of the study is:

- To identify the physical property and chemical composition of sugarcane bagasse and cattle bone ash.
- To evaluate the performance of sugarcane bagasse and cattle bone ash on fresh and mechanical property of concrete.
- To determine the micro-structural property of concrete for different replacements.
- To analyze the cost of concrete per unit volume containing sugarcane bagasse and cattle bone ash with conventional concrete.

1.5. Significance of the Study

As the study uses the combined SBA and CBA, it plays some role in providing other alternative supplementary cementitious material. SBA is reached in silica content and CBA is reached in calcium oxide, combining these two materials as partial replacement may bring good characteristics to concrete. Using combined SBA and CBA as a partial replacement for cement contributes to reducing the environmental contamination and land spoil which results from wastes of SBA and CB. Currently, the cost of cement is high in our country Ethiopia, replaced SBA and CBA may contribute to reducing this cost. It also contributes to reducing greenhouse CO_2 emissions because when compared to cement greenhouse CO_2 emissions are less. And also gives the verdict in providing a good healthy environment may result from SBA and CB spoiling the environment.

1.6. Scope of the Study

The scope of the research is confined to the specific objective of the study which is identifying the physical properties, chemical compositions, and effects on fresh and hardened concrete of combined SBA and cattle bone ash. The study was confined to SBA from Wunji Sugar Factory and CB from in and around Hawassa city. And the experimental tests were done following the requirements and standards provided by ASTM. And the results were compared with the max and min values of the controlled mix.

1.7. Limitations of the Study

Throughout the study, the researcher faces some challenges which limit the research progress. These limitations are a limited amount of cash, laboratory personnel to open on time, every single person wants payments even for letting for the specific time, lack of getting large ashing furnace used to burn sugarcane bagasse ash and cattle bone, renewal of mechanical parts of Wunji sugar factory in the summer, Bureaucracy of some governmental bureau, costs of materials and costs of laboratory tests such as XRD, XRF and SEM. The chemical property of concrete having sugarcane bagasse and cattle bone ash don’t worked in this study.

1.8. Organization of the Study

This study aims to study the replacement of cement using SBA and CBA by weight of cement and organized in five chapters. The first chapters entail the introduction part having sub-topics of background of the study, statement of the problem, general and specific objective’s, significance, scope, limitations and organizations of the study. The second chapter deals about the literature reviews, different works in cement replacement using SBA and CBA has been reviewed in this chapter. The third chapter indicates the materials and methods used in the study. it deals in arranging the experimental set up and procedures adopted in the laboratory work. The fourth chapter deals about results extracted from the research and discussions of the results scientifically by comparing with previous results and controlled mix. Finally, the last chapter five contains the conclusion from the results as per the objectives of the study and recommendations on the study and further studies.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

Concrete is a versatile material cast from different ingredients such as cement, aggregate and water. Production of cement is a very exhausting process which needed high energy. Different scholars have been researching how to replace this material for sustainability and to decrease greenhouse gas and CO_2 emissions. Supplementary cementitious material nowadays used in developed countries and recommended in balancing the weather condition of the world.

2.2. Cement

Concrete is made with cement as one of the ingredients. It is utilized to create a paste that binds the aggregate with the desired amount of water. Among the most widely used building materials is cement. The industry that uses the most energy is cement. Cement demand, however, is increasing quickly in Ethiopia. The manufacture of cement is influenced by geographical, social, and economic variables.

Ethiopia is a country in Sub-Saharan Africa and is situated in the continent's eastern region. After Nigeria, Ethiopia has the second-highest population in Africa. From 2015 to 2025, the Federal Democratic Republic of Ethiopia (FDRE) Ministry of Industry has created new plans to direct the development of Ethiopia's cement sector. According to projections, the nation would consume 19.97 million tons of cement by the end of 2025, whereas a capacity of 25.16 million tons will be needed. This shows, that there would be an increase in capacity of 8.01 million tons by the end of 2025. Cement usage per person is anticipated to rise from 62 kg to 179 kg by 2025. One of the government's strategic goals is to develop Ethiopia's cement sector by encouraging the development of green cement (Shapiro, et al., 2017).

Due to the decarbonization of the limestone in the kiln during cement manufacturing and the burning of fossil fuels, about one ton of CO_2 is released into the atmosphere for every ton of cement produced. Around 1.35 billion tons annually, or roughly 7% of all greenhouse gas emissions to the earth's atmosphere, are thought to be contributed to greenhouse gas emissions by the production of Portland cement worldwide. This effect of cement production on the environment has made the research for alternative materials to cement popular in the last decades. Various works have been conducted in this area, by looking for materials that will totally or partially replace cement in the construction industry; most especially industrial and agro-based waste materials (Gashahun, 2020).

2.2.1. Cement Production

There are now 20 cement manufacturers in Ethiopia, 16 of which are integrated plants and the others are grinding plants. Ethiopia's cement manufacturing facilities at the end of 2014 had a combined annual capacity of roughly 12.6 million metric tons. 10 million tons of cement were produced in Ethiopia in 2017, and 12 million tons of clinker are anticipated to be produced there annually by 2020. In Ethiopia, barely 50% of the available cement production capacity is currently being used. The cement industry faces a serious challenge if this trend continues for the next ten years. The cost of energy for cement manufacture in Ethiopia is well-known. In Ethiopia, the cost of energy makes up between 50% and 60% of the entire cost of operations. Energy use and CO_2 emissions are anticipated to rise as a result of the industry's expansion and growth. In Ethiopia, the manufacturing of cement alone was responsible for 1.4Mt of CO_2 emissions in 2010 (Mulatu et al., 2018).

2.2.1.1. Cement Production Process

In producing cement, the following are the steps. The first step is the Preparation of raw meals. This is the process of making a raw meal. The materials are quarried and predetermined quantities of raw materials are mixed and ground into a fine powder known as a raw meal. After this, the raw meal is led to a silo where it is homogenized through mixing. Homogenization is important in that it enhances the combination of oxides during burning. Regular tests are employed as quality control measures for the chemical composition and fineness of the raw meal (Kwena, 2011).

Clinker production is the second step. This is the process of burning raw meals to produce clinker. The raw meal is fed into a preheating chamber where hot air is blown over it to dry it and make it easy to burn. The raw meal is then led into a rotary kiln with a temperature ranging from 900°C at the inlet to 1550°C at the hottest end.

The third step in the production of cement is Grinding and Packaging. The chemical composition and fineness of cement are closely monitored at all times during the grinding process. Grinding the clinker to fine particles greatly helps in enhancing the strength of concrete. Homogenizing of the raw meal can be done by mixing in water (wet process) or by mixing in dry conditions (dry process). The wet process usually requires additional energy to dry the raw meal before burning but reduces dust emissions. Modern technology however incorporates efficient dust arrestors making the wet process obsolete. The cement is then packaged in 25kg and 50kg (Kwena, 2011).

2.2.1.2. Types of Cement

Cement can be classified as OPC and PPC. OPC (Ordinary Portland cement) is One of the most widely used cement and is the most important hydraulic cement. Modern Portland cement is made from materials which must contain the proper proportions of lime (CaO), silica (SiO_2), alumina (Al_2O_3), and iron (Fe_2O_3) with minor amounts of magnesia and sulfur trioxide. A typical composition of general-purpose Ordinary Portland. The most common classification of Portland cement is that of ASTM. It classifies Portland cement mainly into five groups (non-air entrained) differing only on the relative amount of the compounds and the 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 Hydration Portland cement which is used, when the heat of hydration is low required, like in mass concrete. ASTM type V is Sulphate resisting Portland cement which is used when high sulphate resistance is desired.

The production of PPC (Portland pozzolana cement), the second type of cement, involves mixing OPC clinker with 15 to 35 percent pozzolanic ingredients. Siliceous or aluminous materials with little to no cementitious characteristics on their own are called pozzolan materials. However, in the presence of water, they combine with the calcium hydroxide that is released during the hydration of cement to generate a substance having cementitious properties. PPC has several benefits over OPC as a result of the reaction between the pozzolanic ingredients and calcium hydroxide. Free calcium hydroxide would have been present in the concrete if these pozzolanic components hadn't reacted with the calcium hydroxide, increasing the concrete's permeability and making it more vulnerable to further attacks.

A comparison of the chemical reaction between Portland cement and Portland- pozzolan cement for the main C-S-H forming reaction is shown in the below formula.

$$C_3S + H \xrightarrow{\text{fast}} \text{C-S-H} + CH$$

This reaction stands for the ordinary Portland cement as shown the rate of reaction is very fast.

$$\text{Pozzolan} + CH + H \xrightarrow{\text{slow}} \text{C-S-H} + CH$$

The reaction stands for Pozzolana Portland cement.

The pozzolanic reaction reduces the porosity of the concrete by producing a cementitious compound. It also reduces the heat of hydration since its reaction is slower than that of OPC, which implies that it has a slower rate of strength than OPC, making it suitable for mass concrete construction. In addition to these cement types, there are also other types of cement which are produced by either adding other materials to the clinker or by forming other compounds during burning. They are collectively called modified Portland cement. Expansive cement, calcium sulfoaluminate cement, masonry cement, oil well cement, white cement etc. can be an example of this. There is also non-Portland inorganic cement which is used to some extent (Mulatu et al., 2018).

2.2.1.3. Hydration of Cement

The reactions between the chemical's oxides create the formation of chemical compounds (alite, belite, tricalcium aluminate, and calcium aluminoferrite), calcium sulfate, and water are what cause the cement to hydrate. The reactions take place at various rates to create C-S-H as the primary hydrate, combined with additional phases like portlandite (CH), among others. The rate and progression of this reaction depend on the initial materials' rate of dissolution, the nucleation and growth rates of the hydrates that were simultaneously created, and the rate at which water and dissolved ions diffused through the hydrates (Odler. I., 1998).

the process of hydration that takes place when water and cement interact. Exothermic in nature, the initial reaction produces a lot of heat. The surface of the cement grain develops a layer of a C-S-H phase as a result of the breakdown of C3S. Similarly, C3A and C4AF also dissolve, interacting with calcium sulfate to create ettringite, which precipitates on the cement grain's surface. After some time, this initially quick reaction seems to settle down and produce less heat. The nucleation and development of the hydration products are the key factors that impact the subsequent period of accelerated hydration that follows the slow reaction phase. During this moment of acceleration, the heat output reaches its peak and then quickly begins to reduce as the hydration rate falls. (Macphee & Lachowski, 2003).

The hydration of C_3S is complex, needs detail investigation and gives crystallite calcium silicate hydrate (C-S-H). The hydration of alite (C_3S) is given by chemical formula of (Scrivener, etal., 2015).

- ✓ $\mathbf{3CaO.\ SiO2 + H2O \rightarrow CaO.\ SiO2.\ H2O + 3Ca(OH)2}$**………..……. Equation 2.1.**

C-S-H and C-H clearly formed as a result of reaction as seen in the above chemical formula. The hydration reaction of C_2S (Belite) is:

- ✓ $\mathbf{2CaO.\ SiO2 + H2O \rightarrow CaO.\ SiO2.\ H2O + Ca(OH)2}$**……………….. Equation 2.2.**

Belite also forms C-S-H and C-H as alite the difference in the reaction rate of the two compounds. Alite rate of reaction is fast whereas belite rate of reaction is slow**.**

The third major chemical compound is the C_3A (tricalcium aluminate) hydration reaction is taking place in two distinct parts. The first hydration reaction goes to the reaction without the presence of sulphate. In the absence of sulphate, the C_3A makes a flash setting to the mix. To avoid the aforementioned effect the addition of calcium sulphate (gypsum) to the cement clinker was adopted. The second hydration reaction is the addition of sulphate, it has two distinct sections, the first reaction gives the formation of ettringite (C_6ASH_{12}) and the second is the reaction of ettringite with previously unreacted C_3A (Minard, et al., 2007).

- ✓ **$C3A+3CS\ H2+26H \rightarrow C6AS3\ H32$ (tri-sulphate) ………………… Equation 2.3**
- ✓ **$C6AS3\ H32+2C3A+4H \rightarrow 3C4AS\ H12$ (mono-sulphate) ……….…. Equation 2.4**

Tetra calcium aluminoferite (C_4AlF), the final significant compound for the hydration process, has a slower rate of hydration. Although it happened at the same rate as C3A, the chemical reaction was slower. $C_2(A,F)\ H_8$ and/or $C_4(A,F)\ H_{16}$ are produced when C4AF combines with water without the presence of sulfates (Collepardi, M., 1979). These phases are then transformed into the hydrogarnet phase $C_3(A,F)\ H_6$, which contains iron. When sulphate is present, the hydration process produces the primary hydration product, $C_4(A,F)SH_{12}$ (Ramachandran & Beaudoin, 1980).

The hydration of cement plays a crucial role in the production of concrete. Cement hydrates through an exothermic reaction. This indicates that a significant amount of heat, known as the heat of hydration, is produced during this chemical reaction. When water is added, the temperature increases immediately because the aluminates react with the water (initial reaction). However, this temperature spike only lasts a short while and does not last for a long time. Heat evolution rapidly decreases as the solubility of aluminates is reduced due to the presence of gypsum (induction period). But this time, the sulphates in the form of silica start the chemical reaction while simultaneously releasing heat that raises the temperature to a considerably more moderate extreme (acceleration period). The heat liberation process slows down whenever there is less cement that hasn't been reacted (deceleration period). When the hardened cement paste reaches the final setting, a steady-state situation is reached after a given amount of time in which very little or no heat is released (a period of slow, continued reaction) (Narmluk & Nawa 2011).

2.3. Sugarcane Bagasse Ash as Partial Replacement of Cement

Worldwide, the sugar industry uses sugarcane bagasse, a type of industrial waste, as fuel. After burning sugarcane bagasse, which is itself discovered following the extraction of all economically viable sugar from sugarcane, sugar factories produce SBA as a waste product. The silicate concentration of the ash gave SBA its pozzolanic properties.

Depending on the burning and other characteristics of the raw materials, such as the land on which the sugar cane is cultivated, the silicate content in the ash may vary from one ash to the next (Kiran & Kishore, 2017).

Bagasse ash is a byproduct of burning sugarcane bagasse in boilers to produce electricity in the sugar industry. While the majority of the SBA is useless and negatively effects the environment, a small quantity of bagasse ash has been used as a soil amendment. It has a high concentration of silica and minor levels of iron, aluminium, and alkali and alkaline earth oxides. SBA can, however, make use of the potential use of bagasse ash as an additional cementitious ingredient. Contrary to conventional pozzolanic materials, the SBA-infused concrete exhibits outstanding strength development (Balakrishnan & Batra, 2011).

Bagasse is lateral production of sugarcane that after treatment of sugarcane in the form of light yellow colour particles is produced. The chemical composition of this product is cellulose fibres, water and some soil soluble material such as cube sugar, bypassing time cube sugars converted alcohol also the evaporation of bagasse fibre produces methane gas which can cause a fire in some circumstances. Fincha, Methara, Wonji, and Shoa sugar factory's additional (not including the current production) total aggregate production capacity is expected to be around 365,000 tons of sugar annually (ADERO, 2019).

Bagasse is composed of fibre and pith; the fibre is thick-walled and relatively long. Bagasse is a major by-product of the sugar industry which finds a very useful utilization in the same industry as an energy source. Sugarcane consists of 25-30% bagasse whereas sugar recovered by the industry is about 10%. Bagasse is also used as a raw material for papermaking due to its fibrous content (Habte, et al., 2018).

The data from Ethiopian Sugar Corporation shows all of the factories that are operating currently are now using bagasse as fuel for the boiler. Not only the current factories but the future intended projects will also operate in the same manner as this method reduces energy consumption. When all the factories start to operate at their full capacity, the respective bagasse ash that will be produced by that time will reach up to two million tons per annum.

Bagasse ash of this amount can substantially contribute to both technical and environmental advantages to the cement industry (Destaye, Belachew, 2019).

Table 2.1. Ethiopian annual sugar production capacity and SBA extracted

No.	**Factories**	**Tons of cane per day (TCD)**	**Crushing capacity per annum (ton)**	**Sugarcane bagasse (ton)**	**SBA (ton)**
1	Arjo dedesa	8,000	1,920,000	556,800	69,600
2	Beles I	12,000	2,880,000	835,200	104,400
3	Beles II	12,000	2,880,000	835,200	104,400
4	Beles III	12,000	2,880,000	835,200	104,400
5	Fincha	12,000	2,880,000	835,200	104,400
6	Kesem	11,000	2,640,000	765,600	95,700
7	Kuraz I	12,000	2,880,000	835,200	104,400
8	Kuraz II	12,000	2,880,000	835,200	104,400
9	Kuraz III	12,000	2,880,000	835,200	104,400
10	Kuraz IV	24,000	5,760,000	1,670,400	208,800
11	Kuraz V	24,000	5,760,000	1,670,400	208,800
12	Metehara	5,000	1,200,000	348,000	43,500
13	Tendahu	26,000	6,240,000	1,809,600	226,200
14	Wolkayte	24,000	5,760,000	1,670,400	208,800
15	Wonji Shoa	12,500	3,000,000	870,000	108,750
	Total	**218,500**	**52,440,000**	**15,207,600**	**1,900,950**

Source: (Destaye, 2019)

The amount of bagasse ash extracted from sugar factories is about 1.9 million tons. As the sugar factories increase the amount will increase. Thus, this waste material can easily be reused in replacing cement in concrete production. The performance of the bagasse can be modified as CBA is added to the material. The SBA has a high concentration of silica adding filler material like CBA will improve the chemical oxide content of CaO.

Bagasse is burnt at around 500°C in a controlled process to use its maximum fuel value. The residue after burning, namely, SBA, is collected using a bag-house filter and directly disposed of to the nearest land as slurry. When bagasse is burnt in the boiler of a cogeneration plant under controlled conditions, reactive amorphous silica is formed due to the combustion process and is present in the residual ashes. This amorphous silica content makes SBA a useful cement replacement material in concrete. When pozzolanic materials are used, reactive silica present in these materials reacts with calcium hydroxide and produces additional C–S–H gel. Permeability of concrete is considerably reduced because of pore refinement as well as additional C–S–H formation (Deepika, et al., 2017).

The use of different cement-replacing materials has become a common practice in the construction industry. Most of these cement replacement materials are byproducts of different industries and agricultural wastes. Blast furnace slag, silica fume, fly ash and rice husk can be cited as an example. SBA has also been found to have such pozzolanic property. The 21 and 28-day compressive strength value of concrete with 5% SBA replacement was showing a strength enhancement. 5% partial replacement of cement by SBA in concrete production results in a similar concrete property and higher replacement could also be used with a slight reduction in the performance of the concrete (ADERO, 2019).

Table 2.2 Chemical composition of sugarcane bagasse ash

Comp'd	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O
SBA (%)	53.46	12.82	4.20	1.10	0.56	0.34	1.64	<0.01	1.09	0.25	2.68
Source: (Adero, 2019)											
SBA (%)	74.4	8.3	4.44	1.84	1.08	1.28	2.76	0.20	0.66	0.27	1
Source: (Tsegihana, 2019)											

The chemical compositions of SBA by two researchers have summarized that the SiO_2 and it shows SBA can be classified as pozzolanic material as per ASTM standards. SBA can be used in partial replacement of cement in concrete and mortar productions.

2.4. Cattle Bone Ash as Partial Replacement of Cement

According to its population of cattle, Ethiopia is first in Africa and sixth overall. In Ethiopia, where the average weight of cows and oxen is above 300 kg, the waste products of animal bones account for 10% of the country's livestock that is slaughtered each year. An average of 400.5 million kilograms of animal bone are produced as waste each year out of this quantity, with the weight of the bone accounting for 20 to 30 percent of it. The total cattle population of Ethiopia in 2017 is estimated to be about 59.5 million which covers 44.93% of the Ethiopian Livestock population. Over the next 15 years, the consumption of red meat in Ethiopia is projected to grow by about 276% from 775,000 tons in 2013 to 2.9 million tons in 2028 (Shapiro et al., 2017).

Bone ash cannot be considered a pozzolanic material since the percentage sum of silicate aluminate and ferrite is less than 50%. But it can be used as a cement additive material since it has high calcium oxide content (Getahun & Bewket, 2020). The oxide composition of CBA used in this study does not satisfy the requirement for pozzolanic materials, it can, however, be regarded as a cementitious filler/additive considering its high CaO content which was found to be 63.86% by weight (Okeyinka, et al., 2018).

Environmental pollution by wastes from slaughtering houses and households as well as the waste disposal land requirement is one of the issues for large cities like Hawassa, Bahir Dar, Adama, Mekelle etc. in Ethiopia. Bone is one of the wastes removed from slaughtered animals (oxen and cows) which have high calcium content. On the other hand, 60% to 67% of Portland cement is comprised of calcium oxide. This indicates the bone waste potential for partial replacement of cement. Despite its high calcium oxide content, it causes environmental pollution due to the harmful gases released from burning at the disposal site. Waste disposal for large towns is one source of expense to waste transportation and management. Natural landscape changes due to waste disposal, loss of beauty of city scenery and disease related to respirational causes due to bad smelling are among the major negative impacts on the environment and human well-being. Proper utilization of this bone waste has a dual advantage by creating a sustainable environment and providing low-cost cementing material (Getahun & Bewket, 2020).

The average compressive strength exhibited by the CBA satisfies the 25N/mm2 standard cube compressive strength recommended by the British standard for Grade C25/C30 concrete at 28 days of curing age. This means that at 10% CBA content, CBA blended cement concrete is capable of exhibiting higher compressive strength compared to conventional Grade C25 concrete. Also, the average compressive strength of 20 N/mm2 obtained at a 30% replacement level shows that CBA can be used effectively up to 30% replacement level in cement for the production of lightweight concrete. This may be attributed to the high CaO content of the CBA which may have caused a slight strength increase through reduction of the total ore volume as some of the liquid water is converted to solid form (Okeyinka et al., 2018).

Table 2.3 Chemical composition of cattle bone ash

Oxides	**CBA (%)**	**CBA (%)**
CaO	43.26	76.31
SiO_2	< 0.01	2.28
Al_2O_3	< 0.01	2.94
Fe_2O_3	< 0.01	0.43
Na_2O	< 0.01	0.37
MgO	0.54	1.21
K_2O	< 0.01	0.24
MnO	< 0.01	0.086
P_2O_5	44.67	5.57
SO_3	0.08	-
CuO	-	0.28
LOI	2.26	0.37
Sources	(Getahun & Bewket, 2020)	(Olutaiwo et al, 2018)

From these two researchers, the composition of CBA chemical compositions shows that the amount of CaO is greater than 40%. For ordinary Portland cement percentage requirement of CaO needed is from 60% to 68% while the silica content is very low. Both compounds are crucial for the property of cement as the percentage content is high.

2.5. Experience of Adopting SBA and CBA as Partial Replacement of Cement

Different researches have been carried out in finding supplementary cementitious material which partially replaces cement in construction industry. Such as silica fume, coffee husk ash, sugarcane bagasse ash, granulated blast furnace slag, fly ash and etc. This study has been carried out find out alternative supplementary cementitious material by providing siliceous and calcareous material. In this sub-topic literatures have been tried to discuss the properties determined.

The consistency and setting time of cement having SBA increases as percentage replacement increases. Soundness of the cement also with in the ASTM standard up to 20% replacement of SBA. Cement replacement with SBA possess the pozzolanic reactions, the reaction to the unreacted C-H and compressive and tensile strength also improved. Concrete having SBA within it can improve the strength due to its pozzolanic property (Rowland G.O., 2014). On the other hand, the CBA also possess the same property of consistency, setting time and soundness. The amount of calcium oxide content within CBA makes filler material which improves the property of concrete (Varma, S. M. etal., 2016).

Adopting combined SBA and CBA expected to bring better and improved property to the concrete. According to Getahun and Bewket, providing material which possess pozzolanic property to the CBA enhances and improves further in the property of concrete. as far as, searching for experienced SBA and CBA together for concrete production is not implemented. This study aims to use blended SBA and CBA in the production of normal strength concrete. Carrying out tests for the strength and microstructural property of blended SBA and CBA with cement in the production of concrete and the combined effects were determined.

2.6. Summary of Literatures on SBA and CBA

Different literatures have been done on sugarcane bagasse and cattle bone ash as partial replacement of cement. SBA considered as Pozzolana materials due to its high amount content of silicon oxide, and fulfilling ASTM C-618 standards. The physical and chemical properties of SBA and CBA has been indicated by different literatures. The table 2.4. shows the summary of literatures worked on SBA and CBA.

Table 2.4 Summary of Literature Reviews

Title	Authors	Replaced	Tests	Findings	Gap
An Effective Study on Utilizing Bone Powder Ash as Partial Replacement of Construction Material	Varma, S. M., Naidu, M., Mohan, S., & Reddy, D. (2016).	For 5%, 10%, 15% and 20%	Compressive strength tests	Chemical components of Bone Powder Ash as well as Cement are almost same and 10% replacement shows improved compressive strength at 28 curing ages of concrete.	Tensile strength, micro-structural properties
A Study on Effect of Partial Replacement of Cement by Cattle Bone Ash in Concrete Property	Getahun S., Bewket B. (2021)	For 5%, 10%, 15% and 20%	Chemical composition, compressive strength.	Compressive strength has been improved up to 10% replacement of cement	Microstructural property.
Application of sugarcane bagasse ash as a partial cement replacement	Hailu, B., & Dinku, A. (2012)	For 5%, 10%, 15, and 25%	Compressive and flexural strength tests for mortar and concrete.	SBA considered as class N pozzolana material. Up to 10% shows that improved or equal to the concrete property	Micro-structural, chemical, cost analysis, calcination is not closed process.

Agro-waste sugarcane bagasse ash (ScBA) as partial replacement of binder material in concrete	Jha, P., Sachan, A. K., & Singh, R. P. (2021)	For 5%, 10%, 15%, 20% and 25%	Micro-structure, compressive, tensile strength and durability	10% replacement possess improved concrete property	Thermal effects
Utilization Of Sugarcane Bagasse Ash (SCBA) In Concrete By Partial Replacement of Cement	Reddy, M. V. S., Ashalatha, K., Madhuri, M., & Sumalatha, P. (2015).	For 5%, 10%, 15% and 20%	Fresh and hardened properties of concrete tests	Without substantial change SBA can be replaced up to 10%	Micro-structural, durability, and tensile strength tests.
Use of Bagasse Ash as Partial Replacement of Cement in Concrete	Rowland G.O (2014)	For 2% to 12% with the same pattern	Consistency, initial and final setting time and compressive strength of concrete having SBA.	Up to 2% of SBA have improvement on concrete compressive strength. thus, to improve the compressive strength other additives as a filler were recommended.	Tensile property, chemical property, Microstructural property.
Optimization of Bagasse Ash to Cement Mix Proportion for M30 Grade Concrete	Feyera, T. G.	For 5%, 10% and 15%	Fresh concrete, compressive strength, chemical compositions	Improved compressive strength observed up to 10%.	Micro-structural, chemical property of concrete.

Sugarcane Bagasse Ash as Partial Replacement of Cement in Concrete Production	Tsigehana, G/S (2019)	For 5%, 10%, and 20%.	Compressive strength and chemical compositions and fulfill ASTM standard of ASTM C 618.	Up to 5% of SBA replacement improves the compressive strength of concrete	Chemical, micro-structural property of concrete.
Strength Characteristics of Cattle Bone Ash (CBA) - Cement Blended Laterite Concrete.	Offiong, U. D., Umoren U. E., Ogunjimi L. A., Japhet, E. E. (2018)	For 10%, 20%, 30% and 40%	Strength and chemical composition of the blended CBA cement. Calcium content shows above 70% and loss of ignition is below 2%.	10% of CBA blended shows improvement and suitable for lightweight concrete production.	Characterizing CBA alone, chemical property, microstructural property, and durability tests.
An Effective Study on Utilizing Bone Powder Ash as Partial Replacement of Construction Material	Varma, S.M., Naidu, M.V., Mohan, S.M., & Reddy, S.S. (2016)	For M20 and M30 of 5%, 10%, 15%, and 20%	Compressive and Tensile strength tests have been carried out; chemical composition also carried out.	The chemical composition shows the same result as of cement. It can replace cement.	Durability tests, microstructural property, chemical tests.

Performance Evaluation of Ternary Blends of Pulverized Cow Bone Ash and Waste Glass Powder on the Strength Properties of Concrete	Adetayo, O.A., Umego, O.M., Amu, O.O., Faluyi, F., Odetoye, A.A., & Bucknor, A.O. (2022)	For 10%, 20%, 30% and 40%	Equal amount of PCBA and WGP, Compressive and tensile strength test, physical property and weight compositions of materials.	Shows better improvement in concrete strength, as curing age increases the strength also increases.	Microstructural analysis, chemical analysis.
A Feasibility Study on the Mechanical Properties of Concrete by Replacing Cement with Animal Bone Powder	Nasser, N., Al-Bahri, R., & Wiliams, C.K. (2019)	For 3%, 6%, 9%, 12% and 15%; for C30 grade.	Compressive and tensile strength tests	Optimal replacement was 6% with cement. It shows improved concrete strength tests.	Chemical properties, microstructural and durability.
Effect of Sugarcane Bagasse Ash on Bagasse Fiber Reinforced Concrete Properties	Abate D. & Asteray B. (2020)	For 5%, 10% and 15%	Compressive, splitting and flexural strength tests. Furthermore, physical property tests for individual material.	5% replacement indicates better improvement.	Chemical analysis, durability and microstructural analysis.

Effect of grounded bone powder addition on the mechanical properties of cement mortar	Kotb M., Assas M., & Abd-Elrahman H. (20	For 5%, 10%, 15% by weight	Compressive and Tensile strength test, micro-structural analysis of XRD, SEM for cement & blended cement.	5% replacement indicates improvement to the mix.	Chemical property tests, flexural and durability tests.
Investigating Mechanical Properties of Animal Bone Powder Partially Replaced Cement in Concrete Production	Teshome, B.B. (2019)	For 5%, 10%, 15% and 20%	Elemental analysis using "*Microwave Plasma-Atomic Emission Spectroscopy*" *compressive, tensile and flexural strength.*	Up to 10% replacement shows optimal replacement improving the strength of concrete.	Chemical property tests, microstructural property.
The Effect of Partial Replacement of Cement With Bone Ash and Wood Ash in Concrete	Akinyele, J.O. Adekunle, A.A. Ogundaini. O.	For 5% 10%, 15%, 20% and 25%	Chemical, compressive strength of blended concrete with CBA and wood ash.	CBA possess good pozzolanic property, concrete having CBA shows improvement up to 10% replacements.	Chemical, microstructural, durability property.

2.7. Research Gap

As the table below shows that the chemical composition of OPC has a high amount of calcium oxide and silica oxide which governs the bonding capacity of cement. Whereas SBA has a high percentage of silica and low calcium oxide content and the reverse is true for CBA. Application of the combined SBA (siliceous) and CBA (calcareous) to cement is expected to exhibit some basic properties of concrete. Characterizing the waste agro-industrial materials and determining its effects on strength of concrete. Analyzing the microstructural property of combined SBA and CBA for hardened concrete. Studying the effect of the Combined BA and CBA to use as cement replacement in the production of normal strength concrete. Table 2.4. shows the oxide composition of OPC cement as per ES 1176-6:2005.

Table 2.5 Elemental composition of OPC as per Ethiopian standard.

Elemental oxides	**Percentage compositions (%)**
SiO_2	18-24
Al_2O_3	2.6-8
Fe_2O_3	1.5-7
CaO	61-69
MgO	0.5-4
SO_3	0.2-4
K_2O	0.2-1

The above table 2.1 shows the OPC standards used in Ethiopia. The percentage content 18 to 24 are silicon oxide and 61 to 69 are calcium oxide. Siliceous and calcareous material used as partial replacement of cement can be recommended to improve the binding effect. Thus, applying waste SBA and CBA to the concrete is expected to improve the oxides and compounds in the cement. Later on, improvement of strength is expected. Not only strength but also micros-structural properties also improved. Finally, using waste materials gives two ways significance by using in the industry and decreasing environmental contamination as a result of SBA and CBA waste.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Introduction

This research was conducted at Hawassa University, construction material laboratory. The research aims to investigate the physical, mechanical and chemical properties of partially replacing cement with Bagasse Ash and Cattle Bone Ash for normal strength concrete. Concrete having a compressive strength of 25 MPa (C-25) was used. The proportions of course aggregate, fine aggregate, and water were held constant in the entire test mix while the amount of cement will be variable. A total of 90 (150mm×150mm×150mm) concrete cubes and 90 (dia. of 150mm and height of 300mm) concrete cylinders were cast and tested.

In adopting the combination of potential cementitious materials to replace cement different researchers use an equal amount of replacing the material. But for this study, the amount percentage combination of SBA and CBA was adopted after a trial mix was carried out. After the results of a trial mix of 3 and 7 days, the researcher reached to use an equal amount of Bagasse and CBA in the study. Researches show that average results for percentage replacement of BA and CBA individually lie between 5% to 10%. This research intends to find out the effects of the replacement content of 0%, 5%, 10%, 15% and 20% by weight of cement, introduced to each concrete mix. The workability of each fresh concrete was checked immediately following the mixing. Compressive and Tensile strength tests have been carried out at different ages of concrete 3, 7, 14, 28, 56 and 91 days. Chemical analysis for XRF and microstructural analysis of hardened concrete for TGA, DTA, FT-IR, XRD, and SEM have been carried out in the study. Specific gravity determination for the SBA and CBA was also carried out in the study. All concrete samples have been cast without admixtures and kept constant for water-to-cement ratio (W/C).

3.2. Research Design and Methodology

3.2.1. Research Design

The research design is determined by considering how to link the research questions with data collection methods and analysis of the results. Define research design as the program that guides the investigator in the process of collecting, analyzing and interpreting data. In other words, it considers an action plan for getting from one point to another (from here to there where here is the question to be answered and there is the conclusion to be drawn) (Yin, 2003). Research design is the method of defining ways to conduct research. The research follows experimental research having dependent and independent variables shown in the table below:

Table 3.1 Dependent, Independent and Constant variables

No.	**Variables**		
	Independent	**Dependent**	**Constant**
1	Bagasse ash	Workability	Testing process
2	Cattle bone ash	Compressive strength	curing
4		Tensile strength	The volume of fine aggregate
5			The volume of coarse aggregate
6			Source of Water

3.2.2. Research methods

The research methodology adopted is quantitative which has primary and secondary data. Secondary data were obtained from different review kinds of literature. The primary data was obtained from experiments carried out in the laboratory.

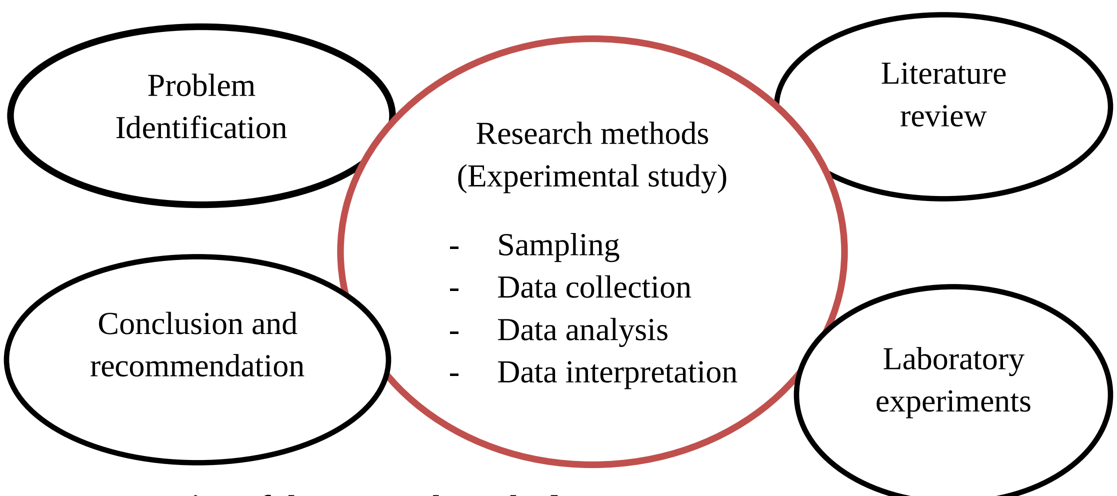


Figure 3.1 Overview of the Research Method

3.2.2.1. Sampling

For this study, the volume-based replacement method has been adopted to create a fixed paste volume for all replacement ratios and to ensure the workability of the concrete. The SBA was collected randomly from the WUNJI sugar factory. A replacement percentage of 5, 10, 15 and 20 were used in this study. This percentage of replacements was chosen based on the observed maximum percentage of replacement shown in earlier research. Most studies conducted on SBA and CBA individually were showing a maximum strength result on the percentage of replacement ranging from 5% to 10%. Thus, based on the above reason, it was anticipated that the increase in the amount of combined SBA and CBA may decrease the strength of the concrete after a percentage of replacement ranging from 5%-15%. Thus, the margin of replacement in this study went up to only 20% and included 5%, 10% and 15% in between. An iterative experiment can be carried out by narrowing the gap between the consecutive percentage of replacements but in this study, these percentages of replacements were enough to show the pattern in finding the optimum percentage of replacement.

3.3. Material Property and Procedure Adopted

3.3.1. Sugarcane Bagasse and Cattle Bone Ash

The materials used to partially replace cement are the waste materials collected from sugar factories and slaughtering houses called SBA and CBA respectively. Characterizing the materials was the first work of the study as determining the specific gravity and the chemical composition of both materials. The tests were carried out in the Ethiopian geological survey laboratory. The specific gravity of material determination is useful to know the physical characteristics of the material. The specific gravity of materials or relative gravity is a dimensionless quantity that is defined as the ratio of the density of a substance to the density of the water at a specified temperature. Specific gravity is determined by dividing the density of a material by the density of water at 4 degrees Celsius. For the calculation, the density of the material and that of the water must be expressed in the same units. The chemical test is important to determine the chemical composition of the bagasse and cattle bone ash. The chemical analysis for the determination of the chemical composition of the bagasse and cattle bone ash is determined using the Complete Silicate Analysis test. The chemical composition tests were carried out for the elements that characterize the nature of SBA which included; Silicon dioxide (SiO_2), Aluminum oxide (Al_2O_3), Iron oxide (Fe_2O_3), Sodium oxide (Na_2O), Potassium oxide (K_2O) Calcium oxide (CaO), Magnesium oxide (MgO), Sulfur trioxide (SO_3), Loss on ignition (LOI) (Kigozi, 2016). These elements are essential elements which play an important role in the property of concrete. Also used in the determination of compounds formed during the ashing of the materials. These compounds are C_3S, C_2S, C_3A and C_4AF crucial for the physical and mechanical properties of concrete.

3.3.1.1. Preparation of Bagasse Ash

The SBA used for the concrete mix collected from the Wunji sugar factory was sieved with a 75µm sieve size opening to get its fineness.

Figure 3.2. Sugarcane Bagasse Ash in Wunji sugar factory

The procedure adopted to prepare Bagasse Ash. First of all, Bagasse ash was collected from the sugar factory. Then, sieved using a sieve with an opening of 75µm and calcine at 700^{o}C for 2 hours. The calcination was selected to get a better property with the elemental oxides of SBA. Works of the literature show minimum and maximum calcination for the SBA ranges from 500^{o}C to 900^{o}C. average calcination was chosen to get better elemental compositions. Finally, Equal percentages with CBA were introduced to the concrete mix.

Figure 3.3. Sugarcane Bagasse Ash before and after calcination

SBA is sieved due to the availability of different substances within it such as plastics and fibres. Sieving the bagasse also gives proper fineness. Burning of the SBA again at a temperature of 700^{o}c was carried out to remove the availability of uncalcined carbon content of the waste SBA collected as raw from the factory.

3.3.1.2. Preparation of Cattle Bone Ash

The CB was collected from in and around Hawassa city slaughterhouses and burned with an ashing furnace in Hawassa city at the temperature of 900°C. The procedure adopted to prepare CBA for concrete mix is:

Initially, CB was Collected from slaughterhouses. Exposed to the normal temperature of the atmosphere for 3 days and prepared for minimum size by cutting into smaller pieces. CB was burned at a temperature of 900°C for 3 hours using an Ashing furnace. Literature has shown that the Cattle bone has fibres within it. Most of the literature tried to burn the cattle bone at a temperature ranging from 800^{o}c to 1000^{o}c with different ashing times. But for this study, the average calcination of CB temperature used was 900^{o}c for 3 hours to get the desired ash. Grinding and sieving CBA to get desired. Sieved with a sieve opening of 75µm and an Equal percentage with CBA were introduced to the concrete mix.

Figure 3.4 Grinding and sieving burned cattle bone

Preparing CBA for the concrete mix was very time-consuming work. Burning the CB took around 4 months to get 23kg of CBA. The ashing furnace used to burn CB has a very small opening having a volume of (5cm*5cm*25cm). figure 3.5. below shows the summary of the preparation of SBA and CBA.

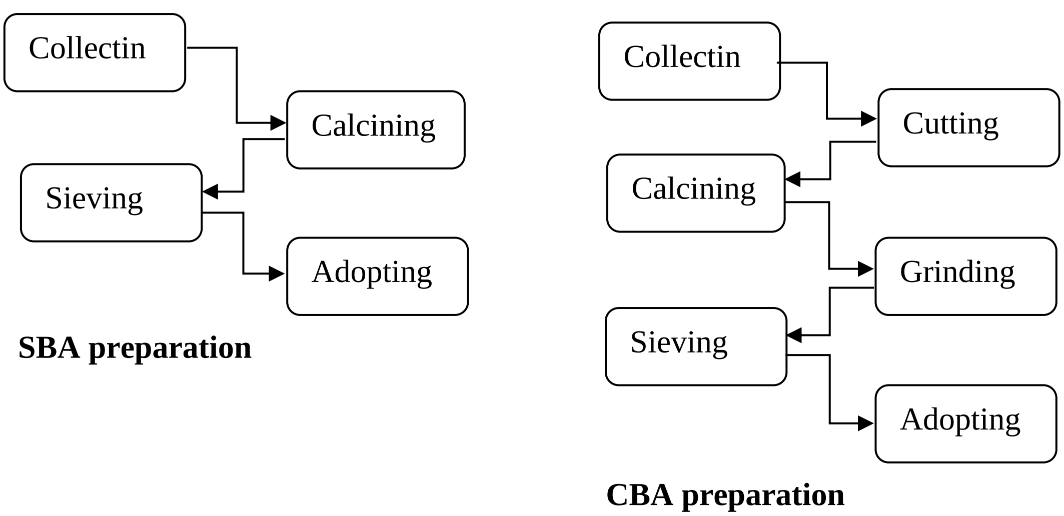


Figure 3.5 Summary of SBA and CBA preparation

3.3.2. Cement

Ordinary Portland cement (OPC), with a grade of 42.5N, is used in the production of concrete. The following tests have been made on cement.

Table 3.2 Tests for Cement

No	Properties	Standard
1	Consistency	ASTM C187
2	Soundness	ASTM C151
3	Setting time	ASTM C191

3.3.2.1. Consistency Test (ASTM C187)

Consistency can be defined as the Cement paste requirement of minimum water in cement paste for initiate the chemical reaction. According to ASTM C 187, The standard consistency of cement paste is defined as the percentage of water added in the 650gm weight of cement. This permits from the Vicat plunger length and 9 to 10 mm diameter to penetrate in cement paste for 23% to 31% of water by weight of cement. This study follows the consistency test of cement pastes and blended cements using ASTM C 187. Figure 3.6. shows the vicat apparatus.

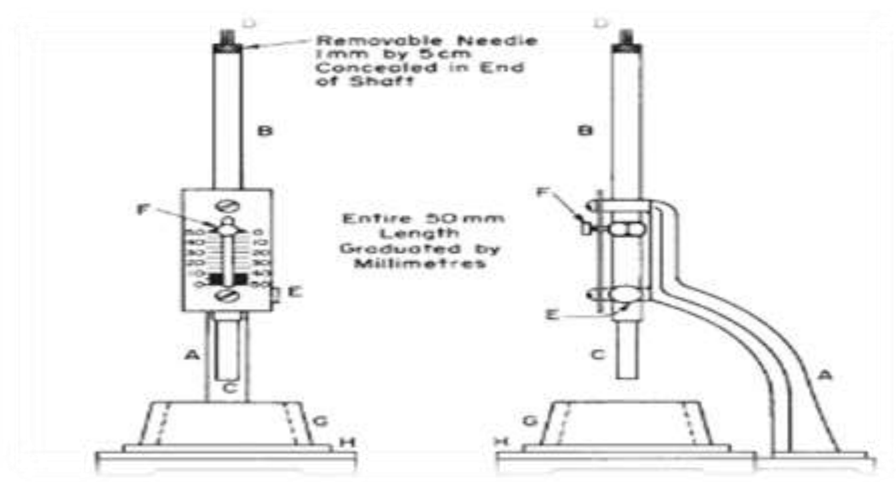


Figure 3.6 Vicat Apparatus (source, ASTM C187)

3.3.2.2. Soundness Test (ASTM C151)

The soundness of cement is an ability of hardened paste after setting to retain its volume and it is very important that the cement shall not undergo any appreciable change of volume after setting. In soundness of cement test a specimen of hardened cement paste is boiled for a fixed time and by doing this any tendency to expand is speeded up and can be detected and most used test for the soundness of cement is “Le Chatelier Apparatus Test”. Normal consistent of cement paste has been used from the first test of consistency as per ASTM C-151. In this study 28% of water by weight of cement has been used in determination of expansion of cement. ASTM C 151 procedure has been used in this study.

3.3.2.3. Setting Time Tests (ASTM C191)

In carrying out the setting time determination ASTM C-191 procedure has been used in this study. Vicat apparatus has been used in determination of initial and final setting time. Initial & Final Setting Time of Cement test is used to detect the deterioration of cement due to storage. Cement starts reaction with the water and starts the hydration process. After the water is mixed with cement, it starts to get into a plastic state for a few minutes. The conversion of plastic state cement into a hardened and rigid mass is known as the setting of cement. The setting time of cement is divided into two portion which are initial and final setting time. The cement’s initial setting time indicates when the cement paste starts to lose its plasticity. ASTM standards indicates that initial setting determined for the penetration of 25mm. the initial setting time differs due to the plenty of reasons such as seasonal changes, weather conditions, type of cement and etc. The cements final setting time shows the cement paste completely loses its plasticity. The form or scaffolding can be removed after the final setting time. The cement is hard enough to touch or place objects on in this period. According to ASTM C-191 final setting determined when no penetration or nearly to 1mm, cement pastes is observed through vicat apparatus.

3.3.3. Coarse Aggregate

Coarse aggregate was taken from one of the crushing plants in Hawassa city. the tests carried out for coarse aggregates are gradation, specific gravity and water absorption, unit weight, and moisture content. Some tests are carried out listed in APPENDIX 9.A1.

Table 3.3 Coarse Aggregate Tests

No	Properties	Standards
1	Moisture content	ASTM C566
2	Gradation	ASTM C136
3	Unit Weight	ASTM C29
4	Specific Gravity	ASTM C127
5	Water Absorption	ASTM C127

3.3.3.1. Procedure for Moisture Content of Coarse Aggregate (ASTM C566)

Aggregates are porous to some extent which absorbs moisture or retained on the surface of the particle as a film of moisture and contributes to the concrete mix. Moisture has four basic states this are oven dry, air dry, saturated surface dry and wet states. The availability of films of moisture affects the amount of water needed for the concrete mix. Therefore, determining the moisture content is crucial and significant. ASTM C566 procedure has been used in this study.

3.3.3.2. Procedure for Gradation of Coarse Aggregate (ASTM C136)

The particle size distribution of the coarse aggregates is termed as “Gradation”. The sieve analysis is conducted to determine this particle size distribution. Grading pattern is assessed by sieving a sample successively through all the sieves mounted one over the other in order of size, with larger sieve on the top. Each sieve openings putted one another as per the opening sizes and sieved using sieve shaker. Weighing the retained with sieve weight and the data has been recorded based on the ASTM C-136 procedures and finally Fineness Modulus of the coarse aggregate has been calculated. The sieve analysis has been determined using ASTM procedures and sieve openings.

3.3.3.3. Procedure for Unit Weight of Coarse Aggregate (ASTM C 29)

The ratio of the weight of a material to its volume is its unit weight, sometimes termed specific weight or weight density. Unit weight or specific weight of any material is its weight per unit volume that means in a unit volume, how much weight of the material can be placed. cylinder with (15cm*30cm) was used to determine the unit weight of coarse aggregate. The unit weight of coarse aggregate has been calculated using ASTM C29 procedure.

3.3.3.4. Procedure For Specific Gravity and Water Absorption (ASTM C127-8)

The specific and absorption of coarse aggregate was determined as per ASTM C-127 procedures. After taking sample of coarse aggregate using the sample splitter. Sieve the sample with 4.75mm sieves and ignore the materials passing through the No.4.75 sieve. Then, wash the sample to remove dust. Put the sample in the oven at 105°C.for 24hours. Then, Get the sample out of the oven, leave it to cool then determine its weight. Submerge the sample in water for 24 hours. Remove the sample from the water and roll it in a large absorbent cloth until all visible films of water are removed. Wipe the larger particles individually. Take care to avoid evaporation of water from aggregate pores during the operation of surface drying. Take the required weight of the sample in its (SSD) (saturated surface dry) condition. After weighing, immediately place the SSD sample in the sample container and determine its weight in water at 23±1°C. Take care to remove all entrapped before weighing by shaking the container while immersed. Dry the test sample to constant weight at a temperature of 110±5°C, Cool in the air at room temperature for 1 to 3 hours, or until the aggregate has cooled to a temperature that is comfortable to handle, and weigh.

3.3.4. Fine Aggregate

Fine aggregate was natural sand collected from Hawassa sand suppliers. Tests carried out for fine aggregate are gradation, specific gravity, water absorption, moisture content and silt contents. Some of the tests carried out have been indicated in APPENDIX 9.A2.

Table 3.4 Tests on Fine Aggregate

No	Properties	Standards
1	Moisture content	ASTM C566
2	Gradation	ASTM C136
3	Unit Weight	ASTM C29
4	Specific Gravity	ASTM C128
5	Water Absorption	ASTM C128

3.3.4.1. Procedure for moisture content for Fine Aggregate (ASTM C 566)

The moisture content of fine aggregate also has impacts in the concrete mix due to the availability of moisture and capacity of absorbing. It also has effects on the amount of water in the mix. The same procedure has been adopted as coarse aggregate. ASTM C-566 procedure has been used to determine the moisture content of fine aggregate.

3.3.4.2. Procedure for Gradation of Fine Aggregate (ASTM C 136)

Gradation for fine aggregate was carried out using sieve analysis. Sieve analysis is given to the sample operation of dividing a sample of fine aggregates into fractions each consisting of particles between specific limits. The analysis is conducted to determine the grading of material proposed for use as aggregates. Gradation is determined by passing the material through a series of sieves stacked with progressively smaller openings from top to bottom and weighing the material retained on each sieve. The procedure used in this study for determinations of gradation of fine aggregate was ASTM C-136 procedure.

3.3.4.3. Procedure for Unit Weight of Fine Aggregate (ASTM C 29)

The test has been carried out as per ASTM C-29 procedures. The procedure used is the same as that of coarse aggregate. Unit weight of fine aggregate entails the specific density of the materials. It is significant for estimating the density of concrete.

3.3.4.4. Procedure for Specific Gravity and Water Absorption of Fine Aggregate (ASTM C 128)

Bulk-specific gravity is defined as the ratio of the weight of the aggregate (oven-dry or saturated surface dry) to the weight in air of an equal volume of gas-free distilled water at the stated temperature. Apparent specific gravity is the ratio of the weight of the aggregate dried in an oven at 100 to 110°C (212 to 230°F) for 24 hrs. to the weight of water occupying a volume equal to that of the solid including the impermeable pores. Absorption values are used to calculate the change in the weight of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition. SSD is the condition in which the permeable pores of aggregate particles are filled with water to the extent achieved by submerging in water for the prescribed period, but without free water on the surface of the particle.

3.3.5. Water

Potable water in the laboratory has been used for the concrete mix and no test has been conducted on the water.

3.4. Mechanical property of Concrete

The study aims were to replace cement with Bagasse and cattle bone ash. Designating the percentage replacement is crucial in differentiating the control mix from other replacements code name has been given. The designations was also used in the determinations of the cement properties. So as Designation given for the replacement percentage of cement by Bagasse and Cattle bone ash is described in the table below.

Table 3.5 Designation for Cement Replacement

Designation	Description
BCBA-0	Control C-25 mix for OPC cement only
BCBA-5	5% replacement of cement with combined Bagasse and Cattle bone ash
BCBA-10	10% replacement of cement with combined Bagasse and Cattle bone ash
BCBA-15	15% replacement of cement with combined Bagasse and Cattle bone ash
BCBA-20	20% replacement of cement with combined Bagasse and Cattle bone ash

Tests have been conducted to investigate Bagasse and Cattle Bone Ash properties and their effects on fresh and hardened concrete properties. Different tests were done. The hardened Concrete properties test is one of the most important properties of hardened concrete after casting and curing, concrete was determined after 3, 7, 14, 28, 56 and 90 days. All samples were cured until the test dates in the curing tank. The reported results are the average of three samples experimented with in the laboratory test.

The hardened property of concrete was obtained after the concrete passes the fresh concrete property. For hardened concrete properties, destructive tests were used to determine the compressive strength and tensile strength tests. To carry out the two tests cube test and splitting test methods were carried out. Properties of hardened concrete properties concrete tests were carried out in the laboratory by using the following standards in the table below.

Table 3.6 Tests for mechanical property of concrete

No	Test	Standard	Property
1	Compressive strength test	ASTM C39	Mechanical Properties of Concrete
2	Tensile strength test	ASTM C496	Mechanical Property of Concrete

Samples needed for compressive and tensile strength showed below. It indicates the number of specimens used in the study for the compressive and tensile strength test.

3.4.1. Test Specimen Preparation for Compressive Strength

Based on the mix design worked using the ACI method, measuring and preparing the required constituents of concrete for mixing is the first step. Then using cube formwork (15mm*15mm*15mm) for casting the mixed concrete deliberately. Then finally after 24hrs dismantle the cube formwork. As shown in the table below a total of **90** concrete Cube specimens (150×150×150) in cubic mm have been cast and tested for compressive strength.

Table 3.7 Test Specimens for compressive strength test

SBCBA	**Number of cubes**						**Total**
Replacements	3 days	7 days	14 days	28 days	56 days	90 days	
BCBA-0	3	3	3	3	3	3	18
BCBA-5	3	3	3	3	3	3	18
BCBA-10	3	3	3	3	3	3	18
BCBA-15	3	3	3	3	3	3	18
BCBA-20	3	3	3	3	3	3	18
Total							**90**

The total concrete volume for compressive strength needed for the study is: 1 cube sample of concrete is (0.15*0.15*0.15) cubic meter which equals 0.003375 cubic meters. For 90 pcs of the sample of concrete 90*0.003375 cubic meters equal 0.30375 cubic meters. Therefore, for compressive strength total volume of concrete needed is 0.30375 cubic meters and the addition of 20% wastage.

3.4.2. Test specimen preparation for Tensile strength

Tensile strength determination will be carried out using the splitting test method. Therefore, cylindrical test specimens are required which have (dia = 150mm and h = 300mm) to be taken as samples for concrete curing age of 3, 7, 14, 28, 56 and 90 days per ASTM C39 Standard Total of 90 samples. The table below shows the summary of test samples for different replacements and the curing age of concrete to carry out the splitting tensile strength test.

Table 3.8 Test Specimen for Tensile strength test

SBCBA	**Number of cubes**						**Total**
Replacements	3 days	7 days	14 days	28 days	56 days	90 days	
0%	3	3	3	3	3	3	18
5%	3	3	3	3	3	3	18
10%	3	3	3	3	3	3	18
15%	3	3	3	3	3	3	18
20%	3	3	3	3	3	3	18
Total							**90**

The total number of concrete samples needed for the tensile strength test using the splitting method is 90. The total concrete volume required to examine the tensile strength of concrete needed is: 1 cylindrical sample of concrete is $(0.3 * \frac{\pi(0.15)^2}{4})$ the cubic meter which equals 0.0053 cubic meters. For 90 pcs of the sample of concrete 90*0.0053 cubic meters equal 0.477 cubic meters. Therefore, for tensile strength total volume of concrete needed is 0.477 cubic meters plus 20% wastage.

3.5. Fresh Concrete Properties Test

The property of fresh concrete will be measured, also in the case with various units of water of fresh concrete. Workability is one of the most important properties of fresh concrete. In this research slump test has been conducted for measuring the consistency of fresh concrete. Table 3.9. summarizes the test type as per the standard of ASTM C143 to check the concrete workability.

Table 3.9 Fresh Concrete Tests

Property	**Slump test**	Workability of fresh concrete
Standard	**ASTM C143**	

3.5.1. Workability of Fresh Concrete

To check the workability of the concrete for each mix slump test has been performed. Based on ASTM C143 the ACI mix design was performed. In the procedure used in the determination of the Concrete Slump test, in the beginning, the mould for the concrete slump test is a frustum of a cone, 300 mm (12 in) in height. The base is 200 mm (8in) in diameter and it has a smaller opening at the top of 100 mm (4 in). The base is placed on a smooth surface and the container is filled with concrete in three layers, whose workability is to be tested. Each layer is temped 25 times with a standard 16 mm (5/8 in) diameter steel rod, rounded at the end. When the mould is filled with concrete, the top surface is struck off (levelled with mould top opening) using the screening and rolling motion of the temping rod. The mould must be firmly held against its base during the entire operation so that it could not move due to the pouring of concrete and this can be done using handles or footrests brazed to the mold. Immediately after filling is completed and the concrete is levelled, the cone is slowly and carefully lifted vertically, an unsupported concrete will now slump. The decrease in the height of the center of the slumped concrete is called a slump. The slump is measured by placing the cone just beside the slumped concrete and the temping rod is placed over the cone so that it should also come over the area of slumped concrete. The decrease in height of concrete to that of mold is noted with scale, usually measured to the nearest 5 mm (1/4 in). Finally, the data was recorded and prepared for analysis.

Figure 3.7 Sample slump test

3.6. Hardened Concrete Property

The strength of the concrete plays a vital role in the construction of any building. The strength of the concrete helps in identifying whether the concrete can be used in construction or not. The strength of the concrete is defined as the maximum amount of load which the concrete can bear. Strength is considered one of the most important and valuable properties of concrete. The hardened concrete property can be identified by carrying out the determination of the strength of the concrete. Compressive strength and tensile strength tests have been carried out for hardened concrete property determination.

3.6.1. Compressive strength and Tensile strength

A compressive strength test was carried out to check the hardened property of concrete. The amount of each constituent of concrete determined using the ACI mix design has been mixed and samples for cylinder, and cube were cast and tested. Procedures adopted sample preparations of compressive strength and tensile strength test in the study are:

Mixing the concrete ingredients based on the ACI-mix design for the intended number of samples. Preparing concrete cube and cylinder moulds having (L=15, W=15, H=15) (H=30, D= 15) in centimeters respectively. Then poured mixed concrete in three layers by tapping the concrete using rods 25 times. Levelling the surface of concrete and giving mark for the concrete After 24hr removing the moulds used in performing the intended cube concrete. Inserting in the moist for curing and compressive and tensile strength test applied in the intended age of concrete using compressive strength machine.

3.7. Micro-structural property of concrete

Micro-structural property of hardened concrete has been carried out for the curing ages of 28 days. The tests carried out are FT-IR, TGA, DTA, XRD and SEM analysis.

3.7.1. XRD (X-ray diffraction)

A method for examining the atomic or molecular structure of materials is called X-ray diffraction, or XRD. The experiment was conducted in Adama Science and Technology Institute laboratory. It is a non-destructive test and functions with fully or partially crystalline materials. The extent to which it happens is determined by how big a wavelength is about how big an obstruction or aperture is. The analysis was performed using Origin pro software.

3.7.2. FTIR (Fourier Transform- Infrared Spectroscopy)

A solid, liquid, or gas's absorption or emission of an infrared spectrum can be obtained using the FT-IR technique. This test has been conducted in Bahir Dar institute of technology university laboratory. vast spectrum range's worth of high-resolution spectral data is concurrently collected by an FTIR spectrometer Functional groups and a fingerprint region are present in the wavelength range of 400 CM^{-1} to 4000 CM^{-1}.

3.7.3. TGA (Thermo-Gravimetric Analysis)

Thermos-gravimetric analysis has been carried out in Bahir Dar institute of technology university laboratory. Thermogravimetric analysis or thermal gravimetric analysis (TGA) is a method of thermal analysis in which the mass of a sample is measured over time as the temperature changes. This measurement provides information about physical phenomena, such as phase transitions, absorption, adsorption and desorption; as well as chemical phenomena including chemisorption, thermal decomposition, and solid-gas reactions.

3.7.4. DTA (Differential thermal analysis)

DTA is a thermos-analytic technique that determines changes in the sample, either exothermic or endothermic, can be detected relative to the inert reference. DTA test was conducted in Bahir Dar institute of technology university laboratory. DTA curve provides data on the transformations that have occurred, such as glass transitions, crystallization, melting and sublimation.

3.7.5. SEM (Scanning Electron Microscope)

SEM is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. The test was carried out in Adama Science and Technology Institute laboratory.

3.8. Cost comparison

The cost comparison between conventional concrete and concrete with partial replacement of cement with combined SBA and CBA has been compared for mixes of BCBA-0, BCBA-10, BCBA-15 and BCBA-20. In calculating the cost of ingredients current market prices have been collected and used in the determination of unit price. SBA and CB are waste materials; therefore, no associated price was asked for the waste. Production costs and collection prices have been estimated in formal and informal estimations. The energy cost of SBA and CBA corresponding to the energy cost of cement has been seen for the determination of energy cost. Informally, labour costs for the collection of 100kg of SBA and CBA are estimated to be 20 ETB each.

3.9. Mix Design

Concrete having a compressive strength of 25 MPa (C-25) has been used to perform this research. The researcher follows ACI 211.1-91 mix design procedure for concrete. The mixed design results are shown in APPENDIX 7.

3.10. Data Analysis

In data analysis, Origin pro-2022 software and excel sheets were used. The data has been discussed as the research intends to use a descriptive or explanatory method.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

This chapter of the research deals with the result extracted from different tests and discusses the results.

4.1. Physical Property of Sugarcane Bagasse and Cattle Bone Ash

Agricultural wastes are nowadays potential supplementary cementitious material to replace cement partially. In this study, an equal amount of combined SBA and CBA were introduced to the concrete mix but it’s crucial to characterize the two materials per standards.

4.1.1. The Specific Gravity of Sugarcane Bagasse and Cattle Bone Ash

The test is carried out in the laboratory to obtain the specific gravity of SBA and CBA by adopting a Le Chatelier flask based on ASTM C-188-95. The specific gravity test of SBA and CBA was carried out in the Ethiopian geological survey laboratory. The test result is shown in the table below.

Table 4.1 Specific gravity test result

Materials	SBA (g/cm^3)	CBA(g/cm^3)	OPC (g/cm^3)
Specific gravity	1.82	2.55	3.15

The specific gravity of SBA is smaller than OPC and CBA. The laboratory experiment result shows that SBA has 1.82g/cm^3 and CBA has 2.55g/cm^3 which is a smaller specific gravity compared to ordinary Portland cement. The specific gravity of SBA is less which is expected to lower the density of the concrete. But when combined with CBA the specific gravity improved so the density of the concrete just compared to the concrete used only with SBA as partial replacement to the cement. It is expected that the density of concrete for using cement only has a much higher density of concrete than the blended cement with partial replacement of combined SBA and CBA.

4.1.2. Chemical Composition of Sugarcane Bagasse and Cattle Bone Ash

Characterizing the agricultural waste ashes for the SBA and CBA whether or not meeting the standards of pozzolana as supplementary cementitious material was crucial. Therefore, complete silicate analysis (XRF) for SBA and CBA was carried out in the Ethiopian Geological survey laboratory. The analysis shows the elemental composition inside the materials does meet the requirements from the specified standard under ASTM C 618. The reviewed literature also indicated that SBA satisfies Class F pozzolana material which can be used as a supplementary cementitious material. While the CBA does not satisfy the ASTM C 618 standard but using it as filler material for cement was recommended. CBA can be used as a filler material due to its high amount of calcium content with it. The test result of the chemical composition of cement, Cattle bone ash and Bagasse has been summarized in the table below:

Table 4.2 Chemical composition of sugarcane bagasse and cattle bone ash

Elemental oxides	Percentage occurrences (%)	
	CBA	SBA
SiO_2	6.92	72.74
Al_2O_3	2.36	10.58
Fe_2O_3	<0.01	4.92
CaO	41.20	0.40
MgO	<0.01	0.24
Na_2O	<0.01	<0.01
K_2O	1.28	6.44
MnO	<0.01	<0.01
P_2O_5	35.70	1.25
TiO_2	<0.01	0.17
H_2O	0.26	0.61
LOI	10.92	2.59
SiO_2+ Al_2O_3+ Fe_2O_3	**9.28**	**88.24**

The above Table 4.2. shows the complete silicate analysis of the SBA and CBA. In characterizing the materials, according to ASTM C618-03 the summation of percentage chemical composition SiO_2, Al_2O_3 and Fe_2O_3 must greater than 50 and 70 to be classified as class c and f pozzolan material respectively. The SBA collected from the Wunji sugar factory is classified under class F pozzolanic material having the summation of SiO_2, Al_2O_3 and Fe_2O_3 are 88.24% greater than 70% and while CBA doesn't fulfil the ASTM C618-03 standard for which the summation of SiO_2, Al_2O_3 and Fe_2O_3 is 9.24%. It can consider filler material as other scholars implied. The LOI result of CBA is 10.98% which is greater than 10% which is specified in ASTM C618-03. The difference is less than 1% and it can be manageable but it has effects. The phosphorous Penta oxide percentage amount in the CBA is much greater amount having 35.70% which affects the workability and strength of concrete. The chemical oxides are different from other researchers due to the type of plants eaten by cattle and the weather condition are the factors to be considered.

Bogue's equation which used to determine the percentage composition of compounds present in concrete. The concrete mix used in the research was to replace cement with combined SBA and CBA at percentage replacement which starts from 0% to 20%. From ASTM C618, the determination of cement compound composition was calculated using bogue's equation for main oxides obtaining main compounds comprised of the important properties of concrete. The main compounds are tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A) and Tetra calcium aluminoferrite (C_4AF). The formula used is listed below from equation 1 to equation 4. The material used is SBA and CBA so the oxides available inside the materials are different. The oxides which have a percentage content of 0.01 and less than 0.01 has been neglected in the calculation for the determination of chemical compounds. The table below summarizes the bogues equation used to determine the percentage of oxides and compounds:

Table 4.3. Bogues equation

Bogues equation
Tri-calcium silicate (Alite) $C_3S = (4.07\times\% CaO) - (7.60\times\% SiO_2) - (6.72\times\% Al_2O_3) - (1.43\times Fe_2O_3) - (2.85\times\% SO_3) - (5.19\times\% CO_2)$

Di-calcium silicate (Belite)
$C_2S = (2.87\times \% SiO_2) - (0.75\times \% C_3S)$
Tri-calcium aluminate
$C_3A = (2.65 \times \% Al_2O_3) - (1.69 \times \% Fe_2O3)$
Tetra-calcium aluminoferite
$C_4AF = (3.04\times\% Fe_2O_3)$
Source: (Neville, A. M., & Brooks, J. J. 1987).

The percentage availability of the compounds in the concrete enacts the different properties of concrete. Thus, the chemical composition and compound composition of the concrete with different percentage replacements using bougees' equation for the main chemical composition (major oxide) is shown in the table below. In calculating the chemical composition of the oxides and compounds the literature result on the chemical composition of OPC of Dangote was used.

Table 4.4 The chemical composition of Dangote OPC

Oxides	CaO	SiO_2	Al_2O_3	Fe_2O_3
OPC (%)	66.32	22.82	5.41	3.37

Source: (Geremew, 2019)

The chemical oxides of SBA and CBA extracted from the laboratory were used to determine the percentage number of oxides and compounds by taking the elemental oxides to result from the above table as a ground for the calculations. In determining the percentage of the oxides and composition equal amount of SBA and CBA was used for the percentage replacement of the cement. It is considered that as the calculated result of the percentage of oxides and compound composition the concrete exhibits the strength and other basic properties of concrete. after the calculations using bogues equations and the results of chemical oxides and compounds for different replacements ranging from 0 to 20 percent results were shown in the table below:

Table 4.5 Composition of chemical oxides and compounds

Percentage replacement	Chemical composition (%)			
	CaO	SiO_2	Al_2O_3	Fe_2O_3
BCBA-0	66.32	22.82	5.41	3.37
BCBA-5	65.28	20.83	5.09	3.25
BCBA-10	64.24	18.84	4.76	3.12
BCBA-15	63.20	16.85	4.44	3
BCBA-20	62.15	14.85	4.12	2.88
	Compound composition (%)			
	C_3S	C_2S	C_3A	C_4AF
BCBA-0	55.32	24.00	8.64	10.25
BCBA-5	68.53	8.39	8.00	9.88
BCBA-10	81.82	-7.29	7.34	9.49
BCBA-15	95.04	-22.92	6.70	9.12
BCBA-20	108.29	-38.60	6.05	8.76

The above Table 4.5. indicates the chemical and compound composition calculated result from laboratory test results carried out in Ethiopia geological survey laboratory. The C_3S compound percentage amount is increasing as the percentage replacement increases from 0 to 20 percent. This shows that the hydration process of the cement paste increases as the percentage replacement increases. On the other hand, the C_2S decreases rapidly which shows that as the percentage of SBA and CBA introduced to the concrete increases the age of the concrete result in less contribution to the strength of the development of the concrete. We can conclude that the early time strength improvement of the concrete increases as an equal amount of combined SBA and CBA is provided into the cement. Its due to the presence of a greater SiO_2 amount in the SBA is responsible for the increase of the C_3S. while the amount of the C_2S decreases, as a result, concrete is expected to be less contribution to the strength of concrete through time after a long period. The other compound compositions are C_3A and C_4AF can be considered constants for showing small percentage decrement and facilitating the silica reaction and giving some role in the property of concrete.

4.2. The Physical Property of Concrete Materials

4.2.1. Hydraulic Cement and Blended Cement

Cement property tests have been carried out as per the standard of ASTM. These tests are consistency, soundness, and initial setting time.

4.2.1.1. Consistency Tests

A consistency test was carried out to determine the amount of water needed to prepare hydraulic cement paste. According to ASTM C187 hydraulic cement consists of a range of 9 to 11 with the percentage of water by weight of hydraulic cement content in the range of 23% to 33%. The table below shows data from a laboratory test for the consistency of hydraulic cement and cement blended with SBA and CBA.

Table 4.6 Consistency test result

Trial No	Water (ml)	Penetration (mm) BCBA -0	Penetration (mm) BCBA -5	Penetration (mm) BCBA -10	Penetration (mm) BCBA -15	Penetration (mm) BCBA -20
1	149.5	5	4	4	4	3
2	156	6	5	5	4	4
3	162.5	6	6	6	5	5
4	169	7	7	6	6	6
5	175.5	8	8	7	7	7
6	182	10	10	10	9	9

The Consistency test shows a 28% percentage content of water is 182ml which fulfils the ASTM C33 standard. The cement is consistent with the amount of water 182ml which can be used for the OPC and the blended cement with SBA and CBA. At 28% percentage amount of cement the pastes shows 10mm for percentage replacement of 0%, 5%, 10% and 9mm for 15% and 20%. Fig 4.1. Below shows that consistency as per the percentage replacement and the Y values was offset result and the gap is 5mm.

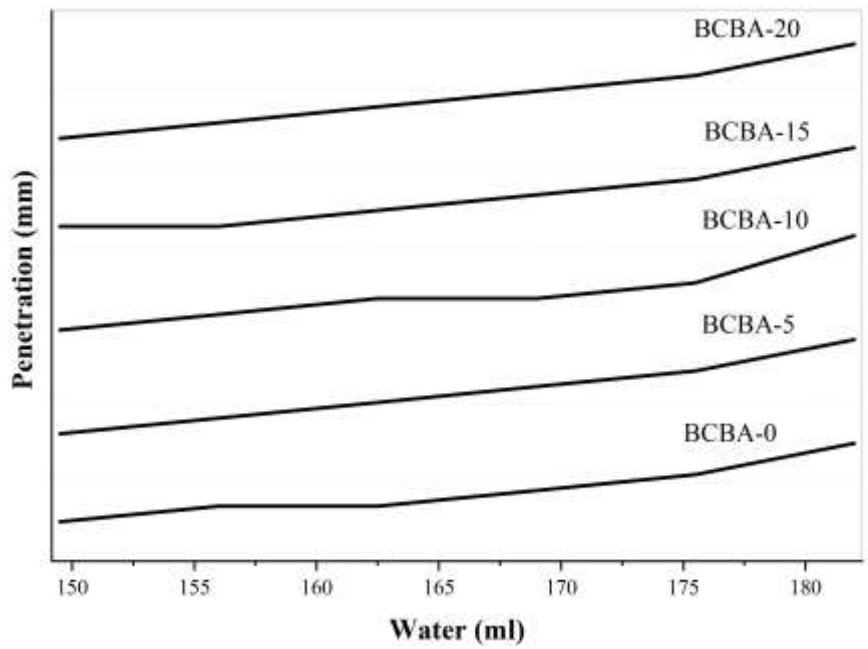


Figure 4.1 Consistency test result

The Fig 4.1. above shows the consistency for different Water amount to give a good concrete paste. Vicat apparatus has been used to determine the penetration from percentage 23% to 28%. At 28% for the sample between 9 to 11mm to call it consistent ASTM C33. The result shows the amount of water to be used was 28% of cement by weight of cement. The replaced percentage of the combined bagasse and CBA 5% to 20% entails the consistency for the amount of water is 28% of the weight of cement resulting in the value of 9- and 10-mm. Percentage replacement increases the amount of water needed to mix the paste also increases (Mutua, B. etal., (2016).

4.2.1.2. Soundness Test

A soundness test of hydraulic cement was carried out to determine the expansion of cement. It provides the soundness of cement. As per ASTM C187, the soundness test has been done for hydraulic cement and blend cement for combined bagasse and cattle bone ash. And the result obtained from the laboratory test is listed below.

Table 4.7 Soundness Test

Trial No	Water (ml)	Average Expansion (mm) BCBA -0	Average Expansion (mm) BCBA -5	Average Expansion (mm) BCBA -10	Average Expansion (mm) BCBA -15	Average Expansion (mm) BCBA -20
1	182	1	1	1	2	2

The average expansion of cement and blended cement shows that the materials are sound. but for the percentage replacement of 15%, the average expansion is 2mm, which entails that as the percentage increases the average expansion of the blended cement increases.

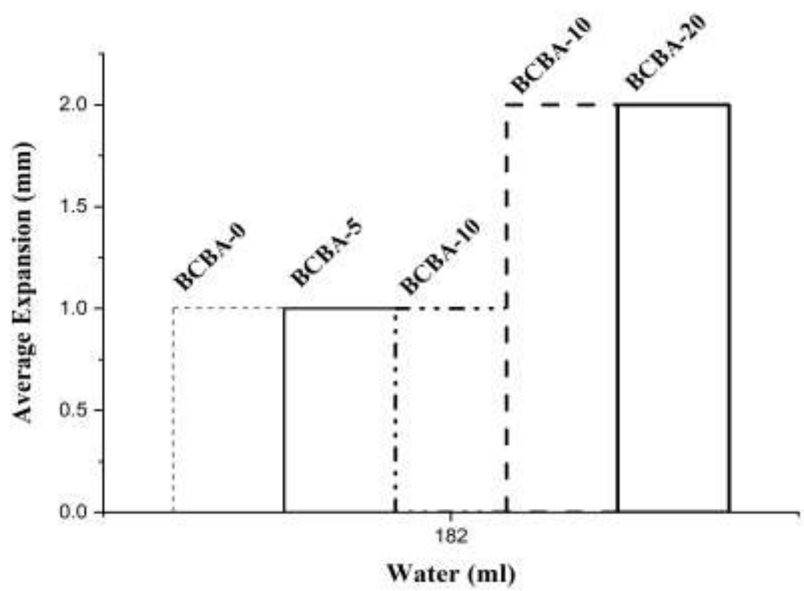


Figure 4.2 Soundness test result

The result shows that the hydraulic cement and blended cement are sound. For hydraulic cement, the average expansion result is 1mm. The cement used in the study Dangote cement with a cement grade of 42.5 is sound. The replaced BCBA with the percentage of 5% and 10% result shows the average expansion is 1mm the same as the hydraulic cement. But as the percentage replacement of 15% to 20% result shows the average expansion increases from 1mm to 2mm. As per ASTM C187, the expansion of pastes does not exceed 10mm and the result of the pastes fulfils the specification.

4.2.1.3. Initial and Final Setting Time

4.2.1.3.1. Initial Setting Time

Initial setting time is the time required for hydraulic cement to reach a point were starting to carry minor loads.

Table 4.8 Initial and final setting time

Designation	Penetration (mm)	Initial setting time (min)	Penetration (mm)	Final setting time (mm)	Remark
BCBA-0	25	42	1	345	
BCBA-5	25	55	1	352.5	
BCBA-10	25	67.5	1	360	
BCBA-15	25	75	1	357.5	
BCBA-20	25	86.25	1	375	

The above laboratory test result listed in table 4.8 shows the initial and final setting time of the concrete with different percentages. The test has been conducted as per ASTM C191, For the control mix of concrete, the initial setting time is minimal compared to the others. But the final setting time of the controlled mix is greater than the blended cement for different percentages. As the percentage of combined SBA and CBA increases the initial setting time also increases and it is true for the final setting time. Different trials were taken to determine the initial and final setting time of the cement and blended cement with a different replacement but the scatter diagram below shows the initial setting time at 25mm penetration and final setting time for 1mm penetration for percentage replacement of combined SBA and CBA ranging from 0 to 20 percent.

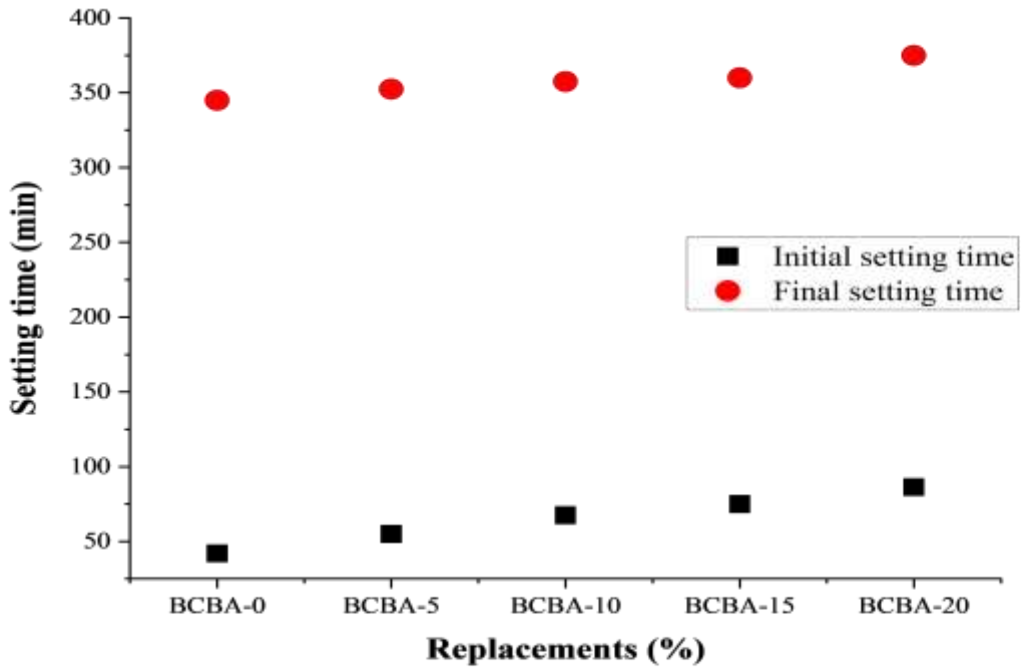


Figure 4.3. Distribution of initial and final setting time

According to ASTM C191, the initial setting time can be found by interpolating for the penetration of 25mm and the final setting time for penetration of 1mm and below for different replacements. As the above fig 4.3. shows the controlled mix has a minimum initial setting time compared to the other blended cement with combined SBA and CBA. The percentage of replacement increases from 0 to 20 percent the expected initial setting time also increases (Mutua, B. etal., 2016). Thus, the controlled mix loses its plasticity before blended cement loses its plasticity. While the final setting time of the controlled mix is also lower than that of the blended cement of combined SBA and CBA as percentage replacement increases. The final setting time is the time at which the cement paste completely loses its plasticity and starts to carry minor loads. The above graph shows that the final setting time increases as the percentage replacement amount of combined SBA and CBA is introduced to the cement. The C_3S and C_3A are responsible compounds in fastening the chemical reaction of cement paste reaction. The C_3S amount increases as combined SBA and CBA added more to the cement which resulted in a maximum final setting time.

4.2.2. Fine Aggregate Properties

Fine aggregates are an aggregate smaller than 4.75mm sieve size. To determine their physical properties gradation, bulk density, specific gravity and water absorption test are carried out in the laboratory.

4.2.2.1. Gradation of Fine Aggregate

Gradation is the particle size distribution of the aggregate as determined by sieve analysis. In the table below find aggregate sieve analysis has been carried out. Total sample weight for the sieve analysis taken 1000g.

Table 4.9 Sieve analysis of fine aggregate

Sieve no.	**Wt. of sieve (g)**	**Wt. Sieve + retain (g)**	**Retain (g)**	**Retain (%)**	**Cum. retain**	**Passing (%)**	**ASTM min. limit**	**ASTM max. limit**	**Remark**
9.5mm	-	-	-	-	-	100	100	100	Ok
4.75mm	410	460	50	5	110	95	95	100	Ok
2.36mm	460	560	100	10	180	85	80	100	Ok
1.18mm	450	630	180	18	330	67	50	85	Ok
600µm	410	670	260	26	590	41	25	60	Ok
300µm	370	600	230	23	820	18	5	30	Ok
150µm	270	380	110	11	930	7	0	10	Ok
Pan	550	620	70	-	-	-			
Total			**1000**		**2870**				
FM = 2870 / 1000 = 2.87									

The gradation satisfies the ASTM C33 grading limit and the fineness modulus of the fine aggregate used is 2.87. The grade of the fine aggregate is crucial in maintaining the strength and other properties of concrete. The gradation results in the above Table 4.9 above satisfy the standard of grading for ASTM C33. Thus, the fine aggregate used in the study affects positively the strength and other properties which require gradation for improvement. Fig 4.4. below shows briefly the gradation result of the fine aggregate (sand).

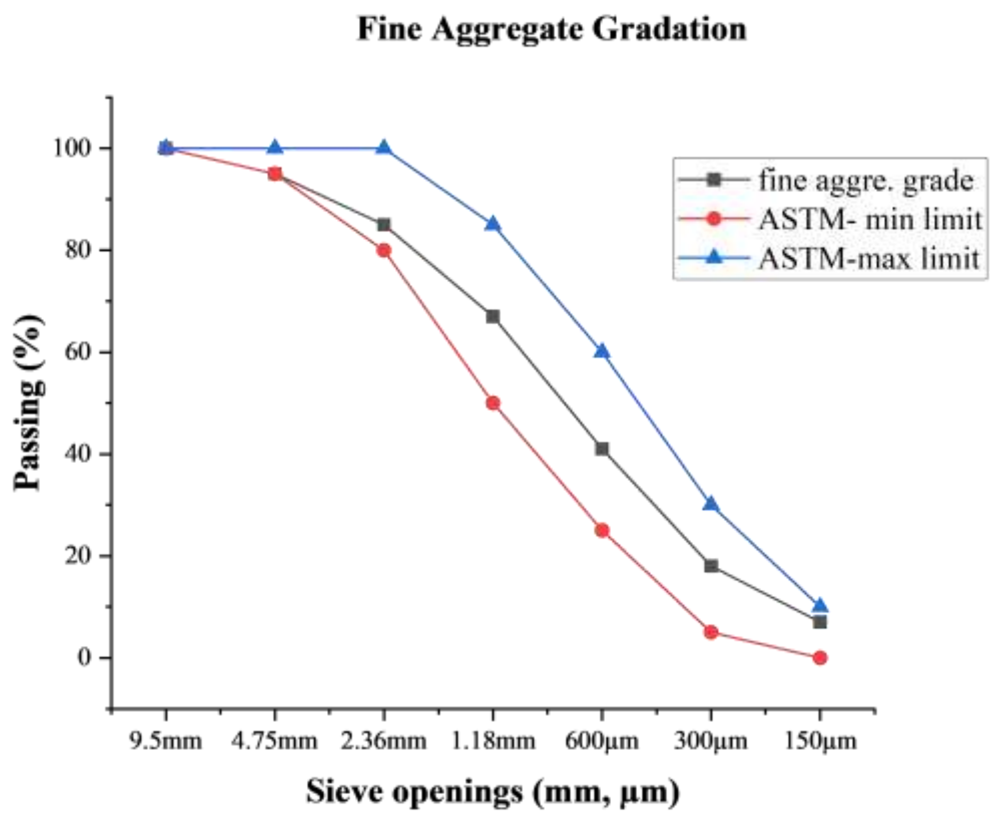


Figure 4.4 Gradation of Fine Aggregate and ASTM C33 Grading Limit

Figure 4.4 shows the gradation of fine aggregate and the ASTM C33 fine aggregate grading limit. The fine aggregate gradation shows that the amount of fine aggregate used for the study fulfils the ASTM standard.

4.2.3. Coarse Aggregate Properties

Coarse aggregate is one of the constituents of concrete having a maximum percentage on the concrete mix. Tests conducted for the physical property of coarse aggregates are gradation.

4.2.3.1. Gradation for Coarse Aggregate

Coarse aggregate is an aggregate larger than 5mm. gradation was carried out to determine the gradation of the coarse aggregate. The sample of coarse aggregate taken for gradation is 3000g riffling the 10 kg coarse aggregate two times. Gradation for coarse aggregate has been carried out under ASTM C33 standard. To facilitate better gradation a sample of 10 kg was taken and riffled using a riffle box two times. 3kg of coarse aggregate was taken for the gradation property test. The sieve size used for fine aggregate is quite different from that of coarse aggregate. The sieve size openings for coarse aggregate used were for that of ASTM standards which are 37.5mm, 25mm, 19mm, 14mm, 9.5mm and 4.75mm.

Table 4.10 Gradation for coarse aggregate

Sieve no.	**Wt. of sieve (g)**	**Wt. Sieve + retain (g)**	**Retain (g)**	**Retain (%)**	**Cum. Retain**	**Passing (%)**	**ASTM min. limit**	**ASTM max. limit**	**Remark**
37.5mm	1450	1500	50	1.67	1.67	98.33	100	100	Ok
25mm	1280	1430	150	5	6.67	93.33	95	100	Ok
19mm	1390	3060	1670	55.67	62.34	37.66	25	85	Ok
14mm	1180	2160	980	32.66	95	5	0	60	Ok
9.5mm	1230	1380	150	5	100	0	0	30	Ok
4.75mm	980	980	0	0	100	0	0	10	Ok
Pan	780	780	-	_	_	_			
Total		**Total**			365.68				
FM = 365.68/100 = 3.66									

Conducting the sieve analysis for coarse aggregate used in the study satisfies the ASTM C 33 standard for all sieve opening but don’t satisfy sieve opening of 25mm. The coarse aggregate used in the study has a 3.66 fineness modulus. Thus, at 25mm the coarse aggregate determined the percentage passing of 93.33% but the minimum ASTM limit grade is 95%. But other sieve openings fulfil the ASTM standard hence the coarse aggregate is accepted and prepared for concrete production. The graph below shows the gradation of percentage passing of the coarse aggregate and ASTM minimum limit and maximum limit. The Maximum size of aggregate is also obtained during the gradation test which is 37.5mm. nominal maximum size of the aggregate is also 37.5mm. figure 4.5. shows the distribution of coarse aggregate in the given sieve size openings vs percentage passing of the coarse aggregate, ASTM min limit and ASTM max limit.

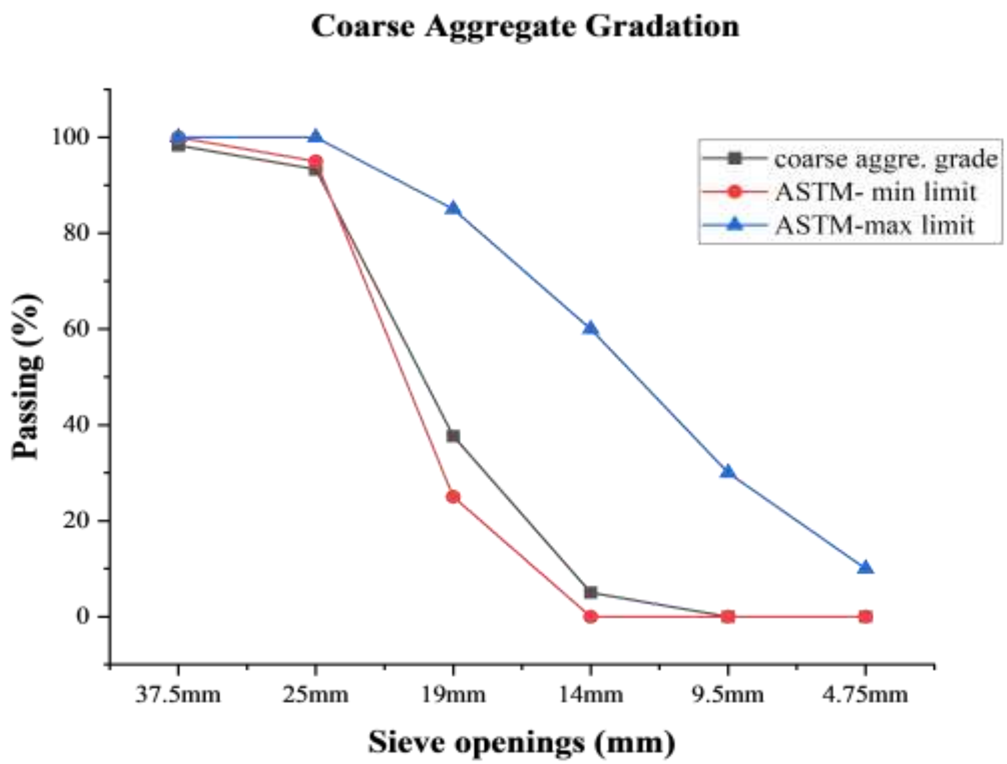


Figure 4.5 Gradation of Coarse Aggregate and ASTM C33 Grading Limit

4.3. Fresh and Mechanical Property

4.3.1. Fresh Concrete Property

workability of concrete is the property of concrete which is determined by the state of freshness after mixing concrete. it is used to check the workability of freshly made concrete for easy placement of concrete. According to ASTM C143, the workability test has been carried out for the using slump test. The cone with a diameter of 200mm at the bottom, 100mm at the top and a height of 300mm. The workability determination is crucial in providing fresh concrete property whether or not the added pozzolana can easily be molded into the desired shape without creating negative effects. The workability test shows the effect of consistency of cement or blended cement. For fresh concrete, the workability test has been carried out for each mix of concrete. The following workability test result has been summarized in the table below.

Table 4.11 Slump test results

Replacements	Slump test result (mm)
BCBA-0	50
BCBA-5	42
BCBA-10	30
BCBA-15	24
BCBA-20	18

The above Table 4.11. shows the slump test result for various replacements. As the percentage replacement increases from 5% to 20% the slump test result decreases. This shows that as the percentage increases the workability of the concrete decreases. The workability of the concrete decreases due to the availability of a high amount of silica (SiO_2) in the SBA and a high amount of phosphorous Penta oxide (P_2O_5) in the CBA.

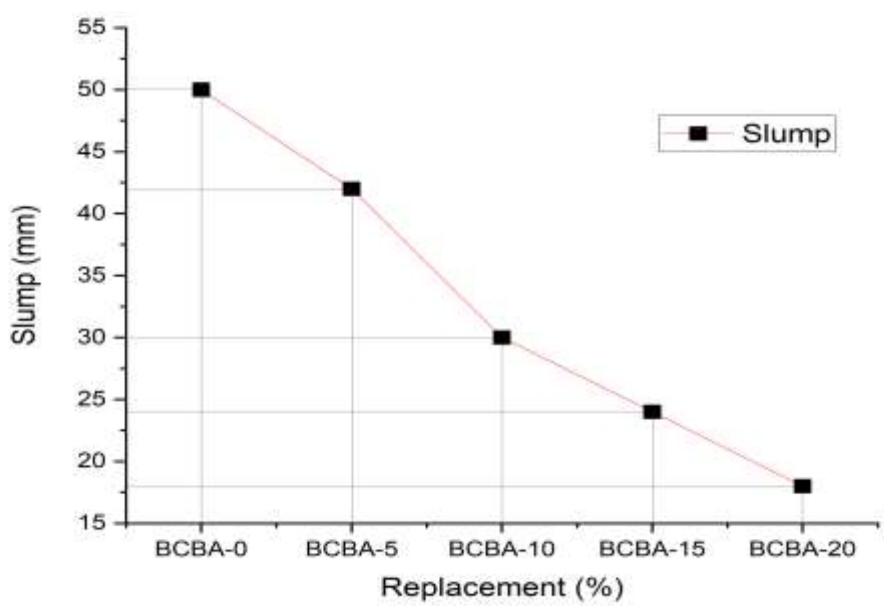


Figure 4.6 Workability of concrete

The porous surface of CBA highly absorbs water resulted in decreasing the workability of concrete as percentage replacement increases Olaoye, R., et al. (2020). Figure 4.6 shows the slump of controlled mix and other replacements. As the slump of concrete increases, the workability of the concrete decreases. Thus, the slump test result of BCBA-20 shows minimum and BCBA-0 is maximum. This shows that BCBA-0 is more workable than the other mixes. The workability of concrete is important to check if the mix has enough paste or not.

4.3.2. Mechanical Property of Concrete

Hardened concrete property is the basic property in which concrete is tested after hardened and passed fresh properties. This study carried out compressive strength and tensile strength for hardened concrete.

4.3.2.1. Compressive Strength

A compressive strength test was carried out in the laboratory using a Compressive test machine for different ages of concrete. In table 4.12. below shows the average compressive strength test result as per ASTM C39 standard.

Table 4.12 Average compressive strength test result

Age of Concrete	Average Compressive strength test result with different replacement				
	BCBA-0	BCBA-5	BCBA-10	BCBA-15	BCBA-20
3 days	26.73	26.96	27.34	24.84	22.64
7 days	27.58	28.49	28.94	26.25	24.92
14 days	30.87	32.17	34	29.5	27.12
28 days	35.58	37.23	39.22	33.02	29.8
56 days	39.31	40.19	41.92	33.82	30.28
90 days	42.48	42.25	43.00	34.02	30.46

Table 4.12. above shows the compressive strength of concrete for different replacements of cement using a cube sample for the compressive strength test. The compressive strength test was carried out after preparing cube samples having (150*150*150) cubic millimeters each.

The figure below shows the compressive strength of the concrete at different replacements of cement. The strength development of the concrete increases gradually from the age of 3 days to 28 days. But after the age of 28 days, the strength development shows a smooth increase. The percentage replacement of cement with BCBA increases from 0% to 10% the compressive strength shows potential increment but when the 15% per cent of BCBA is introduced to the concrete, the compressive strength of the concrete suddenly decreases.

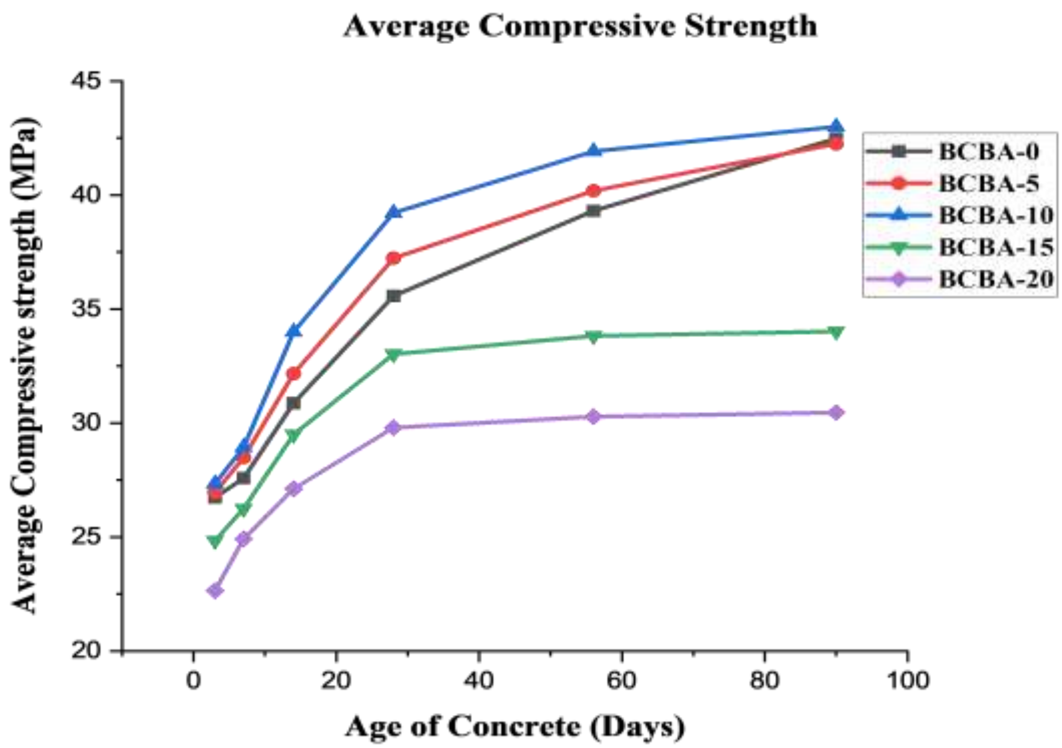


Figure 4.7. Average compressive strength of the concrete

The above figure 4.7 shows the compressive strength test results in MPa for different percentage replacements at different curing ages of concrete. The BCBA-5 and BCBA-10 in the graph show better improvement in compressive strength. But BCBA-15 and BCBA-20 don't show any improvement compared to the controlled mix. BCBA-10 and BCBA-10 show compressive strength improvement at an early age for the concrete due to the presence of a high amount of C_3S compared to a controlled mix. At the age of 90 days, the compressive strength of the controlled mix increases but BCBA-10 still has greater compressive strength and BCBA-5 has less compressive strength. The compressive strength increases at the age of 90 days for the controlled mix (BCBA-0) due to the availability of a high amount of C_2S.

Analyzing the development of the compressive strength has significance in showing the concrete compressive strength development using combined SBA and CBA. The potential development of compressive strength at different ages compared to the controlled mix in percentage has listed below in table 4.13.

Table 4.13. Potential development of compressive strength

Age of Concrete	(%) increment or decrement of compressive strength				
	BCBA-0	BCBA-5	BCBA-10	BCBA-15	BCBA-20
3 days	0	0.43	1.13	- 3.67	- 8.28
7 days	0	1.62	2.41	- 2.47	- 5.07
14 days	0	2.06	4.83	- 2.27	- 6.47
28 days	0	2.27	4.87	- 3.73	- 8.84
56 days	0	1.11	3.21	- 7.51	- 12.98
90 days	0	- 0.27	0.61	- 11.06	- 16.48

The above Table 4.13. shows the compressive strength development compared to the control mix. The negative sign (-) shows the reduction of compressive strength development in percent. At the age of 3 days, the concrete shows the highest compressive strength having 1.13% development for 10% replacement compared to the control mix. But, for 15% and 20%, the development shows no improvement for the concrete. While for 5% replacement better development of compressive strength was observed as 0.43% development compared to the controlled mix. At the age of 7 curing days, the concrete exhibits potential development of compressive strength for 5% and 10% with 1.62% and 2.41% respectively. On the other hand, the compressive strength of concrete doesn’t show any development for 15% and 20% percentage replacement. The same conditions were observed for the laboratory test results of the concrete at the age of 14, 28 and 56 days. But, at the age of 28 days, the compressive strength development of 5% and 10% is the highest compared to other age concrete. The concrete compressive strength development was decreasing for the curing age of 56 and 90 days. F*ig 4.8.* shows potential development of compressive strength of concrete for BCBA-0, BCBA-5 and BCBA-10 replacement at different concrete ages.

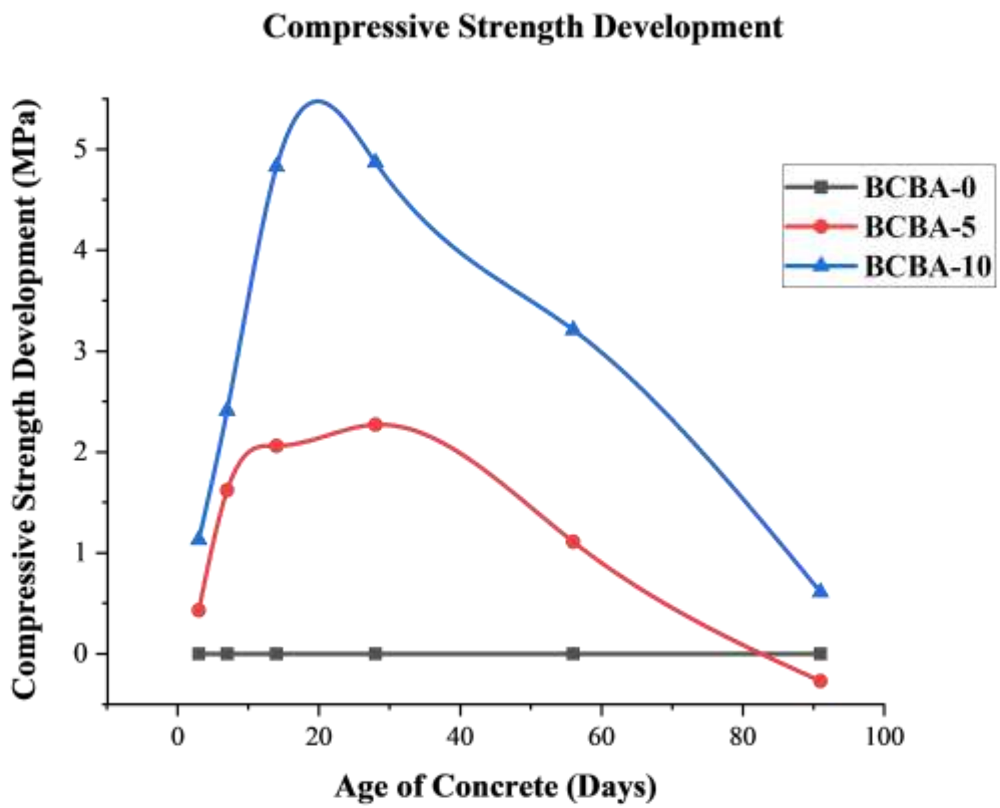


Figure 4.8 Compressive strength development

The above figure 4.8 clearly shows the development of the compressive strength test for BCBA-5 and BCBA-10 compared to the controlled mix of BCBA-0. From 0 to 20 days curing age, BCBA-10 shows increased compressive strength development of concrete due to the availability of a high amount of C_3S compared to BCBA-0. Then it slightly decreases its compressive strength development due to the low amount of C_2S which responsible compound to increase the compressive strength of concrete in a long term. For replacement of BCBA-5, the concrete exhibits an increased compressive strength development from curing age of 0 to 28 days and it falls again as BCBA-10 mainly due to the percentage occurrence of the compounds C_3S and C_2S in the blended cement. Thus, the amount of C_3S available in BCBA-10 is greater than the BCBA-5 replacement. At the curing age of concrete is 90 days, the compressive strength of BCBA-5 shows less than the controlled mix BCBA-0 because the occurrence of C_2S in BCBA-0 is greater than BCBA-5 replacement in the cement. Generally, BCBA-5 and BCBA-10 can be used to attain the early time strength of concrete. Therefore, the application of combined SBA and CBA to cement can improve concrete com1pressive strength up to 10% replacement. it can be considered as the optimum replacing percentage because the BCBA-15 and BCBA- 20 concrete don't improve the compressive strength compared to the controlled mix BCBA-10.

4.3.2.2. Tensile Strength

The tensile strength test has been conducted in the laboratory test using the splitting test method as per ASTM C469. The average tensile strength test result is shown in table 4.14 below.

Table 4.14 Average Tensile strength test result

Age of Concrete	Average Tensile strength test results with different replacement				
	BCBA-0	BCBA-5	BCBA-10	BCBA-15	BCBA-20
3 days	3.58	3.67	3.79	3.42	3.12
7 days	3.99	4.27	4.48	3.68	3.33
14 days	4.56	4.94	5.43	4.08	3.71
28 days	5.4	5.88	6.1	4.56	4.16
56 days	6.53	6.84	7.2	5.25	4.94
90days	7.24	7.82	8.2	5.69	5.31

Table 4.14 above shows the result of the experimental tests carried out for tensile strength using the splitting test method. The graph below shows the Tensile strength of the concrete at different replacements of cement ranging from 0 to 20 percent. The potential tensile strength development of the concrete increases from the curing age of 3 days to 90 days. But compared to the controlled mix BCBA-5 and BCBA-10 shows improvement in tensile strength development. While no improvement was observed for BCBA-15 and BCBA-20.

The graph below shows the average tensile strength of concrete for different replacements at different ages of concrete.

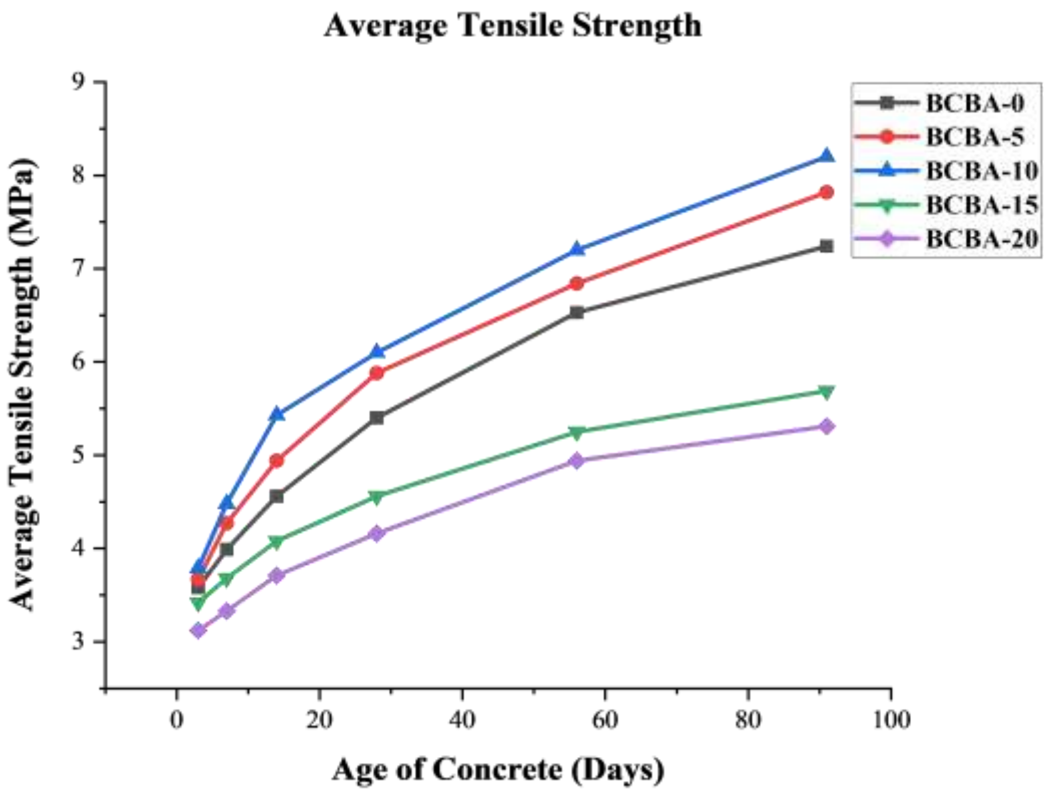


Figure 4.9 Average Tensile Strength

The above figure 4.9. shows the average tensile strength at different ages of concrete. It shows an increase in tensile strength as the age of concrete increases. BCBA-10 shows more tensile strength attainment compared to other replacements. BCBA-15 and BCBA-20 show that minimum result compared to BCBA-0 replacement. While BCBA-5 and BCBA-10 show strength improvement compared to the controlled mix. But the tensile strength test is very low which needs additional material steel to increase the tensile strength. Adopting the combined SBA and CBA to cement up to 10% enhances and provides concrete that improves tensile strength. but the percentage replacement increases above 10 per cent the tensile strength tends to decrease below the controlled mix. The development of tensile strength has been observed from the laboratory test results. Excel sheet has been used to determine the development of tensile strength of concrete for different replacements compared to a controlled mix. The development has been calculated by making BCBA-0 zero.

Table 4.15 Potential development of tensile strength

Age of Concrete	(%) Development of tensile strength				
	BCBA-0	BCBA-5	BCBA-10	BCBA-15	BCBA-20
3 days	0	1.24	2.85	- 2.29	- 6.87
7 days	0	3.39	5.79	- 6.26	- 10.22
14 days	0	4.2	12.77	- 2.82	- 7.42
28 days	0	4.26	9.32	- 10.66	- 13.92
56 days	0	1.92	3.5	- 7.81	- 10.83
90 days	0	1.5	2.8	- 10.46	- 13.87

The above table 4.15. shows the potential development of tensile strength compared to the control mix. At the age of 3 days, concrete has a potential development of tensile strength for combined SBA and CBA replacements of cement for 5% and 10% is 1.24% and 2.85% respectively. But 15% and 20% have shown no strength development instead the controlled mix tensile strength shows 2.29% and 6.87% strength development compared to 15% and 20% respectively. For concrete at age of 7, 14, 28, 56 and 90 days the concrete potential tensile strength development for 5% and 10% while no tensile strength development for 15% and 20% as shown in the above table. the percentage goes from 5% to 10% and is considered to improve the tensile strength, the other hand-controlled mix shows improved tensile strength for 15% to 20% replacements. At age 28 and 90 days, the concrete develops 6.09%, and 7.75% increments for tensile strength at 10% replacements respectively. The improvement of tensile strength increases by 5% and 10 % compared to the control mix. Therefore, Providing BCBA up to 10% enhances the tensile strength of normal concrete. The S-line graph below shows the splitting tensile strength development of BCBA-5 and BCBA-10 compared to the BCBA-0 which is the controlled mix.

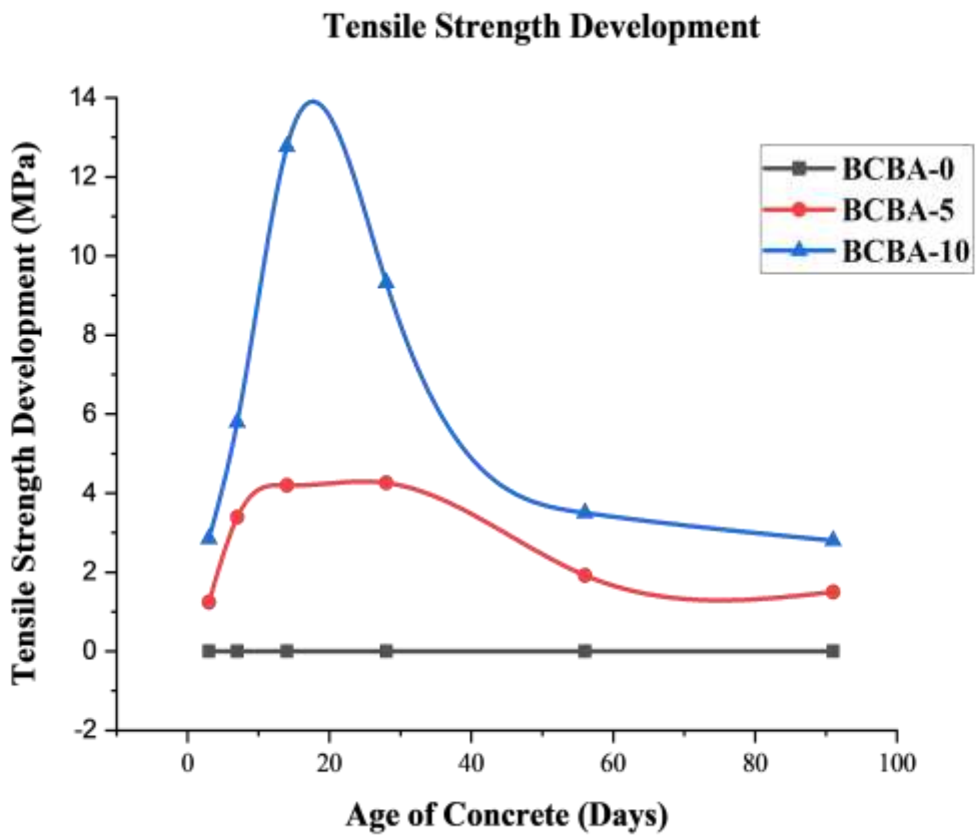


Figure 4.10 Tensile strength development

The above S-line curve graph shows tensile strength development compared to a controlled mix. As shown in the above graph the S-line curve for 5% and 10% shows that splitting tensile strength development is improved compared to the controlled mix as the concrete age increases from 3 days to 90 days. Combined SBA and CBA of 10% replacement of cement show the highest curve of splitting tensile strength development of the concrete compared to the controlled mix and 5% replaced concrete with combined SBA and CBA.

4.4. Microstructural Property of Concrete

4.4.1. XRD Analysis (X-ray diffraction)

XRD test has been conducted in Adama science and technology university laboratory. The test has been carried out for the range between 10 to 80 degrees of two thetas (2Θ). Scherrer Equation was developed in 1918, to determine the nano crystallite size (D) by XRD radiation of wavelength λ (nm) from measuring the full width at half maximum of peaks (β) in radian located at any 2θ in the pattern. The shape factor of K can be taken in a range of 0.62 to 2.08 and is usually taken as about 0.9 (Monshi, A., *2012*). Crystalline size of nanoparticles can be computed as:

$$\mathbf{D}= \frac{\lambda k}{\beta cos\Theta} \text{--Equation 5}$$

The crystallite size 'D' of a material can be defined by the Scherrer equation for the line broadening of the peak. where λ is the wavelength of the X-ray; β, FWHM width of the diffraction peak; θ, diffraction angle; and k, constant. The average grain size of particles can be determined by this equation (Scherrer, P. 1918). Fig 4.11. shows the XRD analysis result for BCBA-0, BCBA-10 and BCBA-20 for 28 days of curing age of concrete. The peaks observed for the 2 theta degrees have been shown.

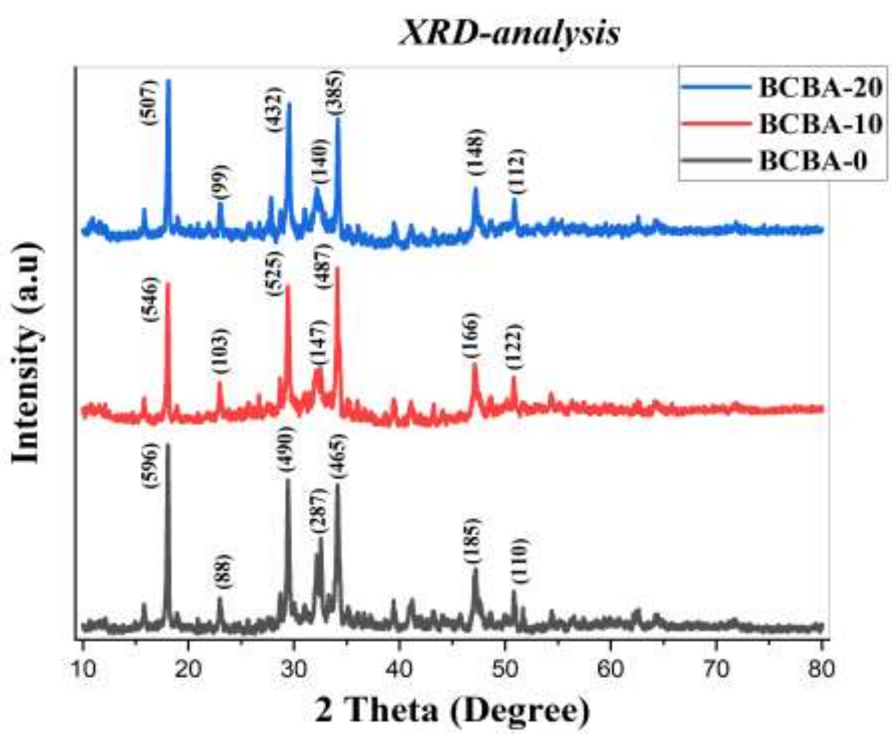


Figure 4.11. XRD analysis for 0%, 10% and 20% replacement for 28 days of curing

Fig 4.11. shows the peaks observed in the XRD analysis. The same patterns but small changes in peak values have been seen which indicates the same compounds observed in FT-IR analysis in fig 4.12 below. The peaks change was due to the percentage addition of SBA to the cement. Using origin pro software analysis, the crystalline size of concrete pastes for BCBA-0, BCBA-10 and BCBA-20 at a curing age of 28 days has been calculated. Using the values of 2 thetas and FWHM, the crystallite size of the cement and blended cement paste with combined SBA and CBA has been determined using the Scherrer equation. The Scherrer equation was used to calculate the crystallite size of the nanoparticle for the 2 theta values and full width at half maximum intensity (FWHM) values extracted from the values of intensity at peak. Table 4.16. indicates the result of 2 theta and FWHM values for the peak observed using origin pro software and the calculation has been performed using an Excel sheet.

Table 4.16 Average crystallite size

Mixes	Scherer constant (k)	X-ray wavelength (λ)	Peak positions (2Θ)	FWHM (β)	Crystallite size (D in nm)	Average crystallite D (nm)
BCBA-0	0.9	1.5406	18.04398	0.03343	2.41E+03	2.56E+03
			29.44045	0.02958	2.78E+03	
			32.36089	0.03213	2.57E+03	
			34.12865	0.02431	3.42E+03	
			47.19695	0.05322	1.63E+03	
BCBA-10	0.9	1.5406	18.07861	2.63E-02	3.06E+03	2.41E+03
			29.49549	0.02298	3.57E+03	
			34.15325	0.04356	1.91E+03	
			31.34694	0.05122	1.61E+03	
			47.23725	0.04577	1.89E+03	
BCBA-20	0.9	1.5406	18.03631	0.04128	1.95E+03	
			29.42821	0.03668	2.24E+03	
			34.12923	0.03232	2.57E+03	
			47.17083	0.03624	2.39E+03	
			50.82939	0.03412	2.58E+03	2.35E+03

Table 4.16. above shows the crystallite size of nanoparticles (cement and cement having combined SBA and CBA) at 28 days of curing age of concrete. BCBA-0 have an average

crystallite size of cement at a curing age of 28 days of 2560nm. While BCBA-10 and BCBA-20 show average crystallite sizes of 2410nm and 2350nm respectively. The average crystallite size of the controlled concrete paste is greater than that of BCBA-10 and BCBA-20. The crystallite or grain size of materials has a significant effect on the strength of concrete. As the size of grains decreases significantly the strength of the concrete increases (Aytekin, B., et al. 2022). The improved strength of concrete has been seen in the percentage replacement of BCBA-10. But as the age of concrete increases, the compressive strength development also decreases, this effect was due to its hydration of C_2S compared to BCBA-0.

X-ray diffraction also entails the formation of compounds at 28 curing ages of concrete. the fig 4.12 shows the compounds formed for 0%, 10% and 20%.

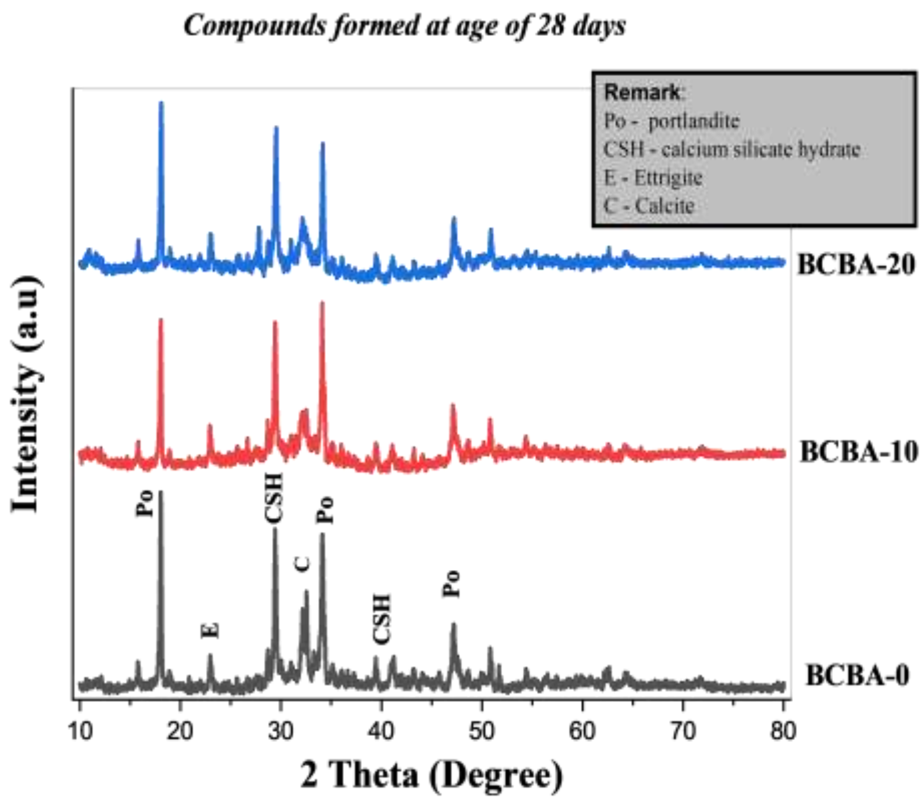


Figure 4.12. XRD analysis for compounds formed for 28 curing ages of concrete for 0%, 10% and 20% replacement.

The XRD analysis also shows that compounds formed after hydration process. As the above graph 4.12. shows the basic compounds formed at 28 curing ages of concrete.

Referring to Rustandi, A., et al. (2018) and Yu, Z., et al. (2013) compounds seen after the analysis of XRD are portlandite (^{-}OH), Quartz (Q), ettringite (E), Calcium silicate hydrate (C-S-H), and calcite $CaCO_3$. The calcium silicate hydrate (C-S-H) of BCBA-10 shows highest peak indicated more C-S-H gel formation. The C-S-H gel improvement also improves the strength of concrete (Rustandi, A., et al. 2018).

4.4.2. FT-IR Analysis (Fourier-Transform Infrared Spectroscopy)

FT-IR analysis has been conducted in the Bahir Dar institute of technology laboratory. The test has been carried out for the range of wave numbers 4000 CM^{-1} to 400 CM^{-1}. FT-IR test determines the functional group of the paste formed at different ages of concrete. The blended paste in percentage replacement of 0%, 10% and 20% were conducted for the 28 days age of concrete. the table below shows the vibrational band peaks collected from the result.

Table 4.17 Vibrational bands discovered for FT-IR analysis

BCBA-0, Bands (CM^{-1})	**BCBA-10, Bands (CM^{-1})**	**BCBA-0, Bands (CM^{-1})**	**Phases**	**References**
3779	3680	3692	Portlandite (OH^-)	Tantawy, M. A. (2017)
3276	3363	3397	Free water (OH^-)	Tantawy, M. A. (2017)
1632	1639	1630	Free water (OH^-)	Tantawy, M. A. (2017)
1411	1409	1413	Calcite ($CaCO_3$)	Tantawy, M. A. (2017)
956	964	956	C-S-H gel	Tantawy, M. A. (2017)
728	730	725	Alite (C_3S)	Tantawy, M. A. (2017)
500	-	-	Belite (C_2S)	Tantawy, M. A. (2017)

Table 4.17. shows the vibrational bands obtained from the analysis of FT-IR for controlled mix and concrete with partial replacement of combined SBA and CBA. As the band shows different compounds have been discovered from the peak values of FT-IR results. The combined vibrational band peaks show the paste exhibits the functional group as of the controlled mix.

Fig. 4.13. below shows the FT-IR analysis result of pastes at the age of 28 days of concrete for 0%, 10% and 20% replacements.

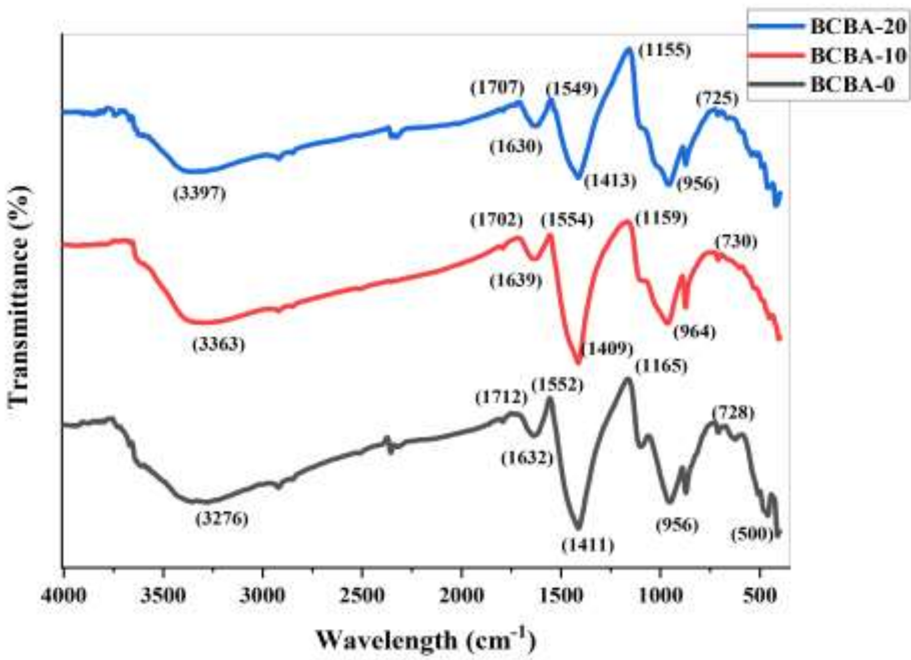


***Figure 4.13. FT-IR analysis for 28 days of concrete age at 0%, 10% and 20% replacements*.**

The above fig 4.13. shows FT-IR spectra of the concrete paste formed at the age of 28 days. The peaks observed in the vibrational bands of BCBA-0 are 500 CM^{-1}, 728 CM^{-1}, 956 CM^{-1}, 1165 CM^{-1}, 1411 CM^{-1}, 1552 CM^{-1}, 1632 CM^{-1}, 1712 CM^{-1} and 3276 CM^{-1} has been observed in all of the spectra (Smith, B., 2018). On the other hand, vibrational bands formed for BCBA-10 and BCBA-20 show a slight difference compared to BCBA-0. The vibrational band occurred at a wavelength peak of 500 CM^{-1} of BCBA-0 showing the occurrence of Belite (C_2S) (Tantawy, M. A. (2017). in the concrete paste compared to BCBA-10 and BCBA-20 responsible compound for strength development in a long time. According to Ylme'n, Alite (C_3S) compound is usually for between the vibrational peak bands at 950–1,100 CM^{-1} (Ylme´n et al. 2009). The FT-IR spectra analysis of BCBA-0, BCAB-10 and BCBA-20 shows the formation of Alite (C_3S) compound and responsible compound for the early time compressive strength of concrete. As the above figure. 4.13.

shows the vibrational band at 3276 CM^{-1}, 3363 CM^{-1} and 3397 CM^{-1} shows the O-H stretched availability of moisture in the paste during the age of concrete (Bakharev, T. 2005). The vibrational band of 1411 CM^{-1}, 1409 CM^{-1} and 1413 CM^{-1} indicates the compound $CaCO_3$ (calcite) presence and is used in fastening the setting time of the paste.

4.4.3. TGA (Thermogravimetric Analysis)

Thermogravimetric analysis has been carried out in Bahir Dar University, Institute of technology laboratory. TGA is used to determine the loss of mass due to the use of the materials as a result of the temperature change, compared to the controlled mix (BCBA-0). The fig 4.14. below shows the thermogravimetric analysis for mass loss of hardened concrete as a result of the change in temperatures.

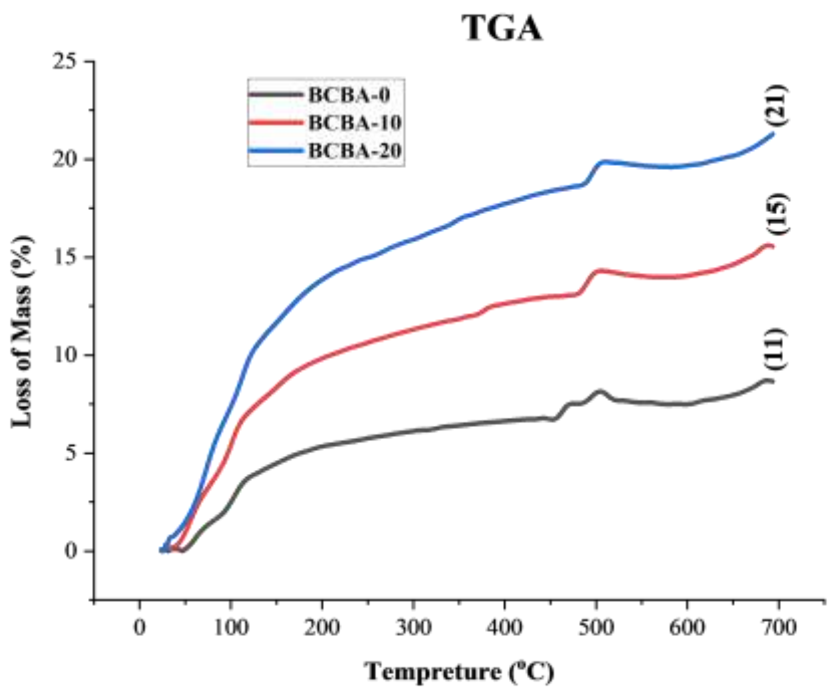


Figure 4.14 TGA analysis for BCBA-0, BCBA-10 and BCBA-20 at 28 days

The above graph in fig. 4.14. shows the loss of mass of BCBA-0, BCBA-10 and BCBA-20 for change in temperature (°C). the mass of the microstructural hardened concrete pastes for all mixes shows decreases in the mass as temperature increases. But the percentage reduction of mass is different. BCBA-0 has a potential decrease in mass as a result of the temperature change but its minimum compared to BCBA-10 and BCBA-20. This indicates that as the percentage replacement of cement by combining SBA and CBA increases the loss of mass increases. Therefore, using higher replacements for cement by BCBA is prone to thermal shrinkage.

In the first 100^{o}C to 300^{o}C, the mass loss is from moisture (free water) content in the hardened concrete paste. The specific gravity of SBA is less than CBA is less than OPC, and the absorption of moisture increases as the specific gravity of materials decreases. This has been seen in fig 4.14. releasing the absorption of moisture is increasing for BCBA-10 and BCBA-20 compared to the controlled mix (BCBA-0). On the other hand, CBA has a high amount of loss on ignition which is 10.92% and it is a responsible ingredient for mass loss of hardened concrete of paste in the replaced mix. After the temperature of 450^{o}C, the loss of mass results from the decomposition of compounds to form major compounds in the chemical reactions.

4.4.4. DTA (Differential Thermal Analysis)

In the laboratory of the Bahir Dar University Institute of Technology, differential thermal analysis has been done. The DTA analysis for temperature ranges from 0^{o}C to 700^{o}C has been calculated. DTA is used to identify the endothermic or exothermic nature of a process, as well as the temperature change, heat evolution, and reaction type. A temperature versus differential temperature map is created (DTA curve). Relative to the inert reference, changes in the sample, whether exothermic or endothermic, can be found. A DTA curve thus offers information on the changes that have taken place, including transitions, crystallization, melting, and sublimation. The heat capacity of the sample has no impact on the area under a DTA peak, which represents the enthalpy change. Fig 4.15. below indicates the reactions created as the temperature increases for BCBA-0, BCBA-10 and BCBA-20 pastes at the curing age of 28 days.

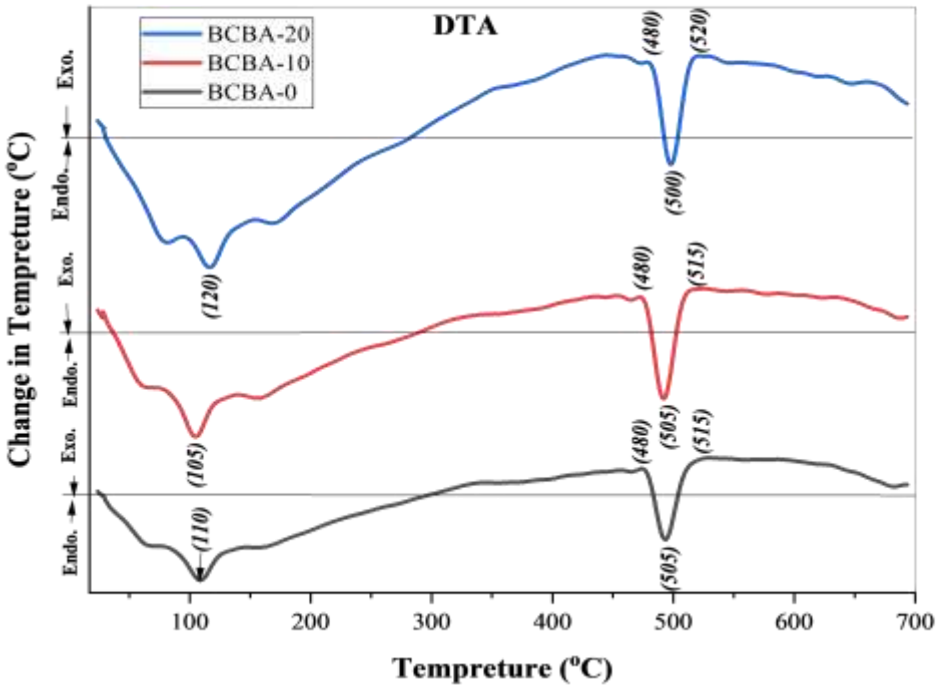


Figure 4.15 DTA for BCBA-0, BCBA-10 and BCBA-20 AT 28 days

Fig 4.15. above shows the change in temperature and reactions possessed by BCBA-0, BCBA-10 and BCBA-20 as the temperature increases from 0°C to700°C for 28 days of curing age of concrete. As the temperature increases from 0°C to 315°C the BCBA-0, BCBA-10 and BCBA-20 possess endothermic reactions seen in the above figure due to the breakdown of calcium silicate hydrate (the so-called C-S-H) of the sample. The peaks in the endothermic reaction show the decomposition of tobermole gel. Meanwhile, the pastes possess the change in reaction from endothermic to exothermic reactions.

As the temperature increases form 315°C to 495°C the pastes start to evolve heat and possess exothermic reactions. Breakdown of calcium hydro-oxide ($Ca(OH)_2$) takes place as the temperature increase from 495°C to 505°C and the reaction is endothermic. As soon as the temperature increases from 505°C it evolves to heat and goes exothermic reaction. Most of the time, the decomposition of calcite begins as CaO_3 decomposes into CaO and CO_2. The evolved heat enables the decomposition of $CaCO_3$ into CaO and CO_2 and suddenly absorbs for the temperature between and starts 495°C to 505°C endothermic reactions and after 505°C starts to take exothermic reactions up to 700°C.

The graph shows BCBA-20 has higher peaks at the temperature endothermic and exothermic reactions take place. This indicates that BCBA-20 possess higher enthalpy of heat compared to BCBA-0 and BCBA-10. On the other hand, due to its high enthalpy change higher loss of mass was incurred to the BCBA-20 as seen in fig 4.14. of TGA result. But BCBA-10 optimum peaks in the DTA curve, which makes it preferable to use as a partial replacement of cement in concrete production.

4.4.5. SEM Analysis (Scanning Electron Microscopy)

The microstructural behaviour of concrete affects the property of concrete. The strength of the concrete also depends on the microstructural formation of concrete. The morphological shape at 28 days of the age of the concrete has been determined in this study. A scanning electron microscope (SEM) has been carried out in Adama Science and Technology Laboratory. The analysis has been carried out at 28 days of the age of concrete for 0%, 10% and 20% replacement of the concrete mix. Graph 4.16. below shows the SEM result of different replacements.

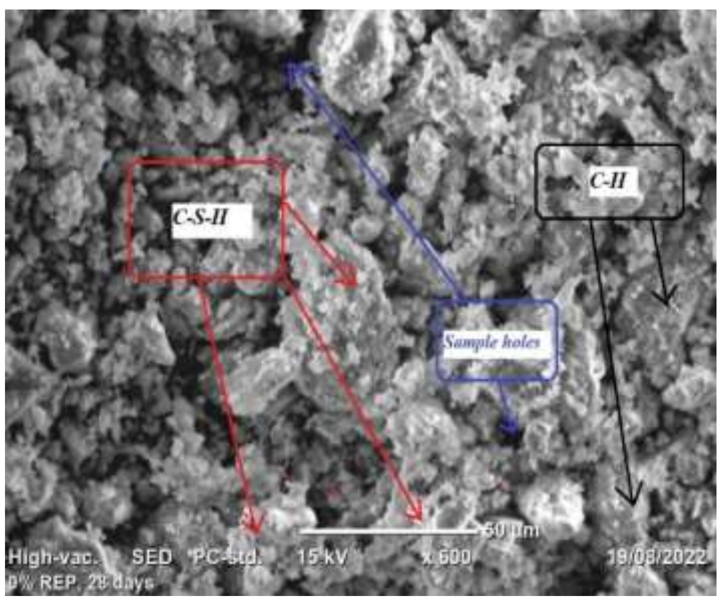
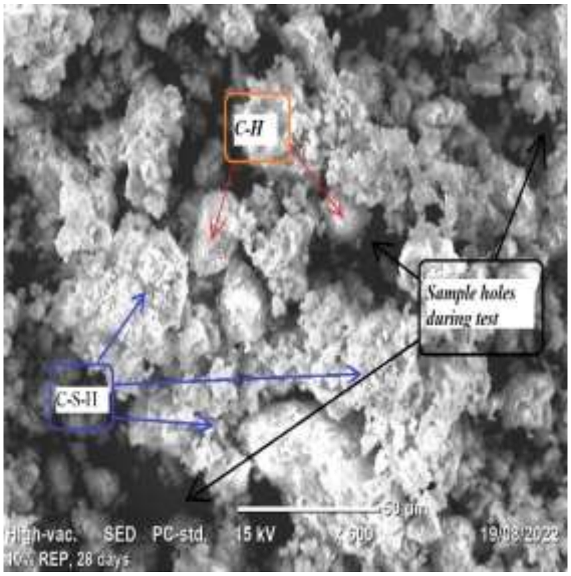


fig 4.16. (a) SEM result for BCBA-0 at 28 days

SEM result of controlled mix shows more C-H which left with out creating C-S-H (calcium silicate hydrate. The figure below shows the SEM result for blended with 10% and 20% of BCBA.



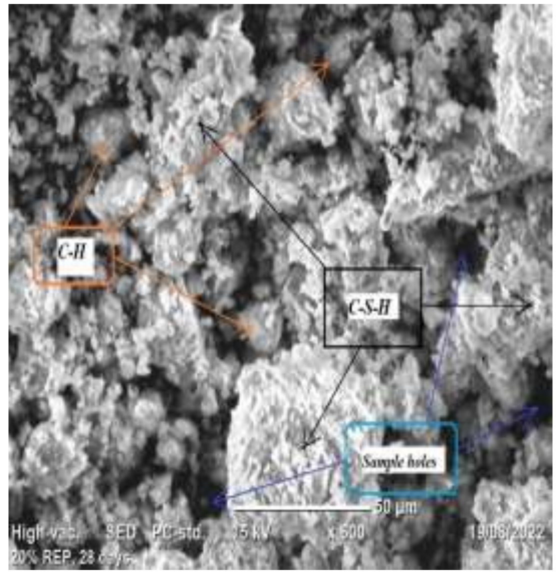


fig 4.16. (b). SEM of BCBA-10 at 28 days fig 4.16. (c). SEM of BCBA-20 at 28 days

Figure 4.16. SEM analysis of BCBA-0, BCBA-10 and BCBA-20 at 28 days

The SEM result shows the morphological shape of the paste at 28 curing ages of concrete for 0%, 10% and 20% replacements. Calcium silicate hydrate (CSH) is the major volume phase in the matrix of Portland cement concrete (Skinner, L. B., 2010). As shown in fig 4.13. the result shows the formation of C-S-H gel, C-H and sample holes. Microstructurally, BCBA-10 shows more formation of C-S-H gel which is calcium silicate hydrate as a result of reactions from the compounds C_3S and C_2S. the more C-S-H gel (tobermole gel) has been formed as a result of C_3S hydration reaction from the combined SBA and CBA availability. The hydration process of the paste is fast due to the availability Alite and aluminate which yields early strength attainment of compressive strength. Silicate chain morphologies contribute greatly to tensile strength (Jin, S., 2020). Not only compressive strength but also slight improvement of tensile strength was due to the addition of SiO_2 from SBA was responsible.

Generally, the C-S-H (tobermole gel) shows a sand-witched structure having an irregular shape (Jin, S., 2010). While C-H (portlandite) shows a plate-like structure. The addition of SBA and CBA to the conventional concrete indicates that the unreacted C-H presents in the BCBA-0 again reacts and creates more C-S-H gel, it can be seen in the SEM analysis of BCBA-10 and BCBA-20. Also, some dark area from the samples is indicated as hole as a result positioning of the sample in the SEM.

4.5. Cost Comparison between Conventional Concrete and Replaced Concrete

SBA and CB materials are waste materials used in this study as partial replacements for cement for concrete production. The initial cost to purchase the waste materials is considered zero but the calcination (energy cost) and labour (for collection of materials) cost of the waste materials has been considered in the analysis of the cost of concrete production per $1m^3$. The cost of partially replaced material combined with SBA and CBA has been compared to the traditional concrete-making materials. The analysis was conducted based on the current market price of ingredients of concrete. Assumptions have been made for Costs of transportation, equipment, labour cost (production of concrete), overhead costs and maintenance and other costs as constants. The current market price of Dangote cement, OPC 42.5 grade has been used in the study. The cost for sand and coarse aggregate is determined from the current market price associated with Hawassa crushing sites. The cost of SBA and CBA has been computed for labour cost associated to collect the raw material and energy cost compared to the Cement energy cost. The cement production process is highly energy intensive with approximately 3-4 GJ energy consumption per ton of cement produced from this 60% to 70% of the energy consumption comes from electricity (Amiri, A., & Vaseghi, M. 2014). The production of cement is an energy-intensive process. Typically, energy consumption accounts for 20-40% of the production costs of cement (Worrell et al., 2008). The average tariff of Ethiopian electricity for businesses and households shows 1.019 and 0.349 ETB per 1Kwh (Hassen. S, 2021). While 1Kwh of energy power equals the 3.6×10^{-3} GJ. The energy and labour cost of SBA and CBA per 1000kg is estimated to be 77.10 and 90.5 ETB respectively.

The current market price of materials other than SBA and CBA were collected for the date September 2 to September 4, 2022 G.C. by informal question. The table below shows the cost breakdown of ingredients according to the current market price.

Table 4.18. The current market price of ingredients

No.	Ingredients	Source	Price (ETB)/100kg	Unit price/kg
1	Cement	Dangote Cement	1300	1.3
2	SBA	Wunji sugar factory	7.10	0.0771
3	CBA	Hawassa, slaughterhouse	9.05	0.0905
4	Sand	Monopole sand site	620	0.53
5	CA	Monopole aggregate site	980	0.78
6	Water	Hawassa	2	0.02

The above table 4.18. indicates the current market price of ingredients. The current market price of SBA and CBA is seen as zero. But, tried to estimate the cost of SBA and CBA based on energy and labour costs for collection. Table 4.19. below shows the cost of materials per cubic meter of production of concrete and the cost difference between the concrete mixes.

Table 4.19. Cost of ingredients and cost differences per m³ of concrete for the replacements

Mix	Materials	Quantity (kg/m³)	Unit price (ETB/kg)	Price (ETB/m³)	Cost difference (%)
BCBA-0	Cement	394	1.3	512.2	0
	Sand	773.29	0.60	463.97	
	Coarse aggregate	1085.8	0.95	1031.51	
	Water	193.78	0.02	3.88	
	Total			**2011.56**	
BCBA-5	Cement	374.3	1.3	486.59	-0.60
	SBA	9.85	0.0771	0.76	
	CBA	9.85	0.0905	0.89	
	Sand	773.29	0.6	463.97	
	Coarse aggregate	1085.8	0.95	1031.51	
	Water	193.78	0.02	3.88	

	Total			**1987.60**	
BCBA-10	Cement	354.6	1.3	460.98	-1.21
	SBA	19.7	0.0771	1.52	
	CBA	19.7	0.0905	1.78	
	Sand	773.29	0.6	463.97	
	Coarse aggregate	1085.8	0.95	1031.51	
	Water	193.78	0.02	3.88	
	Total			**1963.64**	
BCBA-15	Cement	334.9	1.3	435.37	**-1.82**
	SBA	29.55	0.0771	2.28	
	CBA	29.55	0.0905	2.67	
	Sand	773.29	0.6	463.97	
	Coarse aggregate	1085.8	0.95	1031.51	
	Water	193.78	0.02	3.88	
	Total			**1939.68**	
BCBA-20	Cement	315.2	1.3	409.76	**-2.44**
	SBA	39.4	0.0771	3.04	
	CBA	39.4	0.0905	3.57	
	Sand	773.29	0.6	463.97	
	Coarse aggregate	1085.8	0.95	1031.51	
	Water	193.78	0.02	3.88	
	Total			**1915.73**	

The above table 4.19. shows the costs of ingredients per 1 m^3 of concrete production and the cost differences by making the cost of conventional concrete constant or zero. The cost comparison shows the change in the cost of concrete as a replacement of SBA and CBA waste applied to the concrete. A negative sign (-) shows the decrease in the cost of concrete for the application of SBA and CBA as partial replacement of cement. When cement replacement with combined SBA and CBA was taken for BCBA-10 show a 1.21%

reduction in concrete production cost per cubic meter. While BCBA-20 indicates a 2.44% reduction in the cost of concrete production per cubic meter. BCBA-5 and BCBA-15 also show the reduction of costs by 0.6% and 1.82% for one cubic meter of concrete production. Graph 4.17. below shows the costs needed to produce concrete per cubic meter and the linear reduction in percentage.

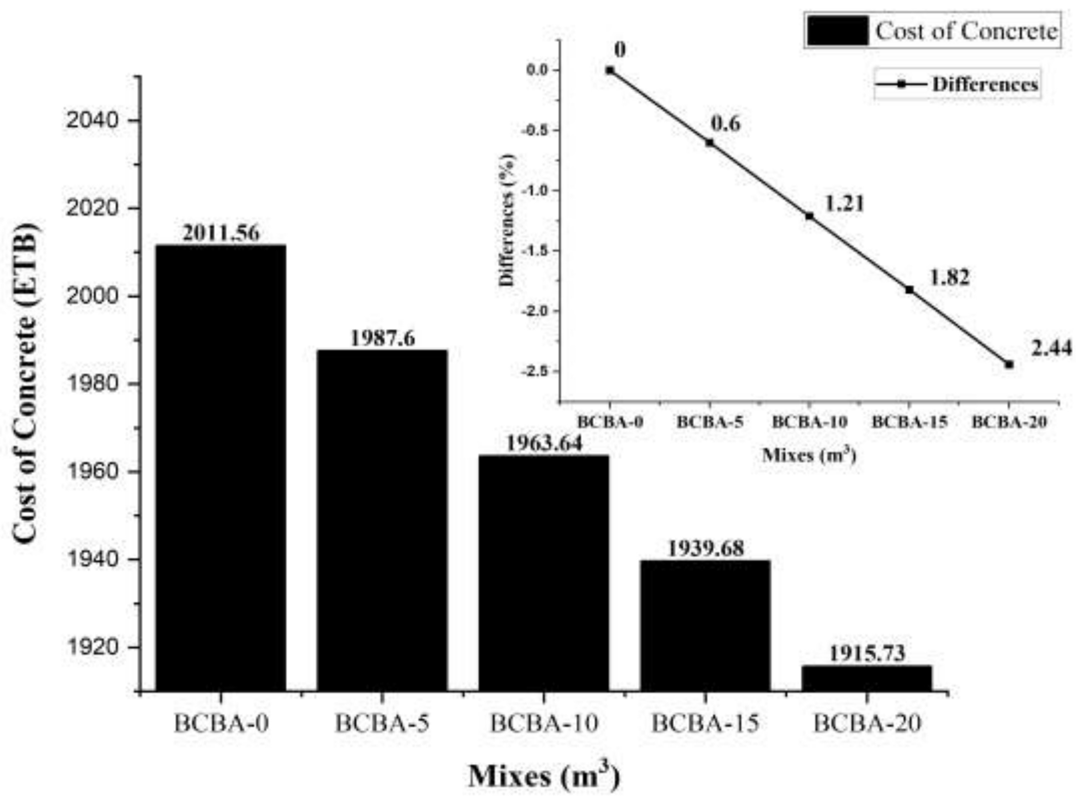


Figure 4.17. Cost comparison of mixes per 1m3 and difference in per cent

The cost of concrete for controlled mix (BCBA-0) Shows greater than the cost of concrete production is 2011.56 ETB per 1 cubic meter. While BCBA-5 cost of 1 cubic meter of concrete indicates 1987.6 ETB which decreases the cost by 0.6% from the controlled mix. On the other hand, the concrete mix BCBA-10 estimated cost is 1963.64 ETB for 1 cubic meter which shows a cost difference of 1.21%. BCBA-15 and BCBA-20 have estimated costs of 1939.68 ETB and 1915.73 ETB having percentage reduction costs of 1.82% and 2.44% respectively compared to the controlled mix.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

This part of the research discusses the conclusion and recommendation. Throughout the research different results have been collected, and analyzed and the researcher arrives at the conclusion and recommendation stated below.

5.1. Conclusion

The general objective of the research initiative aims to investigate the partial replacement of cement by combining sugarcane bagasse and cattle bone ash. As per the specific objective of the research the following conclusion has been drawn:

- ✓ The specific gravity of SBA and CBA is 1.82g/cm^3 and 2.55g/cm^3, which shows that OPC is much denser than SBA, and CBA is denser than SBA. As per ASTM C618 SBA has been categorized under Pozzolana class F while CBA doesn't satisfy the standard but is considered as filler cementitious material.
- ✓ The consistency of indicates that a potential increase in the weight of water when replacement increases. The soundness also shows the average expansion was the same as OPC. As the percentage increases from 15% to 20%, the expansion shows a slight increase. OPC cement requires a minimum initial setting time and final setting compared to blended cement.
- ✓ workability of ordinary concrete is better than that of concrete which has combined cattle bone and bagasse ash. At the early time age of concrete, a high percentage improvement compared to the controlled mix was discovered result which resulted in the availability of a high amount of C_3S. But as it goes to the 90 days age of concrete the controlled mix shows a high increase in compressive strength and tensile strength has been seen to the percentage replacement of 5% and 10%.
- ✓ The microstructural analysis of 10% replacement shows improved calcium silicate hydrate (C-S-H gel). Application of an equal amount of combined SBA and CBA up to 10% replacement gives better improvement to the normal strength of concrete.

5.2. Recommendation

The experimental study was conducted for partial replacement of ordinary Portland cement with combined Bagasse and cattle bone ash to increase the compressive strength of concrete by up to 10%. From this study the following recommendations are forwarded:

- Burning of cattle bone ash has significant health hazards using desired health protective materials is recommended.
- Assessing the chemical property (sulphate, chloride, porosity, etc) of partially replaced concrete with partial replacement of cement by combining sugarcane bagasse and cattle bone ash.
- Determination of the mechanical properties for the flexural strength of the concrete to observe further strength.
- Providing the combined sugarcane bagasse and cattle bone ash for high-performance concrete, lightweight concrete, and mortar production and investigating the effects.
- Assessing the sustainability of using SBA and CBA as partial replacement of cement in concrete and mortar production.

REFERENCES

Adero, D. H. (2019). Impact of bagasse ash on mechanical property and early age temperature development of concrete.

Abate, D. and Asteray, B. (2020). Effect of Sugarcane Bagasse Ash on Bagasse Fiber Reinforced Concrete Properties.

Adetayo, O.A., Umego, O.M., Amu, O.O., Faluyi, F., Odetoye, A.A., & Bucknor, A.O. (2022). Performance Evaluation of Ternary Blends of Pulverized Cow Bone Ash and Waste Glass Powder on the Strength Properties of Concrete. *Trends in Sciences*.

Akinyele, J. O., Adekunle, A. A., & Ogundaini, O. (2016). The effect of partial replacement of cement with bone ash and wood ash in concrete. *Annals of the Faculty of Engineering Hunedoara*, *14*(4), 199.

Amiri, A., & Vaseghi, M. R. (2014). Waste heat recovery power generation systems for cement production process. IEEE Transactions on Industry Applications, 51(1), 13-19.

Aytekin, B., et al. (2022). Effect of Cement Fineness and Grain Size Distribution on Admixture Requirements and Compressive Strength of Mortar Mixture.

Bakharev, T. (2005). Geo polymeric materials prepared using Class F fly ash and elevated temperature curing. *Cement and concrete research*, *35*(6), 1224-1232.

Balakrishnan, M., & Batra, V. S. (2011). Valorization of solid waste in sugar factories with possible applications in India: A review. *Journal of Environmental Management*, *92*(11), 2886-2891.

Collepardi, M., Monosi, S., Moriconi, G., & Corradi, M. (1979). Tetracalcium aluminoferrite hydration in the presence of lime and gypsum. Cement and Concrete Research, 9(4), 431-437.

Deepika, S., Anand, G., Bahurudeen, A., & Santhanam, M. (2017). Construction products with SBA binder. *Journal of Materials in Civil Engineering*, *29*(10), 04017189.

Destaye H., Belachew A. (2019). “Impact of Bagasse ash on mechanical property of early age temperature development of concrete.” Addis Ababa Science and Technology University

Ellis, L. D., Badel, A. F., Chiang, M. L., Park, R. J. Y., & Chiang, Y. M. (2020). Toward electrochemical synthesis of cement—An electrolyzer-based process for decarbonating CaCO3 while producing useful gas streams. *Proceedings of the National Academy of Sciences*, *117*(23), 12584-12591.

Frigione, G., & Marra, S. (1976). Relationship between particle size distribution and compressive strength in Portland cement. *Cement and concrete research*, *6*(1), 113-127.

Galan, I., Glasser, F. P., & Andrade, C. (2013). Calcium carbonate decomposition. Journal of Thermal Analysis and Calorimetry, 111(2), 1197-1202.

Gashahun, A. D. (2020). Assessment on Cement Production Practice and Potential Cement Replacing Materials in Ethiopia. no. February.

Geremew, Miheret (2017). “*Bagasse Ash as a Partial Substitute of Cement on Concrete Rigid Pavement.*” Addis Ababa University.

Getahun, S., & Bewket, B. (2020). *Study on Effect of Partial Replacement of Cement by Cattle Bone Ash in Concrete Property* (Doctoral dissertation).

Gill, F. L., Dewhurst, R. J., Evershed, R. P., McGeough, E., O’Kiely, P., Pancost, R. D., & Bull, I. D. (2011). Analysis of archaeal ether lipids in bovine faeces. *Animal Feed Science and Technology*, *166*, 87-92.

Habte, L., Mulatu, D., & Ahn, J. W. (2018). Applications of Sugarcane by-products to mitigate climate change in Ethiopia. *Journal of Energy Engineering*, *27*(3), 36-40.

Hailu, B., & Dinku, A. (2012). Application of sugarcane bagasse ash as a partial cement replacement material. *Zede journal*, *29*, 1-12.

Hassen, S., Beyene, A. D., Jeuland, M., Mekonnen, A., Meles, T. H., Sebsibie, S., ... & Toman, M. (2021). The effect of electricity price reform on households' electricity consumption in urban Ethiopia. *Available at SSRN 4082607*.

Jha, P., Sachan, A. K., & Singh, R. P. (2021). Agro-waste sugarcane bagasse ash (ScBA) as partial replacement of binder material in concrete. *Materials Today: Proceedings*, *44*, 419-427.

Jin, S., Li, J., Xu, W., & Ding, Q. (2020). Heterogeneous nature of calcium silicate hydrate (CSH) gel: a molecular dynamics study. *Journal of Wuhan University of Technology-Mater. Sci. Ed.*, *35*(2), 435-440.

Kiran, K., & Kishore, I. S. (2017). An experimental study on partial replacement of cement with bagasse ash in concrete mix. *International Journal of Civil Engineering and Technology*, *8*(1), 452-455.

Kotb, M.M., Assas, M.M., & Abd-Elrahman, H.S. (2010). Effect of grounded bone powder addition on the mechanical properties of cement mortar.

Kwena, O. C. (2011). *The Effect of Partial Replacement of Cement with Ground and Unground SBA (ScBA) On Mechanical Properties of Concrete*. F16/1369.

Li, Y., Chai, J., Wang, R., Zhang, X., & Si, Z. (2022). Utilization of sugarcane bagasse ash (SCBA) in construction technology: A state-of-the-art review. *Journal of Building Engineering*, *56*, 104774.

Macphee, D. E., & Lachowski, E. E. (2003). Cement Components and Their Phase. Lea's chemistry of cement and concrete, 95.

Mangi, S. A., Jamaluddin, N., Ibrahim, M. W., Awal, A. A., Sohu, S., & Ali, N. (2017, November). Utilization of sugarcane bagasse ash in concrete as partial replacement of cement. In IOP conference series: materials science and engineering (Vol. 271, No. 1, p. 012001). IOP Publishing.

Mccaffrey, R. (2002). Climate change and the cement industry. *Global cement and lime magazine (environmental special issue)*, *15*, 19.

Mehta, P. K. (2004). High-performance, high-volume fly ash concrete for sustainable development. Proceedings of the international workshop on sustainable development and concrete technology, Iowa State University Ames, IA, USA.

Minard, H., Garrault, S., Regnaud, L., & Nonat, A. (2007). Mechanisms and parameters controlling the tricalcium aluminate reactivity in the presence of gypsum. Cement and Concrete Research, 37(10), 1418-1426.

Monshi, A., Foroughi, M. R., & Monshi, M. R. (2012). Modified Scherrer equation to estimate more accurately nano-crystallite size using XRD. World J Nano Sci Eng, 2012, 2: 154, 160.

Mulatu, D., Habte, L., & Ahn, J. W. (2018). The Cement Industry in Ethiopia. *Journal of Energy Engineering*, *27*(3), 68-73.

Mutua, B. M., Nyomboi, T., & Mutuku, R. N. (2016). Consistency, setting times and chemical properties of sugar cane bagasse ash cement.

Narmluk, M., & Nawa, T. (2011). Effect of fly ash on the kinetics of Portland cement hydration at different curing temperatures. Cement and concrete research, 41(6), 579-589.

Nasser, N., Al-Bahri, R., & Wiliams, C.K. (2019). A Feasibility Study on the Mechanical Properties of Concrete by Replacing Cement with Animal Bone Powder.

Neville, A. M., & Brooks, J. J. (1987). *Concrete technology* (Vol. 438). England: Longman Scientific & Technical.

Odler, I. (1998). Hydration, setting and hardening of Portland cement. Lea's Chemistry of cement and concrete.

Offiong, U., et al. (2018). Strength characteristics of cattle bone ash cement blended laterized concrete.

Okeyinka, O. M., Olutoge, F. A., & Okunlola, L. O. (2018). Durability Performance of Cow-Bone Ash (CBA) Blended Cement Concrete in Aggressive Environment. *International Journal of Scientific and Research Publications*, *8*(12), 37-40.

Olaoye, R., et al. (2020). "Adsorption of selected metals from cassava processing wastewater using cow-bone ash." Scientific African **10**: e00653.

Ramachandran, V. S., & Beaudoin, J. J. (1980). Hydration of C4AF+ gypsum: study of various factors.

Reddy, M. V. S., Ashalatha, K., Madhuri, M., & Sumalatha, P. (2015). Utilization of sugarcane bagasse ash (SCBA) in concrete by partial replacement of cement. *IOSR Journal of Mechanical and Civil Engineering*, *12*(6), 12-16.

Rustandi, A., et al. (2018). "Evaluation of the suitability of tin slag in cementitious materials: Mechanical properties and Leaching behaviour." IOP Conference Series: Materials Science and Engineering **299**: 012046.

Scherrer, P. (1918). Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen. *Mathematisch-Physikalische Klasse*, *2*, 98-100.

Scrivener, K. L., Juilland, P., & Monteiro, P. J. (2015). Advances in understanding hydration of Portland cement. Cement and Concrete Research, 78, 38-56.

Shapiro, B. I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G., & Mechale, H. (2017). Ethiopia livestock sector analysis: A 15-year livestock sector strategy.

Skinner, L. B., Chae, S. R., Benmore, C. J., Wenk, H. R., & Monteiro, P. J. M. (2010). Nanostructure of calcium silicate hydrates in cements. Physical review letters, 104(19), 195502.

Smith, Brian. (2018), Infrared Spectral Interpretation. CRC Press.

Tantawy, M. A. (2017). Effect of high temperatures on the microstructure of cement paste. *Journal of Materials Science and Chemical Engineering*, *5*(11), 33.

Teshome, B.B. (2019). INVESTIGATING MECHANICAL PROPERTIES OF ANIMAL BONE POWDER PARTIALLY REPLACED CEMENT IN CONCRETE PRODUCTION.

Tsigehana, G. (2019). Sugarcane Bagasse Ash as Partial Replacement of Cement in Concrete Production, Addis Ababa University.

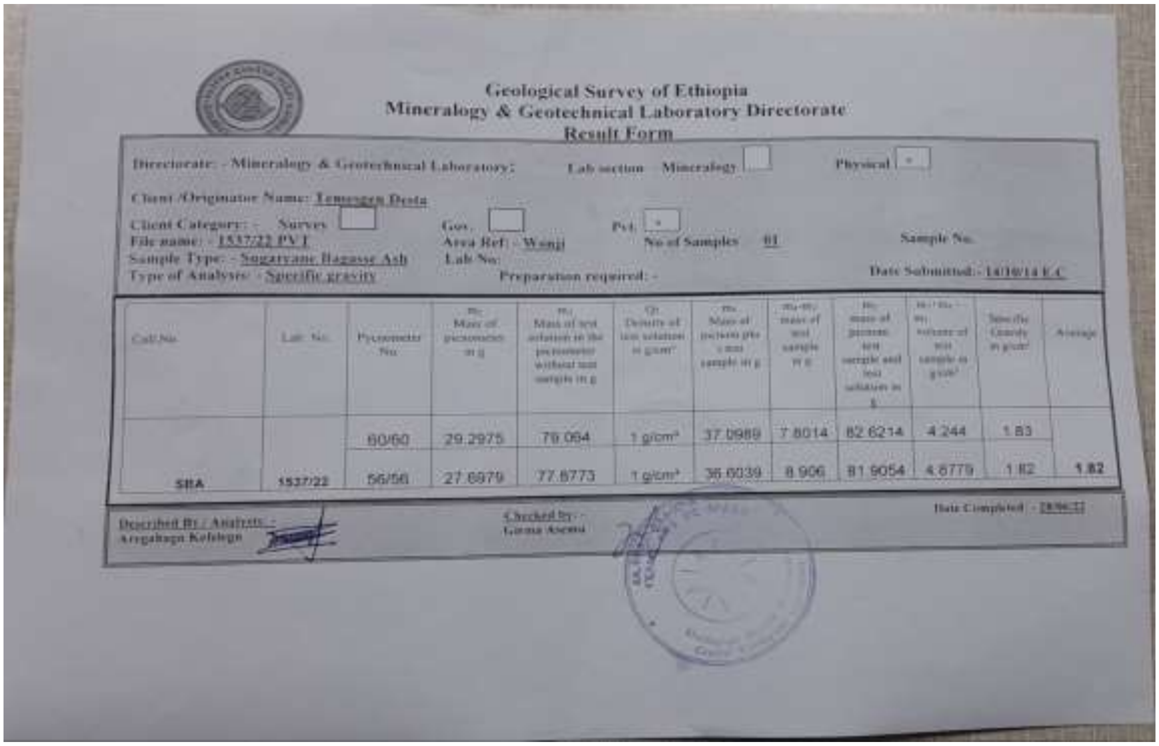
Varma, S. M., Naidu, M., Mohan, S., & Reddy, D. (2016). An Effective study on utilizing bone powder ash as partial replacement of construction material. *International Journal of Innovative Technology and Research*, *4*(3), 3060-3062.

Worrell, E., Galitsky, C., & Price, L. (2008). Energy efficiency improvement and cost saving opportunities for cement making. LBNL-54036-Revision. Ernest Orlando Lawrence Berkeley National Laboratory, University of California, March.

Yin, R. K. (2003). Designing case studies. *Qualitative research methods*, *5*(14), 359-386.

Yu, Z., et al. (2013). Discussion of the evolution of the chloride migration coefficient of Portland cement concrete tested by the rapid chloride migration (RCM) test at long-term curing periods up to 5 years.

Appendix 1. Specific Gravity Test Result



Geological Survey of Ethiopia
Mineralogy & Geotechnical Laboratory Directorate
Result Form

Directorate: - Mineralogy & Geotechnical Laboratory; Lab section: - Mineralogy ☐ Physical ☒

Client /Originator Name: Temesgen Desta

Client Category: - Survey ☐ Gov. ☐ Pvt. ☒

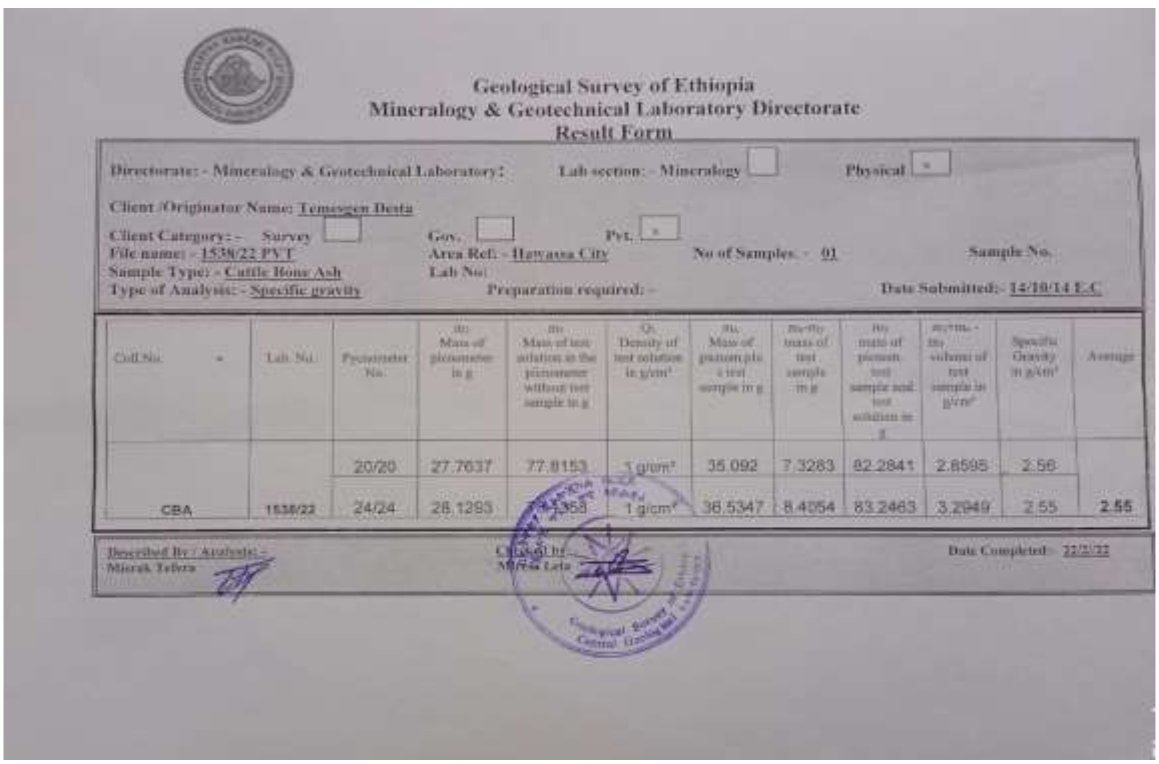
File name: - 1537/22 PVT Area Ref: - Wonji No of Samples 01 Sample No.

Sample Type: - Sugarcane Bagasse Ash Lab No:

Type of Analysis: - Specific gravity Preparation required: - Date Submitted: - 14/10/14 E.C

Coll.No	Lab. No.	Pycnometer No.	m1: Mass of picnometer in g	m2: Mass of test solution in the picnometer without test sample in g	Qt: Density of test solution in g/cm³	m3: Mass of picnometer plus test sample in g	m3-m1: mass of test sample in g	m4: mass of picnom. test sample and test solution in g	volume of test sample in g/cm³	Specific Gravity in g/cm³	Average
		60/60	29.2975	79.064	1 g/cm³	37.0989	7.8014	82.6214	4.244	1.83	
SBA	1537/22	56/56	27.6979	77.8773	1 g/cm³	36.6039	8.906	81.9054	4.8779	1.82	1.82

Described By / Analysis: - Aregahegn Kelelegn Checked by: - Girma Asemu Date Completed: - [illegible]



Geological Survey of Ethiopia
Mineralogy & Geotechnical Laboratory Directorate
Result Form

Directorate: - Mineralogy & Geotechnical Laboratory; Lab section: - Mineralogy ☐ Physical ☒

Client /Originator Name: Temesgen Desta

Client Category: - Survey ☐ Gov. ☐ Pvt. ☒

File name: - 1538/22 PVT Area Ref: - Hawassa City No of Samples: - 01 Sample No.

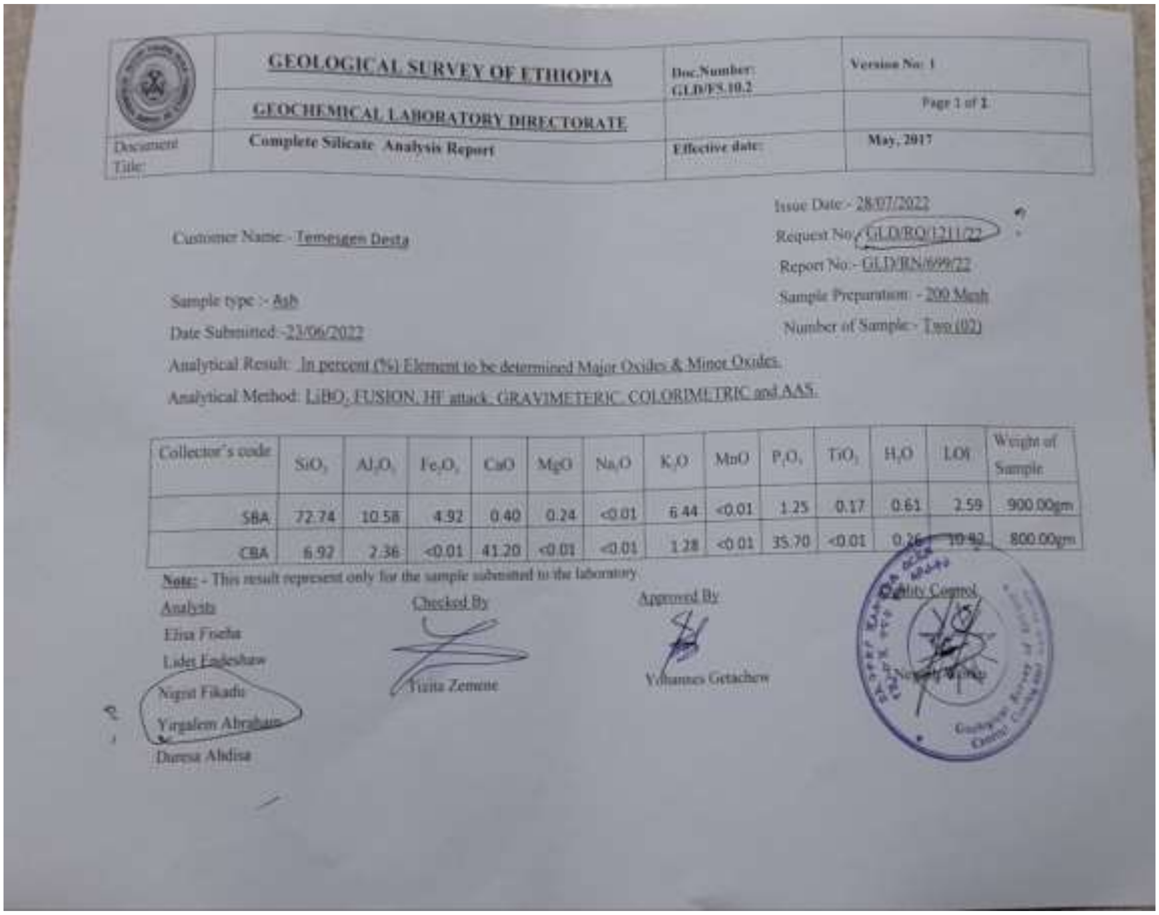
Sample Type: - Cattle Bone Ash Lab No:

Type of Analysis: - Specific gravity Preparation required: - Date Submitted: - 14/10/14 E.C

Coll.No	Lab. No.	Pycnometer No.	m1: Mass of picnometer in g	m2: Mass of test solution in the picnometer without test sample in g	Qt: Density of test solution in g/cm³	m3: Mass of picnometer plus test sample in g	m3-m1: mass of test sample in g	m4: mass of picnom. test sample and test solution in g	volume of test sample in g/cm³	Specific Gravity in g/cm³	Average
		20/20	27.7637	77.8153	1 g/cm³	35.092	7.3283	82.2841	2.8595	2.56	
CBA	1538/22	24/24	28.1293	[illegible]	1 g/cm³	36.5347	8.4054	83.2463	3.2949	2.55	2.55

Described By / Analysis: - Misrak Tefera Checked by: - Mirtu Lela Date Completed: - 22/2/22

Appendix 2. Complete Silicate Analysis Result (XRF)



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

Issue Date:- 28/07/2022

Customer Name:- Temesgen Desta

Request No:- GLD/RQ/1211/22

Report No:- GLD/RN/699/22

Sample type :- Ash

Sample Preparation: - 200 Mesh

Date Submitted -23/06/2022

Number of Sample:- Two (02)

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
SBA	72.74	10.58	4.92	0.40	0.24	<0.01	6.44	<0.01	1.25	0.17	0.61	2.59	900.00gm
CBA	6.92	2.36	<0.01	41.20	<0.01	<0.01	1.28	<0.01	35.70	<0.01	0.26	10.92	800.00gm

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

Analysts
Elisa Fiseha
Lidet Endeshaw
Nigist Fikadu
Yirgalem Abraham
Duresa Abdisa

Checked By
Yizita Zemene

Approved By
Yohannes Getachew

Quality Control

Appendix 3. Consistency test result

Consistency test for (BCBA-0)

Trial No	Cement (g)	Percentage Water	Water (ml)	Initial reading	Final reading	penetration (mm)
1	650	23% of cement	149.5	40	35	5
2	650	24% of cement	156	40	34	6
3	650	25% of cement	162.5	40	34	6
4	650	26% of cement	169	40	33	7
5	650	27% of cement	175.5	40	32	8
6	650	28% of cement	182	40	30	10

Consistency test for (BCBA-5)

Trial No	Blended cement (g)	Percentage Water	Water (ml)	Initial reading	Final reading	penetration (mm)
1	650	23% of cement	149.5	40	36	4
2	650	24% of cement	156	40	35	5
3	650	25% of cement	162.5	40	34	6
4	650	26% of cement	169	40	33	7
5	650	27% of cement	175.5	40	32	8
6	650	28% of cement	182	40	30	10

Consistency test for (BCBA-10)

Trial No	Blended cement (g)	Percentage Water	Water (ml)	Initial reading	Final reading	penetration (mm)
1	650	23% of cement	149.5	40	36	4
2	650	24% of cement	156	40	35	5
3	650	25% of cement	162.5	40	34	6
4	650	26% of cement	169	40	34	6
5	650	27% of cement	175.5	40	33	7
6	650	28% of cement	182	40	30	10

Consistency test for (BCBA-15)

Trial No	Blended cement (g)	Percentage Water	Water (ml)	Initial reading	Final reading	penetration (mm)
1	650	23% of cement	149.5	40	36	4
2	650	24% of cement	156	40	36	4
3	650	25% of cement	162.5	40	35	5
4	650	26% of cement	169	40	34	6
5	650	27% of cement	175.5	40	33	7
6	650	28% of cement	182	40	31	9

Consistency test for (BCBA-20)

Trial No	Blended cement (g)	Percentage Water	Water (ml)	Initial reading	Final reading	penetration (mm)
1	650	23% of cement	149.5	40	37	3
2	650	24% of cement	156	40	36	4
3	650	25% of cement	162.5	40	35	5
4	650	26% of cement	169	40	34	6
5	650	27% of cement	175.5	40	33	7
6	650	28% of cement	182	40	31	9

Appendix 4. Soundness Test Result

Soundness test for (BCBA-0)

Sample no.	Cement (g)	Water (ml)	Initial distance (mm)	Final distance (mm)	Expansion (mm)	Average expansion (mm)
1	650	182	11	12	1	
2	650	182	12	13	1	1
3	650	182	11	12	1	

Soundness test for (BCBA-5)

Sample no.	Cement (g)	Water (ml)	Initial distance (mm)	Final distance (mm)	Expansion (mm)	Average expansion (mm)
1	650	182	14	15	1	
2	650	182	13	14	1	1
3	650	182	11	12	1	

Soundness test for (BCBA-10)

Sample no.	Cement (g)	Water (ml)	Initial distance (mm)	Final distance (mm)	Expansion (mm)	Average expansion (mm)
1	650	182	10	11	1	
2	650	182	12	13	1	1
3	650	182	12	13	1	

Soundness test for (BCBA-15)

Sample no.	Cement (g)	Water (ml)	Initial distance (mm)	Final distance (mm)	Expansion (mm)	Average expansion (mm)
1	650	182	11	14	3	
2	650	182	12	13	1	2
3	650	182	12	14	2	

Soundness test for (BCBA-20)						
Sample no.	Cement (g)	Water (ml)	Initial distance (mm)	Final distance (mm)	Expansion (mm)	Average expansion (mm)
1	650	182	10	12	2	
2	650	182	12	14	2	2
3	650	182	11	13	2	

Appendix 5. Initial and Final Setting Time

Initial setting time for BCBA-0

Trial No	Minutes	Initial Reading (mm)	Final Reading (Mm)	Penetration (Mm)	Remark
1	0	40	40	0	
2	15	40	28	12	
3	30	40	19	21	IS1
4	45	40	14	26	IS2
5	60	40	12	28	
6	75	40	11	29	
7	90	40	11	29	
8	105	40	10	30	
9	120	40	10	30	
10	135	40	9	31	
11	150	40	9	31	
12	165	40	8	32	
13	180	40	7	33	
14	195	40	7	34	
15	210	40	6	34	
16	225	40	6	35	
17	240	40	5	35	
18	255	40	5	36	
19	270	40	4	37	
20	285	40	4	37	
21	300	40	3	37	
22	315	40	3	38	
23	330	40	2	38	
24	345	40	2	38	
25	360	40	2	38	
26	375	40	1	39	FS

Initial setting time for BCBA-5					
Trial No	**Minutes**	**Initial Reading (Mm)**	**Final Reading (Mm)**	**Penetration (Mm)**	**Remark**
1	0	40	40	0	
2	15	40	28	12	
3	30	40	23	17	
4	45	40	17	23	IS1
5	60	40	14	26	IS2
6	75	40	12	28	
7	90	40	11	29	
8	105	40	11	29	
9	120	40	10	30	
10	135	40	10	30	
11	150	40	9	31	
12	165	40	9	31	
13	180	40	9	31	
14	195	40	8	32	
15	210	40	8	32	
16	225	40	7	33	
17	240	40	6	34	
18	255	40	6	34	
19	270	40	5	35	
20	285	40	5	35	
21	300	40	4	36	
22	315	40	4	36	
23	330	40	3	37	
24	345	40	2	38	
25	360	40	1	39	FS1
26	375	40	1	39	FS2
27	390	40	0	40	

Initial setting time for BCBA-10					
Trial No	**Minutes**	**Initial Reading (Mm)**	**Final Reading (Mm)**	**Penetration (Mm)**	**Remark**
1	0	40	0	0	
2	15	40	30	10	
3	30	40	24	16	
4	45	40	20	20	
5	60	40	16	24	IS1
6	75	40	14	26	IS2
7	90	40	13	27	
8	105	40	12	28	
9	120	40	11	29	
10	135	40	11	29	
11	150	40	10	30	
12	165	40	9	31	
13	180	40	9	31	
14	195	40	8	32	
15	210	40	8	32	
16	225	40	7	33	
17	240	40	7	33	
18	255	40	6	34	
19	270	40	5	35	
20	285	40	5	35	
21	300	40	4	36	
22	315	40	3	37	
23	330	40	2	38	
24	345	40	2	38	
25	360	40	1	39	FS1
26	375	40	0	40	
27	390	40	0	40	

Initial setting time for BCBA-15					
Trial No	**Minutes**	**Initial Reading (Mm)**	**Final Reading (Mm)**	**Penetration (Mm)**	**Remark**
1	0	40	40	0	
2	15	40	32	8	
3	30	40	27	13	
4	45	40	22	18	
5	60	40	18	22	
6	75	40	15	25	IS
7	90	40	14	26	
8	105	40	13	27	
9	120	40	12	28	
10	135	40	12	28	
11	150	40	11	29	
12	165	40	10	30	
13	180	40	10	30	
14	195	40	9	31	
15	210	40	8	32	
16	225	40	7	33	
17	240	40	7	33	
18	255	40	6	34	
19	270	40	6	34	
20	285	40	5	35	
21	300	40	4	36	
22	315	40	3	37	
23	330	40	2	38	
24	345	40	1	39	FS2
25	360	40	1	39	FS2
26	375	40	0	40	
27	390	40	0	40	

Initial setting time for BCBA-20					
Trial No	Minutes	Initial Reading (Mm)	Final Reading (Mm)	Penetration (Mm)	Remark
1	0	40	40	0	
2	15	40	33	7	
3	30	40	28	12	
4	45	40	23	17	
5	60	40	21	19	
6	75	40	18	22	IS 1
7	90	40	14	26	IS 2
8	105	40	13	27	
9	120	40	12	28	
10	135	40	12	28	
11	150	40	11	29	
12	165	40	10	30	
13	180	40	10	30	
14	195	40	9	31	
15	210	40	8	32	
16	225	40	8	32	
17	240	40	7	33	
18	255	40	7	33	
19	270	40	6	34	
20	285	40	5	35	
21	300	40	4	36	
22	315	40	3	37	
23	330	40	2	38	
24	345	40	1	39	FS
25	360	40	0	40	
26	375	40	0	40	
27	390	40	0	40	

Designation	Penetration (mm)	Initial setting time (min)	Penetration (mm)	Final setting time (mm)	Remark
BCBA-0	25	42	1	345	
BCBA-5	25	55	1	352.5	
BCBA-10	25	67.5	1	367.5	
BCBA-15	25	75	1	375	
BCBA-20	25	86.25	1	382.5	

Appendix 7. Compressive Strength Test Result

Age (days)	Mixes	Sample	Compressive strength test			
			Weight (Kg)	**Load failure (N)**	**Result (MPa)**	**Average**
3	BCBA-0	1	7.49	672.65	26.34	26.7333
		2	7.32	682.34	27.01	
		3	7.92	695.32	26.85	
	BCBA-5	1	7.62	689.21	26.84	26.9567
		2	7.61	652.31	26.39	
		3	7.93	700.21	27.64	
	BCBA-10	1	8.12	723.82	27.54	27.3367
		2	8.04	708.34	27.41	
		3	7.85	698.2	27.06	
	BCBA-15	1	7.62	675.34	25.12	24.8367
		2	7.54	674.62	24.18	
		3	8.02	699.65	25.21	
	BCBA-20	1	8.02	684.32	25.16	24.6367
		2	8.07	687.45	24.52	
		3	7.35	631.25	24.23	
7	BCBA-0	1	8.22	732.5	27.99	27.5833
		2	8.1	715.34	27.54	
		3	7.58	684.32	27.22	
	BCBA-5	1	8.23	776.31	28.46	28.49
		2	8.22	764.45	28.84	
		3	7.95	697.85	28.17	
	BCBA-10	1	8.23	787.34	29.84	28.94
		2	8.04	762.4	28.64	
		3	8.17	732.5	28.34	
	BCBA-15	1	8.01	716.41	26.62	26.2533
		2	8.32	724.6	25.92	
		3	8.16	712.54	26.22	

	BCBA-20	1	8.13	704.21	24.91	24.9166
		2	8.07	698.24	25.31	
		3	8.01	684.54	24.53	
14	BCBA-0	1	8.42	789.64	30.29	30.8666
		2	8.32	762.54	31.7	
		3	8.24	751.24	30.61	
	BCBA-5	1	8.51	799.34	32.18	32.1666
		2	8.52	800.01	32.65	
		3	8.21	784.21	31.67	
	BCBA-10	1	8.49	794.62	33.87	34.0133
		2	8.24	787.59	34.56	
		3	8.36	800.42	33.61	
	BCBA-15	1	8.02	787.23	29.35	29.51
		2	7.89	743.57	29.03	
		3	8.17	786.57	30.15	
	BCBA-20	1	7.82	712.64	27.34	27.1233
		2	7.93	724.65	27.69	
		3	7.32	682.46	26.34	
28	BCBA-0	1	8.32	821.4	36.12	35.5766
		2	8.18	810.32	35.34	
		3	8.26	816.45	35.27	
	BCBA-5	1	8.26	819.23	36.29	36.9633
		2	8.42	834.67	37.63	
		3	8.31	829.36	36.97	
	BCBA-10	1	8.13	809.58	39.12	39.2166
		2	8.34	836.59	38.95	
		3	8.56	843.32	39.58	
	BCBA-15	1	7.99	734.65	32.82	33.02333
		2	7.68	720.49	33.31	
		3	8.03	798.67	32.94	

	BCBA-20	1	7.67	721.45	30.21	29.8
		2	7.98	724.95	29.74	
		3	7.12	682.65	29.45	
56	BCBA-0	1	8.22	843.42	38.64	39.3133
		2	8.36	867.21	39.98	
		3	8.27	860.97	39.32	
	BCBA-5	1	8.62	912.34	39.92	40.1933
		2	8.42	898.75	40.34	
		3	8.51	901.65	40.32	
	BCBA-10	1	8.42	900.05	42.85	41.9166
		2	8.31	904.67	41.23	
		3	8.01	887.64	41.67	
	BCBA-15	1	7.98	795.37	33.46	33.8166
		2	8.03	802.4	33.87	
		3	8.07	810.67	34.12	
	BCBA-20	1	7.59	732.54	30.46	30.2766
		2	7.99	769.24	30.24	
		3	7.64	749.49	30.13	
90	BCBA-0	1	8.32	998.34	43.43	42.4833
		2	8.04	976.31	42.68	
		3	8.12	941.38	41.34	
	BCBA-5	1	8.42	1000.34	41.81	42.25333
		2	8.39	997.64	42.01	
		3	8.29	978.54	42.94	
	BCBA-10	1	7.98	945.68	42.18	43
		2	8.36	1015.42	44.34	
		3	8.29	1001.76	42.48	
	BCBA-15	1	8.03	810.32	33.85	34.02
		2	7.62	852.64	33.64	
		3	7.98	812.64	34.57	

BCBA-20	1	7.42	834.9	30.29	30.463333
	2	8.01	825.96	30.24	
	3	7.42	810.94	30.86	

Appendix 8. Tensile Strength Test Result (Splitting Test Method)

Age (days)	Mixes	Sample	Tensile strength test			
			Weight (Kg)	Load failure (N)	Result (MPa)	Average
3	BCBA-0	1	11.32	125.34	3.64	3.58
		2	10.92	120.31	3.12	
		3	11.12	142.35	3.98	
	BCBA-5	1	11.22	134.25	3.68	3.67
		2	11.2	124.31	3.54	
		3	10.54	130.12	3.79	
	BCBA-10	1	10.85	131.31	3.81	3.79
		2	11.13	135.64	3.87	
		3	11.32	122.34	3.69	
	BCBA-15	1	11.43	109.31	3.62	3.416667
		2	10.35	112.34	3.27	
		3	11.24	123.34	3.36	
	BCBA-20	1	11.31	111.24	3.13	3.106667
		2	10.92	116.42	3.15	
		3	11.23	106.12	3.04	
7	BCBA-0	1	10.99	134.7	3.95	3.99
		2	11.42	122.31	3.82	
		3	11.35	138.34	4.2	
	BCBA-5	1	11.04	144.32	4.51	4.27
		2	11.32	130.31	4.31	
		3	10.97	122.54	3.99	
	BCBA-10	1	10.97	147.63	4.53	4.476667
		2	11.23	139.31	4.39	
		3	11.28	132.54	4.51	
	BCBA-15	1	11.36	116.21	3.64	3.416667
		2	11.24	123.21	3.24	
		3	11.03	118.97	3.37	

	BCBA-20	1	11.04	110.54	3.24	3.123333
		2	11.31	109.32	3.21	
		3	11.29	111.28	2.92	
14	BCBA-0	1	10.98	149.31	4.19	4.203333
		2	11.21	152.34	4.23	
		3	11.23	146.24	4.19	
	BCBA-5	1	11.08	153.21	4.41	4.356667
		2	11.21	124.31	4.28	
		3	10.96	142.34	4.38	
	BCBA-10	1	11.05	159.32	5.49	5.43
		2	11.24	132.4	5.28	
		3	11.19	143.1	5.52	
	BCBA-15	1	10.94	122.45	3.97	3.973333
		2	11.73	139.54	3.66	
		3	10.94	117.34	4.29	
	BCBA-20	1	10.96	120.34	3.99	3.623333
		2	11.32	116.39	3.72	
		3	11.37	124.31	3.16	
28	BCBA-0	1	11.52	163.54	5.62	5.396667
		2	11.31	142.38	5.36	
		3	10.98	130.28	5.21	
	BCBA-5	1	11.21	164.32	6.24	5.88
		2	11.03	152.34	5.98	
		3	10.98	135.21	5.42	
	BCBA-10	1	10.99	152.34	6.08	6.096667
		2	11.34	149.32	5.97	
		3	11.65	153.37	6.24	
	BCBA-15	1	11.34	130.21	4.71	4.356667
		2	11.02	123.21	4.75	
		3	11.05	125.34	3.61	

	BCBA-20	1	11.04	123.39	4.05	4.076667
		2	10.87	120.54	4.15	
		3	11.64	116.21	4.03	
56	BCBA-0	1	11.64	163.28	6.25	6.14
		2	11.5	152.34	5.99	
		3	11.11	159.39	6.18	
	BCBA-5	1	11.13	165.38	6.45	6.376667
		2	11.21	159.34	6.34	
		3	11.32	160.25	6.34	
	BCBA-10	1	10.98	149.32	6.21	6.546667
		2	11.34	169.78	6.73	
		3	11.12	165.34	6.7	
	BCBA-15	1	10.99	132.59	5.34	5.246667
		2	11.08	126.87	5.17	
		3	11.07	122.65	5.23	
	BCBA-20	1	10.88	122.38	5.03	4.936667
		2	11.12	120.25	4.74	
		3	11.42	119.38	5.04	
90	BCBA-0	1	11.56	182.38	7.31	7.023333
		2	11.31	165.37	7.42	
		3	11.25	160.56	6.34	
	BCBA-5	1	11.24	181.23	7.61	7.966667
		2	11.31	192.42	7.98	
		3	11.12	181.34	7.74	
	BCBA-10	1	10.99	182.34	8.18	8.203333
		2	11.02	191.34	8.09	
		3	11.04	192.34	8.34	
	BCBA-15	1	11.34	134.38	5.97	5.686667
		2	11.36	129.65	5.66	
		3	11.21	134.12	5.43	

	1	10.99	128.34	5.57	
BCBA-20	2	11.34	121.3	5.11	5.306667
	3	11.19	119.82	5.24	

Appendix 9. Aggregate Tests

A9.1. Coarse Aggregate Test Results

ASTM standards have been used in conducting tests for coarse aggregate such as moisture content, unit weight, and absorption.

A9.1.1. Moisture Content of Coarse Aggregate (ASTM C 566)

Description	Weights (g)
Weight of sample (A)	3000
Weight of oven-dried samples (B)	2980
Moisture content $= \frac{A-B}{B} = \frac{3000 - 2980}{2980} =$ **0.67%**	

The moisture content of the coarse aggregate is 0.67%.

A9.1.2. Specific Gravity and Absorption of Coarse Aggregate (ASTM C 127)

Description	Weight (g)
Mass of oven-dry test sample in air (A)	2980
Mass of saturated-surface-dry test sample in air (B)	2985
Apparent mass of saturated test sample in water (C)	1930
Relative density (specific gravity) $= \frac{B}{B-C} = \frac{2985}{2985-1930}$ = 2.829 = **2.83**	
Apparent relative density (apparent specific gravity) $= \frac{A}{A-C} = \frac{2980}{2980-1930}$ = **2.84**	
Absorption, % = $\frac{B-A}{A} = \frac{2985-2980}{2980} * 100$ = **0.17%**	

The relative and apparent specific gravity of coarse aggregate is 2.83 and 2.84 respectively and the absorption of coarse aggregate used in the study is 0.17%. the absorption of coarse aggregate is less than moisture content (0.17% < 0.67%) therefore the coarse aggregate doesn't provide water for the mixes before water adjustments.

A9.1.3. Unit Weight of Coarse Aggregate (ASTM C29)

Three samples for determinations of unit weight of coarse aggregate have been observed and calculated.

FORMULAS
Unit Weight = $(\frac{A-B}{C})$
VOID Content = $\frac{s.g(Density\ of\ water)-unit\ weight\ of\ caorse\ aggr.}{s.g\ (Density\ of\ water)} * 100$

Sample	Weight of measure (B) (kg)	Weight of measure and sample (A) (kg)	Volume of measure (C) (m^3)	Unit weight (kg/m^3)	Average unit weight (kg/m^3)
1	2.4	19.5	0.011	1554.55	
2	2.4	20	0.011	1600	1593.94
3	2.4	20.3	0.011	1627.27	

The average unit weight of coarse aggregate used in the study is 1593.94 kg/m^3.

A9.2. Fine Aggregate Test Results

The tests carried out for fine aggregate is based on ASTM standard.

A9.2.1. Moisture Content of Fine Aggregate (ASTM C566)

Moisture content of fine aggregate is crucial in mix design water adjustments and the test has been carried out in accordance with ASTM C566.

Description	**Weight**
Weight of sample (A)	500
Weight of oven-dried samples (B)	495
Moisture content, % = $\frac{A-B}{B} = \frac{500-495}{495} * 100 = \mathbf{1\%}$	

The moisture content of fine aggregate is 1%, the mix water content should be adjusted.

5.2.1.1.Specific Gravity and Water Absorption Test Result

The specific gravity of fine aggregate (sand) is the ratio of the weight of the given volume of aggregates to the weight of an equal volume of water. Table 4.10 shows the values taken from the laboratory tests.

Fine aggregate laboratory result

Symbol	Description	Weight (g)
S	Sample	500
A	After oven dried for 24 hr at a temperature of 105^0C	490
B	Pycnometer weight + Water weight	1300
C	Pycnometer weight + Water weight + Sample at the calibration point	1620

Computation for the bulk specific density (OD), Bulk Specific gravity (SSD), Apparent specific gravity and water absorption of fine aggregate was calculated as follows:

a) Bulk specific gravity (OD)= $\frac{A}{B+S-C} = \frac{490}{1300+500-1620}$ = 2.72

b) Bulk Specific gravity (SSD) = $\frac{S}{B+S-C} = \frac{500}{1300+500-1620}$ = 2.78

c) Apparent specific gravity = $\frac{A}{B+A-C} = \frac{490}{1300+490-1620}$ = 2.88

d) Water Absorption = $\frac{S-A}{A} * 100 = \frac{500-490}{490}$ * 100= 0.02*100 = 2%

A9.2.3. Unit Weight of Fine Aggregate (ASTM C29)

Sample	Weight of measure (B) (kg)	Weight of measure and sample (A) (kg)	Volume of measure (C) (m^3)	Unit weight (kg/m^3)	Average unit weight (kg/m^3)
1	1.6	6.6	0.0032	1562.5	
2	1.6	7.62	0.0032	1881.25	1684.38
3	1.6	6.75	0.0032	1609.38	

The average unit weight of fine aggregate used in the study shows that 1684 kg/m^3.

A9.2.4. Silt Content of Fine Aggregate (ASTM C 117)

Fine aggregate sit content was determined according to ASTM C 117, it covers the determination of the amount of material finer than a 75-µm (No. 200) sieve in aggregate by washing.

No.	Description	Sample 1	Sample 2	Sample 3
S1	Volume of sample Sand (V2)	2	2.5	2
S2	Volume of silt layer (V1)	148	148.5	148
S3	Percentage of silt = $(\frac{V1}{V2})*100$	1.35	1.69	1.35
	Average	**1.46%**		

The silt content of fine aggregate is 1.46% which shows as it is less than 5% as of other concrete specified in ASTM C117 standard. Therefore, the silt content of fine aggregate satisfies the standard.

Appendix 10. Mix Design

Information about the concrete constituents used in the ACI mix design:	
Cement	
Specific gravity	3.15
Fine Aggregate	
Silt content	1.46%
Fineness modulus	2.87
Specific gravity	2.78
Moisture	1%
Absorption	2%
Coarse Aggregate	
Fineness modulus	3.66
Moisture content	0.67%
Specific gravity	2.83
Absorption	0.17%
Unit weight	1593.94
Sugarcane bagasse ash	
Specific gravity	1.82
Cattle bone ash	
Specific gravity	2.55

ACI 211.1-91 mix design procedure adopted for the Normal strength concrete (C-25)

ACI-Mix design

$f'cr = f'c + 8.5$ _*this forula is for compressive between* $21MPa$ *to* $35MPa$

$f'cr = 25 + 8.5 = 33.5MPa$

Step 1. Choice of slump

The slump was chosen for column and beam structure	25mm to 100mm
The slump taken for the study is	100mm

Step 2. Choice of maximum size of aggregate

The maximum size of aggregate retained in the sieve size is 37.5mm

And the nominal maximum size of aggregate is 25mm

Step 3. Selection of water and Air content

Required water content using Max aggregate size 25mm and slump 50 to 100 mm from ACI 211.1-91 table 9.5, the requires Weight of water approximately is 193 kg/m^3

With corresponding Air content of 2%

Step 4. Determination of W/C for (C-25)

Using table 9.3 from ACI 211.1-91, W/C = 0.49 for concrete with compressive strength of 33.5 MPa by interpolation method.

Step 5. Calculation of cement

Cement can be computed from the finding in step 3 and step 4, Cement = 394 kg/m^3

Step 6. Estimation of coarse aggregate

For max. size of aggregate 25mm and fineness modulus of fine aggregate 2.87, Table 9.4 of ACI 211.1-91 gives 0.687m^3 (using interpolation) and Coarse aggregate = 1593.94*0.687 = 1095 kg/m^3

Step 7. Estimation of fine aggregate

Calculating the absolute volume of ingredients is very important and given below:

Volume of air entrapped = 0.015 m^3

Absolute volume of water = $\frac{193}{1000}$ = 0.193 m^3

Absolute volume of cement = $\frac{394}{3.15*1000}$ = 0.126 m^3

Absolute volume of coarse aggregate = $\frac{1095}{2.83*1000}$ = 0.387 m^3

Absolute volume of fine aggregate = 1- (0.015 + 0.193 + 0.126 + 0.387) = 0.279 m^3

Fine aggregate = 0.279 * 2.78 * 1000 = 775.62 kg/m^3

The Weight and absolute volume of ingredients before adjustment written below:

Ingredients	Absolute volume (m^3)	Weight (Kg/ m^3
air	0.015	-
Cement	0.126	394
Water	0.193	193
Sand	0.279	775.62
Coarse aggregate	0.387	1095

Step 8. Adjustments

Adjustments were carried out based on the absorption and moisture content of the coarse aggregate and fine aggregate. Thus, water amount should also be adjusted.

Coarse aggregate

Coarse aggregate absorbs 0.17% and has moisture content of 0.67%

= 1095 – ((0.17/100 *1095) +(0.67/100*1095)) = 1085.8 kg/m^3

Fine aggregate

Fine aggregate absorbs 2% and has moisture content of 1%, the adjusted weight is:

= 775.62 – ((2/100 * 775.62) +(1/100 * 775.62)) = 773.29 kg/m^3

Water

Additional amount water of was required for aggregates absorbance:

= 193 + ((2-1)/100 * 775.62) = 193.78 kg/m^3

Adjusted weight of concrete

Ingredients	Adjusted weights (Kg/m^3)
Cement	394
Water	193.78
Sand	773.29
Coarse aggregate	1085.8

The total volume of concrete samples needed for compressive strength test is given by:

Volume of sample = (0.15*0.15*0.15) * 90 + 20% wastage = 0.3645 m^3

Mixes for compressive strength	Water (kg)	Cement (kg)	Sand (kg)	Coarse aggregate (kg)
Per m^3	193.78	394	773.29	1085.8
Per trial mix of 0.3645 m^3	70.54	143.42	281.45	395.23

The total volume of concrete samples for tensile strength test is given by:

Volume of sample = (∏ * 0.075* 0.075* 0.3/) * 90 * 20% of wastage = 0.572 m^3

Mixes for tensile strength	Water (kg)	Cement (kg)	Sand (kg)	Coarse aggregate (kg)
Per m^3	193.78	394	773.29	1085.8
Per trial mix of 0.572m^3	110.84	225.37	442.32	621.08

Appendix 10: Trial Mix Result for Compressive Strength Tests

Trial	BCBA-5	Age (days)	Sample	Compressive Strength (MPa)	Average (MPa)	Remark
1	25%SBA 75%CBA	3	1	25.34	25.953333	3rd choice
			2	26.51		
			3	26.01		
		7	1	29.25	28.903333	2nd choice
			2	28.36		
			3	29.1		
2	50%SBA 50%CBA	3	1	26.42	26.636667	1st choice
			2	26.18		
			3	27.31		
		7	1	29.21	29.536667	1st choice
			2	29.09		
			3	30.31		
3	75%SBA 25%CBA	3	1	26.21	26.123333	2nd choice
			2	25.98		
			3	26.18		
		7	1	30.21	28.816667	3rd choice
			2	28.21		
			3	28.03		

Trial	BCBA-10	Age (days)	Sample	Compressive Strength (MPa)	Average (MPa)	Remark
1	25%SBA 75%CBA	3	1	28.34	28.11	3rd choice
			2	28.34		
			3	27.65		
		7	1	31.21	30.486667	2nd choice
			2	30.34		
			3	29.91		

2	50%SBA 50%CBA	3	1	31.32	30.92	1st choice
			2	30.57		
			3	30.87		
		7	1	32.01	31.716667	1st choice
			2	30.98		
			3	32.16		
3	75%SBA 25%CBA	3	1	29.34	29.473333	2nd choice
			2	30.1		
			3	28.98		
		7	1	31.65	30.276667	3rd choice
			2	29.21		
			3	29.97		

Appendix 11. Some Photos from Laboratory Work

Sieved SBA and CBA

Batching of concrete

Cement paste mixer

Destructive test machine

Vicat apparatus

Splitting test

Sample result of CS

Sample after Testing

Sample during test

Weighing ingriedients

Sample after removal

Calcined and sieved SBA

Calcined and sieved CBA

Ashing furnace

Waste CBA

Waste SBA