THE EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH BAMBOO LEAF ASH ON THE MECHANICAL AND DURABILITY PROPERTY OF C25 CONCRETE PRODUCTION

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The Effect of Partial Replacement of Cement with Bamboo Leaf Ash on the Mechanical and Durability Property of C25 Concrete Production

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DECLARATION

I hereby declare that this Master Thesis entitled ‘‘The Effect of Partial Replacement of Cement with Bamboo Leaf Ash on the Mechanical and Durability Property of C25 Concrete Production” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled ‘‘The Effect of Partial Replacement of Cement with Bamboo Leaf Ash on the Mechanical and Durability Property of C25 Concrete Production” prepared under my guidance by Sadam Gudeto Bedaso submitted in partial fulfilment of the requirements for the degree of Mater’s of Science in Civil engineering (Construction Engineering and Management). Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

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I, the advisors of the thesis entitled ''The Effect of Partial Replacement of Cement with Bamboo Leaf Ash on the Mechanical and Durability Property of C25 Concrete Production" developed by Sadam Gudeto Bedaso, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Sadam Gudeto Bedaso have read and evaluated the thesis entitled ''The Effect of Partial Replacement of Cement with Bamboo Leaf Ash on the Mechanical and Durability Property of C25 Concrete Production" and examined the candidate during open defence. This is, therefore, to certify that the thesis is accepted for partial fulfilment of the requirement of the degree of Master of Science in Civil engineering (Construction Engineering and Management).

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ABSTRACT

The construction industry plays a major role in driving economic growth of developed and developing countries. Ethiopia is one of developing country and dramatically expanding construction than ever before. Concrete is the most essential in construction industry and Cement is the basic ingredient of concrete. Nowadays, the construction industry is challenged by the scarcity of cement, price escalation of the cement market and CO2 emissions during cement production. On the other hand, Efficient utilization of agricultural byproduct is the need of today's environment to optimize the production cost of materials with the same nature and use. Bamboo leaf is one of such an agricultural waste which is available in high amount in Ethiopia but didn't get that much attention. Therefore, the objective of this research work is to investigate the potential of Bamboo Leaf Ash (BLA) as partially replacing cementitious material. In this study, the capability of Ethiopian highland Bamboo Leaf Ash (Yushania alpine) as a partial substitute for cement in C-25 concrete production with 0%, 5%, 10%, 15%, 20% and 25% replacement of OPC were investigated. The chemical composition of Bamboo leaf ash was examined and the summation of major oxide (SiO2, AlO3, and FeO3) is 73.98 % and classified as class F pozzolan. The workability of concrete decreases as the BLA replacement increases, but the setting time, consistency, and soundness of cement paste are increase. On the 28th day, the compressive strength of concrete made with partial replacement of cement by BLA up to 10% attains the target mean strength (33.5Mpa). The flexural strength of concrete made with partial replacement of cement by BLA up to 10% satisfied the required strengths 3.5Mpa for C25. The water absorption and permeability of the BLA blended concrete was lower than the control at 5% ,10% and 15% BLA content, at higher levels of BLA substitution (BLA20% and 25%) observed higher than the control. Concrete mixes with 5% and 10% BLA observed less compressive and flexural strength less in comparison to the control mix due to sodium sulphate attack. Further increase beyond 10% BLA replacement would lead to more compressive and flexural strength less. The result of the SEM pictures shows that the image of BLA10% gives a better mechanical interlocked than control. Generally: BLA has good pozzolanic characteristics and the optimum replacement of cement investigated 10% according to the result and any further increase beyond 10% BLA replacement would lead to strength reduction.

Key words: *Bamboo leaf ash, Chemical analysis, Compressive strength, Flexural Strength, Durability, SEM.*

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LIST OF ACRONYMS AND ABBREVIATION

ACI	American concrete institute
ACS	Average compressive strength
AFS	Average flexural strength
ASTM	America Society for Testing and Materials
BLA	Bamboo Leaf Ash
BS	British standard
C-H-S	Calcium Hydro Silicate Gel
CEM I	pure Ordinary Portland Cement
MOI	Ministry of Industry
MoARD	Ministry of Agriculture and Rural Development
OPC	Ordinary Portland cement
SEM	Scanning Electron Microscopy
XRD	X-ray diffraction

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Concrete is a composite material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens (cures) over time. Concrete is the second-most-used substance in the world after water and is the most widely used building material (Damtoft et al., 2008). Throughout the world, concrete is being widely used for the construction of most of the buildings, bridges etc. Hence, it has been properly labeled as the backbone to the infrastructure development of a nation. At present, for a variety of reasons, the concrete construction industry is not sustainable. Firstly, it consumes huge quantities of virgin materials which can remain for next generations. Raw material over, 2.5 million tonnes is consumed for production of cement per year. A single plant producing 600,000 tons of cement a year would consume about 1,000,000 tons of raw materials (Jorge, 2019). Secondly, production of Portland cement which is the principal binder of concrete is contributor to greenhouse gas emissions that are implicated in global warming and climate change. It contributed 7% to global CO2 emission, largely due to the sintering of limestone and clay at 1500°C. The CO2 emission of concrete is directly proportional to the cement content used in the concrete mix (Pawar et al., 2018). Thirdly, From the economical view point, ordinary Portland cement is known to be more expensive as its production is highly energy intensive (Oladunmoye & Olutoge, 2017). The typical electrical energy consumption of a modern cement plant is about 110–120 kWh per tone of cement. Fourthly, many demolished concrete structures waste pollute environment. Construction and demolition activities generate huge amount of waste and constitutes nearly 20 to 30% of total solid waste. It is creates harmful effects on the environment, ecological resources and human life. It is contributing to various types of pollution like air pollution, water pollution, soil pollution and nose pollution. It is affecting the entire living world as along with human beings, plants and animals are also not unscathed (Suman, 2020). These issues have led to rigorous research into searching various materials that can be used as pozzolans. Researchers are continually pushing the limits with the help of innovative chemical admixtures and supplementary cementitious materials. Supplementary cementitious materials are often incorporated in the concrete mix to reduce cement contents, improve workability, increase strength and enhance durability. Supplementary cementitious materials date back to the ancient Greeks incorporated volcanic ash with hydraulic lime to create a cementitious mortar. The Greek passed this knowledge on to the Romans, constructed such engineering marvels as the Roman aqueducts and the coliseum, which still stand today. Early supplementary cementitious materials consisted of natural, readily available materials such as volcanic ash. Nowadays, some agricultural by-products and wastes are attracting much research because of their pozzolanic content for use as additives in commercial Portland cement. This illustrates that a significant replacement of Portland cement by agricultural by-product cementitious material is a cost-effective means to produce concrete (Oladunmoye & Olutoge, 2017).The agricultural by-products (wasted), mixtures of Portland cement that partially replace cement are known as blended cements or composite cements. By definition, blended cements are hydraulic binders in which a part of Portland cement is replaced by other hydraulic or non-hydraulic materials. Their general behavior is quite similar to that of Portland cement since they hardened when mixed with water and form the same hydration products. The most common ingredients for blending with Portland cements clinkers are latent hydraulic components (blast furnace slag or pozzoanic component such as pozzolanna, fly ash, rice husk ash, condensed silica fume, burnt clay or filler component such as limestone and other waste materials (Dwivedi et al., 2006). During hydration of Portland cement, Ca(OH)2 is obtained as one of the hydration products which in fact is responsible for deterioration of concrete. But when certain pozzolanic materials containing amorphous silica is added during hydration of Portland cement, it reacts with lime giving additional amount of Calcium Silicate hydrate (C-S-H), the main cement component. Thus pozzolanic material reduces the amount of Ca(OH)2 and increases the amount of calcium silicate hydrate (C-S-H) . Thus if a good quality pozzolanic material in suitable amount is added during the hydration of Portland cement, the cementing quality is enhanced (Dwivedi et al., 2006), (Oladunmoye & Olutoge, 2017). Bamboo leaf is one of agricultural byproduct highly available over the world. Several research studies on the use of bamboo leaf ash (BLA) as a pozzolanic material in the making of concrete have been undertaken across the world. Investigated that the bamboo leaf ash is a good pozzolanic material that reacts with calcium hydroxide forming calcium silicate hydrate. In Ethiopia, only two bamboo species are growing and both are endemic to Africa. These species are Yushania alpina (highland bamboo) and Oxytenanthera abyssinica (lowland bamboo). Ethiopia has over one million hectares of highland and lowland bamboo resources, which account for about 67% of African bamboo resources and more than 7% of the world total area covered by bamboo(Mekuriaw et al., 2022). In Ethiopia little attention was given on the use of the bamboo leaf other than using bamboo culm for construction, furniture (traditional processors and modern workshops) and fencing (Mathewos, 2017). Due to the high availability of Bamboo in Ethiopia, nothing has been done so far to check the feasibility of the Bamboo leaf Ash related to construction use. This research investigates the use of Bamboo leaf Ash as cement replacing material in concrete production. The physical, chemical properties, Mechanical properties and durability of concrete with bamboo leaf ash studied.

1.2 Statement of the Problem

Carbon dioxide emissions from cement production of Ethiopia increased from 13 thousand metric tons in 1965 to 734 thousand metric tons in 2014 growing at an average annual rate of 10.57 % (Taffese & Abegaz, 2019). The Ethiopian Ministry of Trade has reported that all the cement manufacturers are increasing production cost because the price of imported coal that the cement factories abundantly use is also escalated, and transport cost has increased. The Energy cost for production of cement includes cost of material for fuel, natural gas, and coil. Cost of fuel oil (diesel), natural gas, coal is $0.587 per litter, $per 10000ft3, $68.9 per tons respectively. Hence, it leads to scarcity of cement in Ethiopia and difficulty to afford it. Ethiopia has announced a new cement price regulation to tackle the rising cost of cement products in the country 2022. According to the Ethiopian Ministry of Trade and Regional Integration, the factory selling price for a quintal (100kg) of cement was between ETB510-683.44 (US$9.50-12.74). Cement factories in Ethiopia were initially asked to make price adjustments but the prices suggested were too high, prompting the ministry to establish a task force to study the production process and come up with price suggestions. The average per capita cement consumption of the country has increased from 39kg to 62kg (Abebaw et al., 2021). However, this is still way below the global average per capita consumption of 500kg. Abundant agricultural wastes are discharged in Ethiopia yearly; Bamboo leaf is more often considered waste of agricultural activities; when harvesting bamboo poles (timber), the disposal of Bamboo leaf becomes an ecological crisis. Especially around bamboo plantation centers the bamboo leaf drop from the bamboo pole, accumulated and putrefy (decay) can be considerable sources for contamination of water sources and people living around bamboo harvesting area have complains about pollution of rivers and its associated health impact and deposed bamboo leaf take space. This research is carried out to overcome the problem of disposal of farming waste

(Bamboo leaf) and the experiment was examined the practicability of bamboo leaf ash as partial replacement of cement in concrete production.

1.3 Objective of the Study

1.3.1 General Objective

To investigate the Effect of Partial Replacement of Cement with Bamboo Leaf Ash on the Mechanical and Durability Property of C25 Concrete Production.

1.3.2 Specific objectives

- To investigate the physical and chemical properties of Bamboo leaf ash as a pozzolanic material.
- To investigate the effect of replacing Cement with varying percentages of Bamboo leaf ash on the mechanical properties of concrete.
- To investigate the effect of partial replacement of cement with Bamboo leaf ash on durability of concrete.

1.4 Research Questions

- What physical and chemical properties of Bamboo leaf ash as a pozzolanic material?
- What are the effects of using different proportions of BLA as a partial replacement of cement on mechanical properties of concrete?
- What is the effect of using BLA as cement replacement material on durability of concrete?

1.5 Significance of the Study

The recent increase in the price of building materials which lead to high cost of construction, also the population increase in urban have created a lot of housing problem, where as local materials like bamboo leaves are being wasted. Pozzolan being readily available and cheaper will eventually bring a lot of cost savings. Replacing cement with bamboo leaf ash can contribute to reduction in cost and environmental hazard associated with cement production as well as waste pollution caused by the littered bamboo leaves. Hence, the Cultivation of Bamboo creates job opportunity and stimulates the economy of the community. Whereas, it will be a good trend for the green economy. Thus, it’s important to extend the concept of BLA as a partial replacement of cement.

1.6 Scope of Study

The research addresses, studying the chemical composition of BLA, physical properties of the material, workability, compressive, flexural strength, and durability of BLA blended concrete. The workability of fresh concrete was conducted employing a slump test. The hardened properties of concrete were investigated by testing the compressive strength of the concrete cube and flexural strength of the concrete beam using a compressive and flexural strength machine. C-25 grade concrete is selected for this study and six types of mix code are developed (Control OPC, BLA5%, BLA10%, BLA15%, BLA20% and BLA25%). For the sake of this experiment concrete specimens were casted in (15cmx15cmx15cm) cubes and (50cm*10cm*10cm) beam mold for each proportion. The effect of BLA replacement in microstructure by SEM (scanning electron microscopy) of the concrete test was conducted by testing device in Adama science and Technology University, Material engineering department Laboratory. The sample is taken from Yushania alpina (highland bamboo) species in Ethiopia.

1.7 Limitations

Due to time, budget, and laboratory equipment constraints, the following limitations were imposed on this study. Due to a lack of grinder to grind bamboo leaf in Adama science and technology Laboratory research center, grinding mechanism is performed by using local grinder (wofco). Due to Limitation of testing equipment and difficult to get on time in the Adama science and Technology University, the XRD (X-Ray diffraction) of the concrete test were not performed.

1.8 Structure of the Thesis

The research is organized into five chapters and each chapter contains some sections and additional subsections.

Chapter one: A general introduction was provided along with the research objective and significance.

Chapter two: it includes literature reviews on supplementary cementitious materials, as well as the fresh and hardened properties of concrete containing Bamboo Leaf ash.

Chapter Three: covers the methodology and materials used in the research. It explains the properties of materials, mix proportions, mixing, casting, and curing procedures used in the attempt to find out in a systematic and scientific study.

Chapter four: covers the experimental program of the study, results, and discussions of the tests conducted.

Chapter five: Its covers the conclusions and recommendation then, comes References followed by Appendices.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Concrete is manmade composite construction material. Basically composed of cement, aggregates, chemical admixtures, mineral admixtures, and water. The active constituent of concrete is cement paste and the performance of concrete is largely determined by the cement paste (Abebaw et al., 2021). From the 20th century, there had been an increase in the economic consumption of mineral admixtures by the cement and concrete industries. The increasing demand for cement and concrete is conformed to by partial replacement of cement. Significant cost savings can result when by-products are used as a partial replacement for the energy acute Portland cement. The use of Agricultural by-products also reduces the pollution and proved as an environmental friendly method of disposal of large quantities of waste materials that would otherwise pollute land, air and water (Harshit & Roorkee, 2016). Cement replacing materials help reducing the proportion of cement in concrete, and at the same time they also can improve the properties of concrete in several ways. Besides pozzolans, finely ground inert material known as filler is also used widely there is a growing interest in reducing carbon emission related to cement production from industrial sectors. Different studies have been made worldwide to use wastes from agricultural byproduct by converting them in to ash for cement replacement purpose at different proportions (Selamawit, 2020). Scholars are studied for feasibility of bamboo leaf ash as a cement replacing material in some parts of the world and has been found to improve some of the properties of concrete (Abebaw et al., 2021). Ethiopia has about one million hectares of high and low land Bamboo (Mekonnen et al., 2014). This study focused on the effects of high land Bamboo Leaf ash in concrete production.

This chapter is, therefore, devoted to review cement, performance criteria of concrete, pozzolanas, bamboo leaf ash as cement replacement material, method and design reviewed. The overall summary of literature is discussed in the following subchapters.

2.2 Cement

Cements are adhesive substances, which when mixed with water form paste and the paste is temporarily plastic and may be molded or deformed. But later it sets and hardens to a rigid mass. The credit for its discovery is given to the Romans, which mixed lime

($CaCO_3$) with volcanic ash, producing a cement mortar which was used during construction of such impressive structures as the Colosseum (Peter & Lea's, 2004). The Cement mixed with water and aggregates result concrete. Concrete is second only to water as the most consumed substance on Earth (Hailu, 2011). The consumption of cement correlates to the economic development of a country as a base for new building, factories and infrastructures which are the root of development. As a result of this cement manufacturing has increased sharply in those developing countries.

2.2.1 Types of Cement

There are different types of cement depending on their composition, method of manufacturing (grinding, burning, etc.) and also the relative proportion of the different compounds. One of these types and the most commonly used one is Portland cement, which in turn is divided into many types. The other common type of cement is Portland pozzolana cement which contains some amount of pozzolanic materials.

2.2.2 Portland cement

Portland cement is one of the most widely used cement and is the most important hydraulic cement. It can also be used for mortar and plaster production. It is used in all types of structural concrete like walls, floors, bridges, tunnels, etc. It is further used in all types of masonry works like foundations, footings, dams, retaining walls, and pavements. When Portland cement is mixed with sand and lime, it serves as mortar for laying brick and stone; and when it is mixed with coarse aggregate and fine aggregate (sand) together with enough water, to ensure a good consistency, it get concrete. The origin of the name "Portland cement" is usually attributed to Joseph Aspdin, a brick mason in England who in 1824 took out a patent for making a powder made from mixed and ground hard limestone and finely divided clay. This forms into slurry and then is calcined in a furnace till the CO_2 was expelled. The author called the resulting material Portland cement because when the mortar made with it hardened it produced a material resembling the stone which was quarried near Portland, England (Shetty, 2005). The method of making cement has been improved upon since that time but the basic process has remained the same. Modern Portland cement is made from materials which must contain the proper proportions of lime (CaO), silica (SiO_2), alumina (Al_2O_3), iron (Fe_2O_3) with minor amounts of magnesia and sulfur trioxide. A typical composition of general purpose Ordinary Portland cement is shown in the Table 2.1 below:

Table 2.1 Typical composition of ordinary Portland cement

Chemical Name	Chemical formula	Shorthand Notation	Weight percentage
Tricalcium silicate	3CaO.SiO2	C3S	55
Dicalcium silicate	2CaO.SiO2	C2S	18
Tricalcium aluminate	3CaO.Al2O3	C3A	10
Tetracalcium aluminoferrite	4CaO.Al2O3.FeO3	C4AF	8
Calcium sulfate dehydrate (gypsum)	CaSO4.2H2O	CSH2	6

Of these compounds, C3S and C3A are mainly responsible for early strength of concrete. High percentages of C3S (low C2S) results in high early strength but also high heat generation as the concrete sets. The reverse combination, that is, low C3S and high C2S develops strength more slowly and generates less heat. C3A causes undesirable heat and rapid reacting properties, which can be prevented by adding CaSO4 to the final product. 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 (Hailu, 2011) .

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

II. 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.

III. 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.

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

V. Finally ASTM type V is Sulphate -resisting Portland cement which is used when high sulphate resistance is desired.

2.2.3 Portland Pozzolana Cement

Portland pozzolana cement (PPC) is manufactured by the inter-grinding of OPC clinker with 15 to 35 % of pozzolanic materials (Shetty, 2005). Pozzolanic materials are siliceous or aluminous materials which by themselves possess little or no cementitious properties. But in the presence of water they react with calcium hydroxide which is liberated from the hydration of cement to form a compound possessing cementitious property. The reaction of the pozzolanic materials with calcium hydroxide results in many advantages of PPC over OPC. If these pozzolanic materials were not reacted with the calcium hydroxide, free calcium hydroxide would have been present in the concrete resulting in higher permeability of the concrete and susceptibility to other attacks. The pozzolanic reaction reduces the porosity of the concrete by producing cementitious compound. It also reduces the heat of hydration since its reaction is slower than that of OPC, which implies that it has 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 cements. Expansive cement, calcium sulfoaluminate cement, masonry cement, oil well cement, white cement etc. can be an example for this. There are also non-Portland inorganic cements which are used to some extent.

2.2.4 Hydration of Cement

When water and Portland cement are mixed, the constituent compounds of the cement and the water undergo a chemical reaction resulting in hardening of the concrete. This chemical reaction of the cement and the water is called hydration, and it results in new compounds called hydration products. Both C3S and C2S react with water to produce an amorphous calcium silicate hydrate known as C–S–H gel which is the main ‘‘glue’’ which binds the sand and coarse aggregate particles together in concrete. Each of the compounds found in the cement react with water, but the rate at which they react is different. C3S and C3A are the most reactive compounds, whereas C2S reacts much more slowly. Approximately half of the C3S present in typical cement will be hydrated by 3 days and 80% by 28 days, in contrast, the hydration of C2S does not normally proceed to a significant extent until approximately 14 days. Gypsum is added to lower the rate of hydration of C3A. The hydration of C3S and C2S are shown in Equation 2.1 and 2.2.

$C3S + 4.3H \longrightarrow C1.7SH3 + 1.3CH$…………………………… (Eq.2.1)

$C2S + 3.3H \longrightarrow C1.7SH3 + 0.3CH$……………………………. (Eq.2.2)

After a rapid initial reaction C3S will pass through a dormant stage which has a practical significance because it allows concrete to be placed and compacted before setting and hardening commences (Hailu, 2011).

2.2.5 Physical properties of cement

An understanding of the significance of some of the physical properties is helpful in interpreting results of cement tests.

2.2.5.1 Fineness

The fineness of cement affects many of its properties. The heat released and the rates of hydration are the main properties which are affected by the fineness of cement. These properties of the cement in turn affect many other properties, like normal consistency, setting time, strength, etc. Fineness of cement can be measured mainly by specific surface area method and particle size distribution. The specific surface area is the summation of the surface area of all of the particles in 1 gm or 1 kg of cement. Most of the time, it is a general practice to describe fineness by a single parameter, specific surface area (Sidney et al., 2003). Although it is possible to measure the particle size distribution of cement, there is still no agreement on what would contribute a best grading curve for cement. Due to this and other factors the specific surface area is preferred over the particle size distribution. The surface area is measured by the Blaine air-permeability test (ASTM C 204 or AASHTO T153) that indirectly measures the surface area of the cement particle per unit mass. According to the Ethiopian standard ordinary Portland cement shall have a specific surface area of not less than 2250 cm2/g (Dinku, 2002).

2.2.5.2 Consistency of Cement Paste

Many of the properties of concrete are affected by its water content. The physical requirements of cement paste like setting and soundness depends on the water content of the neat cement paste. Therefore it is necessary to define and study the water content at which to do these tests. This is defined in terms of the normal consistency of the paste which is measured according to ASTM C 187. The amount of water required to achieve a normal consistency as defined by a penetration of 10 ± 1 mm of the Vicat plunger (ASTM

C 187) is expressed as a percentage by weight of the dry cement, the usual range being about 26% to 33% (Dinku, 2002). The test is very sensitive to the conditions under which it is being carried out, particularly the temperature and the way the cement is compacted into the mold. The test does not correlate to the quality of the cement; it only measures the plasticity of cement paste.

2.2.5.3 Setting Time

Setting is a process in which cementitious mixtures of plastic consistency is converted into a set material which has lost its deformability and crumbles under the effect of sufficiently great external force (Peter & Lea's, 2004). It is preceded by a stiffening of the paste in which the apparent viscosity of the material increases without losing its plastic character. There are two types of setting time i.e. initial and final setting times. The initial setting time indicates the time at which the paste begins to stiffen considerably and can no longer be molded; while the final setting time indicates the time at which the paste has hardened to the point at which it can sustain some load. Like normal consistency these tests are also used for quality control. Ethiopian standard recommends that the initial setting time for cement not to be less than 45 minutes and the final setting time not to exceed 10 hours (Dinku, 2002).

2.2.6 Cement production in Ethiopia

In Ethiopia, the first cement factory was established by Italians in 1936 during the five year fascist occupation of the Country. This was the Dire dawa cement factory.

Table 2.2 Ethiopian cement demand consumption (In Million Ton) per Year

Year	Domestic Production	Import	Total Consumption
2005/6	2.75	0.89	3.64
2006/7	1.72	0.89	2.57
2007/8	1.66	1.24	2.90
2008/9	1.69	0.10	1.79
2009/10	1.62	0.49	2.11
2010/11	2.72	0.29	3.01
2011/12	3.77	0.01	3.77
2012/13	4.73	0.00	4.73
2013/14	5.47	0.00	5.48

Cement demand in Ethiopia reached approximately 12Mt in 2019, but domestic cement producers are only providing about 8.9Mt of this total, according to the Chemical and Construction Inputs Development Institute (CCIDI), in spite of nominal installed capacity in the region of 20Mta (MOI, 2021).

2.3 Concrete

Concrete is the most commonly used modern construction materials. It forms the basis of the modern construction system. Many of our activities directly or indirectly are affected by concrete structures; the living buildings and other work in, the roads to drive on, the dams from which get water and energy, etc can be an example. The ability of concrete to be cast into any desired shapes and configurations is the reason for its versatility. The word concrete comes from a Latin word concretus which means to grow together (Sidney et al., 2003). which implies that it is a composite of different materials. It is composed of coarse granular material called aggregate or filler which is embedded in a hard matrix of material (cement or binder with water) binding the aggregates together and filling the space formed between them. When the constituents are mixed with water the concrete solidifies and hardens due to a chemical reaction between the water and the cement called hydration, which finally forms a stone like material by binding the aggregates together. Concrete is mainly composed of cement, aggregate and water. Cementitious materials, pozzolanic materials, filler materials, chemical admixtures, and some other additives may also be the constituents of concrete depending on the need and their availability. All the constituents have their own purpose in the concrete. Cement with water acts as a binding medium in which the aggregates which accounts 70% to 80% of the concrete are bound together to form the concrete. Economy, dimensional stability and wear resistance are the main reasons behind using aggregates. Different types of admixtures are used to modify the properties of ordinary concrete so as to make it suitable for any situation. If a concrete is to be suitable for a particular purpose, it is necessary to select the constituent materials and combine them in such a manner as to develop the special qualities required as economical as possible (Hailu, 2011). Therefore the selection of constituents of concrete depends on the quality and economy of the particular concrete required.

2.3.1 Workability of Concrete

Workability is the measure of how easy or difficult it is to place, consolidate and finish concrete. It contains in it different aspects like consistency, flow ability, mobility, compactability, finishability, and harshness (Sidney et al., 2003). It can also be defined in terms of the amount of mechanical work, or energy required producing full compaction of the concrete without segregation. This property of concrete is affected by a number of factors like: water content of the mix, mix proportions, aggregate properties, time, temperature, characteristics of the cement and admixtures. Water content is the most important factor affecting the workability of concrete. Increasing the amount of water will increase the workability of the concrete. However the increase in water content of the mix will decrease the strength and also result in segregation and bleeding. When considering the effect of aggregate the amount of aggregate, the proportion of coarse and fine aggregate and the shape and texture of the aggregate particles affect the workability of concrete. Keeping the water content and cement content constant increasing the amount of aggregate reduces the workability of concrete. Spherical and smooth aggregate result in a more workable mix, whereas flat, elongated and rough aggregate particles will result in reduction of workability. The increase in the ambient temperature will reduce the workability of the concrete, due to increase of evaporation and rate of hydration caused by the higher temperature. The cement content and cement replacing materials also affect the workability. Higher cement content reduces workability. The effect of cement replacing materials depends on their nature. Finer materials result in reduction of workability while spherical materials increase it (Hailu, 2011) .

2.3.2 Strength of Concrete

Strength of concrete is commonly considered its most valuable property, although in many practical cases other characteristics, such as durability and permeability, may in fact be more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because it is directly related to the structure of the hardened cement paste (Neville, 2010). The strength of concrete is dependent on many things. The hydration reaction, water to Cement ratio, aggregate type, amount and size, water content, cement content, curing condition, cement type, compaction method used etc. have an effect on the strength of concrete. Strength at any W/C ratio depends on the degree of hydration of the cement and its physical and chemical properties. The decrease in the water content of the concrete results in a higher strength of the concrete. The water required for the hydration reaction is less than that of the mixing water; the extra water provided is used to make the concrete more workable. The compaction of the fresh concrete reduces the amount of entrapped air and therefore increases the strength of the concrete. It is found that for each 1 % of air entrapped there will be a 5 to 6 % loss on strength (Dinku, 2002). Curing temperature affects the hydration of cement and hence the duration of strength gains. Cubes kept at about 10oC will have their 7 day strength reduced by 30% and their 28 day strength by 15%. Different pozzolanic materials have different effect on Concerete strength(Dinku, 2002).

2.4 Pozzolans

The modern concrete technology uses different types of admixtures in order to enhance the properties of the fresh and hardened concrete. pozzolans are a broad class of siliceous and aluminous materials which, in themselves, possess little or no cementitious value but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide ($Ca(OH)_2$) at ordinary temperature to form compounds possessing cementitious properties (Mehta, 2019). The quantification of the capacity of a pozzolan to react with calcium hydroxide and water is given by measuring its pozzolanic activity (Snellings et al., 2012). The more commonly accepted classification concerns the origin of pozzolanic materials are natural and artificial materials (Abebaw et al., 2021). This research area is concerned with natural pozzolanic.

2.4.1 Pozzolanic Materials

Pozzolanic materials are siliceous or siliceous and aluminous materials which alone possess little or no cementitious value but , in finely divided form and in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. Their recognition dates back long ago to the ancient Greeks and Romans. The Greeks used volcanic ash and the Romans adopted and extended the Greeks technology using ash from varieties of sources from around their empire. Pozzolanic materials can be divided into two groups: natural pozzolana and artificial pozzolana. Clay and shales, opalinc chert, diatomaceous earth, and volcanic ash are an example of natural pozzolans while fly ash, blast furnace slag, silica fume, rice husk ash, and metakaoline are example of artificial pozzolans. Most of the pozzolans in use today are mainly byproduct materials that are widely available. Because of the diversity of pozzolans their chemical composition also varies. Therefore classifying pozzolans only depending on their chemical composition would be difficult. For this reason ASTM C 618 classifies pozzolans depending on performance basis. ASTM C 618 chemical composition for pozzolans is as shown in Table 2.3.

Table 2.3 ASTM C 618 chemical requirement for Pozzolan (ASTM C618, 2014)

Chemicals	Pozollan class		
	N	**F**	**S**
$SiO_2+Al_2O_3+Fe_2O_3$ (min %)	70	70	50
MgO (max %)	5	…	5
SO_3 (max %)	4	5	5
Moisture content (max %)	3	3	3
Loss on ignition (max %)	10	12	10
Available alkalis as Na_2O (max %)	…	1.5	1.5

2.4.2 Pozzolanic Reaction

The hydration of tri-calcium silicate and di-calcium silicate with water gives calcium silicate hydrate and calcium hydroxide. The first compound have very low solubility in water while the later one is very much soluble in water and has no cementitious value and is found as a free lime in the concrete, resulting in porosity of the concrete, which in turn results in durability problems. The siliceous and aluminous compounds found in the pozzolan in a finely divided form react with the calcium hydroxide to form highly stable cementitious substances of complex composition involving water, calcium and silica. Finely divided pozzolans and amorphous silicates result a better pozzolanic reaction. The principal reaction taking place is as shown in Eq. 2.2 (Sidney et al., 2003).

Pozzolan + Calcium Hydroxide + water $\longrightarrow$ Calcium Silicate Hydrate (gel)

S + CH + H $\longrightarrow$ C-S-H ……………………………………………………(Eq.2.3)

this reaction is called pozzolanic reaction. It results in the consumption of the calcium hydroxide produced by the hydration of the cement and as a result lowers its amount in the concrete. The C-S-H formed in this reaction is not very different from that formed in the regular reaction, except the slightly lower ratio of C/S, which is the case for most of the pozzolans. The normal C/S ratio is believed to be around 2 (Neville, 2010). The pozzolanic reaction in Eq. 2.3 and its kinetics are more similar to the slow rate of hydration of C_2S

(Sidney et al., 2003). Thus the addition of pozzolans has similar effect with increasing the amount of C2S. This results in the reduction of the rate of strength development and the heat of hydration, which makes it advantageous in mass concrete structures. The progress of hydration of cement can be measured by measuring the amount of Calcium hydroxide in the paste. In a similar manner the extent of pozzolanic reaction can be followed by monitoring the decrease in calcium hydroxide over time (Hailu, 2011) .

2.5 Bamboo Leaf

Bamboo is a type of grass with a hard, woody, hollow stem. It is a perennial evergreen with annual leaf exchange. A new leaf emerges in the springtime to gently push off old foliage, meaning it grows every year and stays green year round. Hundreds of kinds grow in different regions of the world (MacDonald, 2022). Bamboo leaf ash (BLA) is a fine waste derived from the combustion of bamboo leaves in a controlled or uncontrolled burning process (Dwivedi et al., 2006), (Abebaw et al., 2021).

Figure 2.1 Bamboo leaf

2.5.1 Pozzolanic Property of Bamboo Leaf Ash

Bamboo leaf fired in an open atmosphere and then heated at 600 oC for 2 hr in a furnace was found to be an amorphous material containing amorphous silica. The ash was characterized by chemical analysis, powder X-ray diffraction and SEM techniques. Bamboo leaf ash is a good pozzolanic material which reacts with calcium hydroxide forming calcium silicate hydrate. The pozzolanic activity of bamboo leaf ash increases with increase of time and temperature. Pozzolanas and Pozzolanic property of artificial pozolanic material such as BLA gain a distinct pozzolanic activity when burned at temperatures between 600°C and 900°C. When 20% weight of bamboo leaf ash was mixed with Portland cement, the compressive strength at 28 days of hydration was comparable to that without ash (control mix) and observed better results. This was due to pozzolanic reactions (Dwivedi et al., 2006)

2.5.2 Bamboo Leaf Ash Production

There are two main types of bamboo leaf ash production techniques: controlled production process and uncontrolled (open-air) production process:

Control Production process: Combustion of the grinded bamboo leaf ash is performed using a muffle furnace under controlled Temperature and time. The BLA sample is then combusted in the muffle furnace at temperatures of 600Oc for 2hrs (Abebaw et al., 2021). Uncontrolled (open-air) production process: Dried bamboo leaf was collected and burnt completely to ash in an open air (Olanrewaju et al., 2021).

2.5.3 Physical Properties of Bamboo Leaf Ash

Physical property of Bamboo leaf ash is a property such as color, specific gravity, Fineness, Soundness, Consistency, Setting time, Heat of hydration. Loss of ignition and Bulk density that not involving in its manifestation a chemical change.

Table 2.4 Physical properties of BLA

No	Parameter	Physical properties of BLA by Different Author				
		Hnin et al., (2018)	Abebaw et al., (2021)	Onikeku et al., (2019)	Umoh & Odesola, (2015)	Asha et al., (2014)
1.	Color	Gray	Dark Gray	Dark gray	Black	Gray
2.	Specific gravity (g/cc)	2.65	2.15	2.79	2.64	2.76
3.	Fineness (%)	-	30.5	-	32.85	-
4.	Soundness	-		-	-	-
5.	Initial Setting time	-		-	-	145min
6.	Final setting time	-		-	-	270 min

2.5.4 Chemical Properties of Bamboo Leaf Ash

Chemical composition of Bamboo leaf ash refers to identity and number of the chemical elements that make up particular compound (Bamboo leaf ash). The effect of temperature and time of the burning of the Bamboo Leaf affect the chemical composition of BLA (Abebaw et al., 2021).

Table 2.5 The chemical composition of BLA (Oxide % by weight)

No	Oxide	Oxide % by weight			
		Abebaw et al., (2021)	Dwivedi et al., (2006)	Alake et al., (2018)	Oladunmoye & Olutoge, (2017)
1.	SiO_2	65.66	75.90	83.33	75.00
2.	Al_2O_3	6.41	4.13	1.03	4.13
3.	Fe_2O_3	4.28	1.22	1.95	1.22
4.	CaO	15.22	7.47	4.44	7.47
5.	MgO	2.48	1.85	1.02	1.85
6.	Na_2O_3	2.76	0.21	0.05	---
7.	K_2O	4.84	5.62	3.09	5.62
8.	MnO	---	---	0.22	0.016
9.	P_2O_5	---	---	0.73	3.22
10.	TiO_2	---	0.20	0.34	---
11.	H_2O	---	---	---	---
12.	SO_3	---	1.06	0.10	---
13.	LOI	9.65	---	0.40	---
14.	SiO_2+ Al_2O_3+ Fe_2O_3	76.35	81.25	86.33	80.33

2.6 Microstructure Analysis

Accordingly, Ikumapayi, (2017) microstructural analysis, Ordinary Portland cement was partially replaced with BLA at 0%, 8%, 12%, and 16% percentage, concrete pastes were made and cured for 7 and 28 days. The research work has been approved out rough X-ray fluorescence spectrometer, X-ray diffraction analysis as well as scanning electron microscopy to determine, existing, and examine the quality and quantity of structure and hydration performance of the diverse paste. The tests established BLA as capable of successfully replacing cement in concrete production with added advantages in the properties of such concrete in terms of mineral arrangement and microstructure interlocking. The X-ray diffraction outlines were observed for OPC, BLA8%, and

BLA25% pastes at 7 days to explain the methods behind their hydration behavior. The results of the XRD pattern, as well as XRF, show the prevalent of silica in BLA paste and ash respectively. Similarly (Singh et al., 2007) examines that pozzolanic activity by using chemical methods, differential scanning calorimetry, X-ray diffraction, and scanning electron microscopic techniques. The hydration behaviors of 20% BLA blended ordinary Portland cement (OPC) were researched using various experimental methodologies, and it was discovered that after 28 days of hydration, the compressive strength value for 20% BLA blended cement mortar was relatively equivalent to that of OPC mortar. The X-ray diffraction pattern of the sample (CH+BLA) hydrated at 28 days is shown in Figure 2.2 the picture shows the development of the calcium silicate hydrate (C-S- H) phase from unreacted calcium hydroxide. The diffraction pattern confirms that BLA is a pozzolanic material and during the reaction, calcium silicate hydrate is formed.

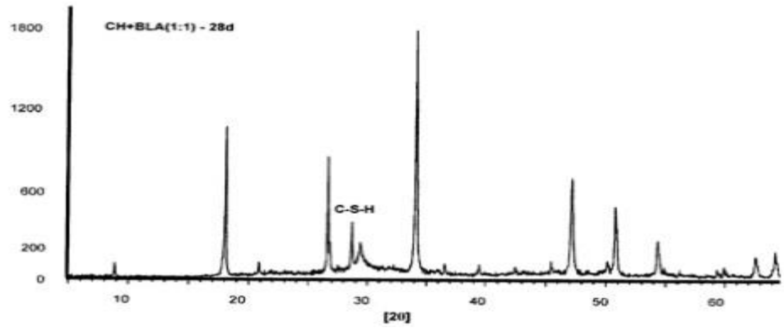
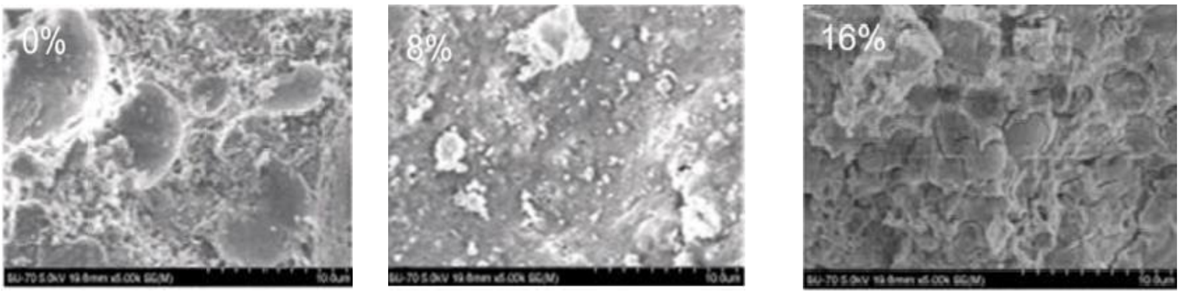


Figure 2.2 XRD patterns of CH+BLA at 28 days

The result of the SEM pictures for hydrated samples of OPC, BLA 8%, and BLA16% at 28days curing are shown in the following Figure 2.2 (Ikumapayi, 2017)



A. SEM 0%BLA B. SEM 8%BLA C.SEM 16%BLA

Figure 2.3 SEM pictures for BLA blended paste

The result shows that the image of BLA8% is tightly interlocked when compared with OPC and BLA16%, while that of OPC gives a better mechanical interlocked than BLA16%. This result further supports that the addition of pozzolanic material to concrete will improve the microstructural property of such concrete which in turn will improve the other properties like compressive strength and durability.

2.7 Effect of bamboo leaf ash on fresh Concrete Properties

2.7.1 Workability of Concrete with BLA

`Workability of Concrete is a broad and subjective term describing how easily freshly mixed concrete can be mixed, placed, consolidated, and finished with minimal loss of homogeneity. The slump test is the simplest test for workability and it is the most widely used on construction sites. Scholars were done the effect of Bamboo leaf ash on the workability of concrete. Slump levels of BLA at 0% and 5%. The percentage replacement rates of 10%, 15%, and 20% were investigated. As a consequence, the slump increased from 60mm with 0% BLA replacement to 63mm at 5% BLA replacement (Onikeku et al., 2019). The concrete with 100% cement exhibits a higher slump compared to the one with BLA replacement. It was observed that the increase the replacement of percentage BLA, the lesser the slump. At an assumed water-cement ratio, the small addition of BLA (10 to 20%) enhanced the workability of the concrete by dropping the inclination to bleeding and segregation. This was due to the large surface area of BLA. The greater amount of percentage BLA to substitute cement (30 to 40%) produced less workable concrete mix(Oladunmoye & Olutoge, 2017). The workability of concrete decreases as the BLA replacement amount increases, but the setting time, water percentage for consistency, and soundness of cement paste all increase(Abebaw et al., 2021).

Table 2.6 Slump value of fresh concrete with cement and blended BLA

S. No	Mix code	Abebaw et al., (2021),		Onikeku et al., (2019)	
		W/C ratio	Slump (mm)	Compacting Factor (CF)	slump (mm)
1	Control	0.49	30	0.955	60
2	BLA5	0.49	25	0.945	63
3	BLA10	0.49	25	0.934	58
4	BLA15	0.49	20	0.925	56.5
5	BLA20	0.49	20	0.91	53
6	BLA25	------	----	0.9	52

2.7.2 Effect of BLA on Setting Time of Concrete

Both initial and final setting time of concrete increased with increase in the percentages of BLA as partial replacement for OPC (Oladunmoye & Olutoge, 2017). The concrete setting times of the blended cement at 5% substitution level was almost unchanged compared with those of the control. However, higher substitution levels witnessed a marked increase in setting times especially when attain the 15% level and above (Olanrewaju et al., 2021).

2.7.3 Effect of BLA on Mechanical properties of Hardened Concrete

Performance of concrete is evaluated from mechanical properties which include compressive strength, tensile strength, flexural strength, and modulus of elasticity. But addition of material as partial replacement of cement influences the mechanical characteristics of hardened concrete. the effects of the same amount of different mineral admixtures on the mechanical properties of hardened concrete are not same (Ayub et al., 2014).

2.7.4 Effect of BLA on Compressive Strength of Concrete

Compressive strength of concrete is an indexing property as concrete designed to carry compressive loadings. Compressive strength test is mechanical test measuring the maximum amount of compressive load a material can bear before fracturing. The test piece, usually in the form of a cube is compressed between the platens of a compression-testing machine by a gradually applied load (Ayub et al., 2014). According to (Abebaw et al., 2021) On the 28th day, the compressive strength of concrete made with partial replacement of cement by up to 10% attains the target mean strength (33.5Mpa), and there is a 1.84% and 0.12% enhancement in compressive strength values for 5%and 10% replacement compared to the control mix on the 56th day. While the density reduced as the BLA replacement increase. (Onikeku et al., 2019) discovered that there was an early strength generation at 7 days for percentage replacements ranging from 5% to 10%, and decline in strength for 15% and 20% replacements. These patterns also apply to compressive strength of 28, 56, and 90 days. The maximum strength was recorded at 10% BLA replacement at 7th, 28th, 56th, and 90th days curing age, respectively. The results of the compressive strength of BLA blended cement mortar presented by (Umoh & Odesola, 2015) indicated that the strength increases with increased in hydration period for each of the replacement level of cement with BLA. It is equally observed that at the replacement levels of 10%, higher strength values were attained when compared to the reference specimens (that is 0% BLA content).

Table 2.7 Compressive strength of BLA blended concrete

Curing age (Days)	Compressive strength Mpa											
	Abebaw et al. (2021)					Onikeku et al., (2019)				Oladunmoye & Olutoge, (2017)		
	0%	5%	10%	15%	20%	0%	5%	10%	15%	0%	10%	20%
7th	29.41	28.39	26.37	23.31	20.83	19.7	21	21.1	17.6	16.4	10.22	8.44
14th	----	----	----	----	----	-----	----	----	---	20.67	15.78	13.78
28th	37.7	36.16	35.96	32.32	29.51	26.9	27.6	28.5	25.5	30.22	28.56	25.89
56th	39.93	40.68	39.38	38.68	38.23	29	30.4	32.3	28.6		----	---
90th	----	----	----	----	----	33.9	35.8	38.5	32.1		----	---

2.7.5 Flexural Strength

Flexural strength is an indirect measure of the tensile strength of concrete. It is a measure of the maximum stress on the tension face of an unreinforced concrete at the point of failure in bending. It is measured by loading concrete beams with a span length at least three times the depth and determined by standard test methods ASTM C78 or ASTM C293). Flexural strength increased as the percentage replacement of BLA increased from 3.5MPa at 0% to 3.9MPa at 10%. There was a slight reduction in flexural strength at 15% and drastic decrement was noticed at 20% BLA replacement. The improvement in strength could be related to the high amount of amorphous silica and CaO which increased the strength. The maximum flexural strength was found at 10% BLA replacement. The reduction in strength could be that maximum percentage replacement should not exceed 10% - 15%. Any further increment would lead to a reduction in flexural strength. This trend suggests that BLA increased the brittleness of the concrete up to 15% percentage replacement. The results obtained satisfied the limit of between 3 - 4MPa based on BS EN 12390-5 (2009) (Onikeku et al., 2019).

2.8 Durability of concrete

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Durability of concrete tasted by: Absorption Tests, sulphate attack test, Rapid Chloride Permeability test, Water Permeability test.

2.8.1 Effects of BLA on Sulphate Attack of Concrete

Sulphate attack of concrete is a complex process, which includes physical salt attack due to salt crystallization and chemical sulphate attack by sulphates from soil, groundwater, or seawater. Sulphate attack occurs when sulphates react with compounds in the cement paste such as mono sulphate, portlandite, and C–S–H gel. The reaction products may include ettringite, gypsum, and thaumasite. Destabilization of the C–S–H gel may be another consequence of the reaction. External sulphate attack occurs when the sulphates enter the concrete from the surrounding environment. Internal sulphate attack occurs when there is an excess of sulphate in the original mixture. The compressive strength loss due to sodium sulphate attack after immersed the specimens for 56 days in the 5% sodium sulfate solution for control mix (BLA0%) was assessed 4.58%. The BLA blended mix, BLA5%, BLA10%, BLA15% and BLA20% suffered 3.37%, 3.93%, 4.63%, and 4.79% strength loss at their age of 56th day. Maximum strength loss was experienced in BLA 20%, whereas minimum loss noticed in BLA5%. Loss of strength increased with BLA as the replacement amount increased. But, concrete mixes with 5% and 10% Bamboo leaf ash suffered less strength loss in comparison to the control mix. Loss of strength increased with BLA content (Abebaw et al., 2021). The value of the strength loss increases as the concentration of the sulphate increases from 1 % to 5 % concentration, and exposure period from 32 days to 182 days. Magnesium sulphate solution at 5 % concentration and 182 days exposure had greater effect on the compressive and tensile strength reduction of both plain and BLA blended cement concrete. Statistically it was observed that the sulphate type, sulphate concentration, BLA content and exposure period, each and collectively had effect on the concrete compressive and tensile strength (Alake et al., 2018).

2.8.1.1 Effect of BLA on Water Absorption of Concrete

Water absorption is defined as the amount of water absorbed by a material and is calculated as the ratio of the weight of water absorbed to the weight of the dry material. The water absorption of BLA concrete samples had low water absorption as compared with reference concrete. This reduction in water absorption could be as a result of initial filling of the voids by BLA concretes there by acting as a water repellent (Onikeku et al., 2019). Decrease in the weight of water absorbed was observed as the percentage BLA substitution increases from 0% to 10% and starts increasing from 15% to 20%. The percentage water absorption range between 1.02% and 2.84% with the least value attained at 90 days with 10% BLA content, and the greatest value of 2.84% attained by the reference concrete at 90 days. Generally, the water absorption of the blended cement concrete specimens has less water absorption than the reference; an indication that the incorporation of BLA causes a reduction in the voids thereby causing impermeability (Umoh & Odesola, 2015). A general decrease in the weight of water absorbed was observed at the percentage of BLA substitution of 5% and 10% then starts increasing from 15% to 20%. The percentage water absorption ranges between 2.9% and 3.6% with the least value attained at 5% BLA (2.90%) content, and the greatest value of 3.6% attained at 20% BLA content at 28th day. The water absorption of the 5% and 10% BLA blended cement concrete specimens did not have much water absorption as the reference; which is an indication that the integration of BLA in the voids thereby causing impermeability. The decrease in water absorbed at lower BLA replacement is also qualified to the initial filling of the voids by the BLA ingredient (Abebaw et al., 2021).

2.8.2 Availability of BLA in Ethiopia

According to the latest figure published in the Food and agriculture organization (FAO) of united nation global forest resource assessment 2020 (FRA) there are likely to be more than 35 million hectares of bamboo around the world. In fact (FRA) 2020 reports a 50% increase in bamboo area between 1990 to 2020, largely because of new expansion in China and India. Ethiopia has over one million hectares of highland and lowland bamboo resources, which account for about 67% of African bamboo resources and more than 7% of the world total area covered by bamboo (Mekuriaw et al., 2022).

2.9 Literature Summary and Gap Identification

Bamboo leaf is an agricultural by-product. The physical and chemical properties of Bamboo Leaf vary significantly depending on several factors, especially the species of Bamboo. The common physical properties of Bamboo Leaf are light weight, flexible, tough, high tensile. Bamboo leaf is cheap material than the other building materials. Bamboo can be used in various building works. According to (Abebaw et al., 2021) On the 28th day, the compressive strength of concrete made with partial replacement of cement by up to 10% attains the target mean strength (33.5Mpa), and there is a 1.84% and 0.12% enhancement in compressive strength values for 5%and 10% replacement compared to the control mix on the 56th day. While the density reduced as the BLA replacement increase. (Onikeku et al., 2019) discovered that there was an early strength generation at 7 days for percentage replacements ranging from 5% to 10%, and decline in strength for 15% and 20% replacements. These patterns also apply to compressive strength of 28, 56, and 90 days. The maximum strength was recorded at 10% BLA replacement at 7th, 28th, 56th, and 90th days curing age, respectively. The results of the compressive strength of BLA blended cement mortar presented by (Umoh & Odesola, 2015) indicated that the strength increases with increased in hydration period for each of the replacement level of cement with BLA. It is equally observed that at the replacement levels of 10%, higher strength values were attained when compared to the reference specimens (that is 0% BLA content).The reduction in strength could be that maximum percentage replacement should not exceed 10% - 15%. Any further increment would lead to a reduction in flexural strength. This trend suggests that BLA increased the brittleness of the concrete up to 15% percentage replacement. The results obtained satisfied the limit of between 3 - 4MPa based on BS EN 12390-5 (2009) (Onikeku et al., 2019). The BLA blended mix, BLA5%, BLA10%, BLA15% and BLA20% suffered 3.37%, 3.93%, 4.63%, and 4.79% strength loss due to sodium sulfate attack at their age of 56th day. Maximum strength loss was experienced in BLA 20%, whereas minimum loss noticed in BLA5%. Loss of strength increased with BLA as the replacement amount increased. But, concrete mixes with 5% and 10% Bamboo leaf ash suffered less strength loss in comparison to the control mix. Loss of strength increased with BLA content (Abebaw et al., 2021).

The result from different researchers, conducted in different countries is varied. This is because of the difference in species of Bamboo used to replace cement in different countries. The mechanical and physical properties of bamboo are varied due to species (Zakikhani et al., 2017). Ethiopia has over one million hectares of highland and lowland bamboo resources, which account for about 67% of African bamboo resources and more than 7% of the world total area covered by bamboo. In Ethiopia, only two bamboo species are growing and both are endemic to Africa. These species are Yushania alpina k. Schum (highland bamboo) and Oxytenanthera abyssinica Munro (lowland bamboo) (Mekuriaw et al., 2022). Attention was given to using bamboo culm for construction, furniture (traditional processors and modern workshops) and fencing. (Mathewos, 2017). However, the effect of partially replacing cement with high land bamboo leaf ash on the production of concrete hasn’t been studied in Ethiopia.

Based on these gaps, this research work is to bridge this important gap by studying the effect of highland bamboo leaf ash (Yushania alpine) as cement replacing material in concrete production and study workability, setting time, compressive strength, flexural strength, water absorption, sulfate attack, and microstructural analysis of concrete.

CHAPTER THREE

MATERIALS AND METHODS

This chapter deals with the material and methodology of the study. The materials used for the research are described concerning their source, relevant physical and chemical properties. Methodology encompasses the way in which intend to carry out this research. its includes the techniques or procedures of selecting of raw materials, physical properties and chemical analysis of Bamboo Leaf Ash (BLA), sample preparation, mix designing and casting concrete cubes and beam, conducting tests, and analysing the experimental result and finally, conclusions and recommendations were drawn based on the findings.

Experimental design (procedure):

- Set objectives
- Select process variables
- Select an experimental design
- Execute the design
- Check that the data are consistent with the experimental assumptions
- Analyses and interpret the results.
- Use/present the results

The main task done in this research is summarized as following Figure 3.1

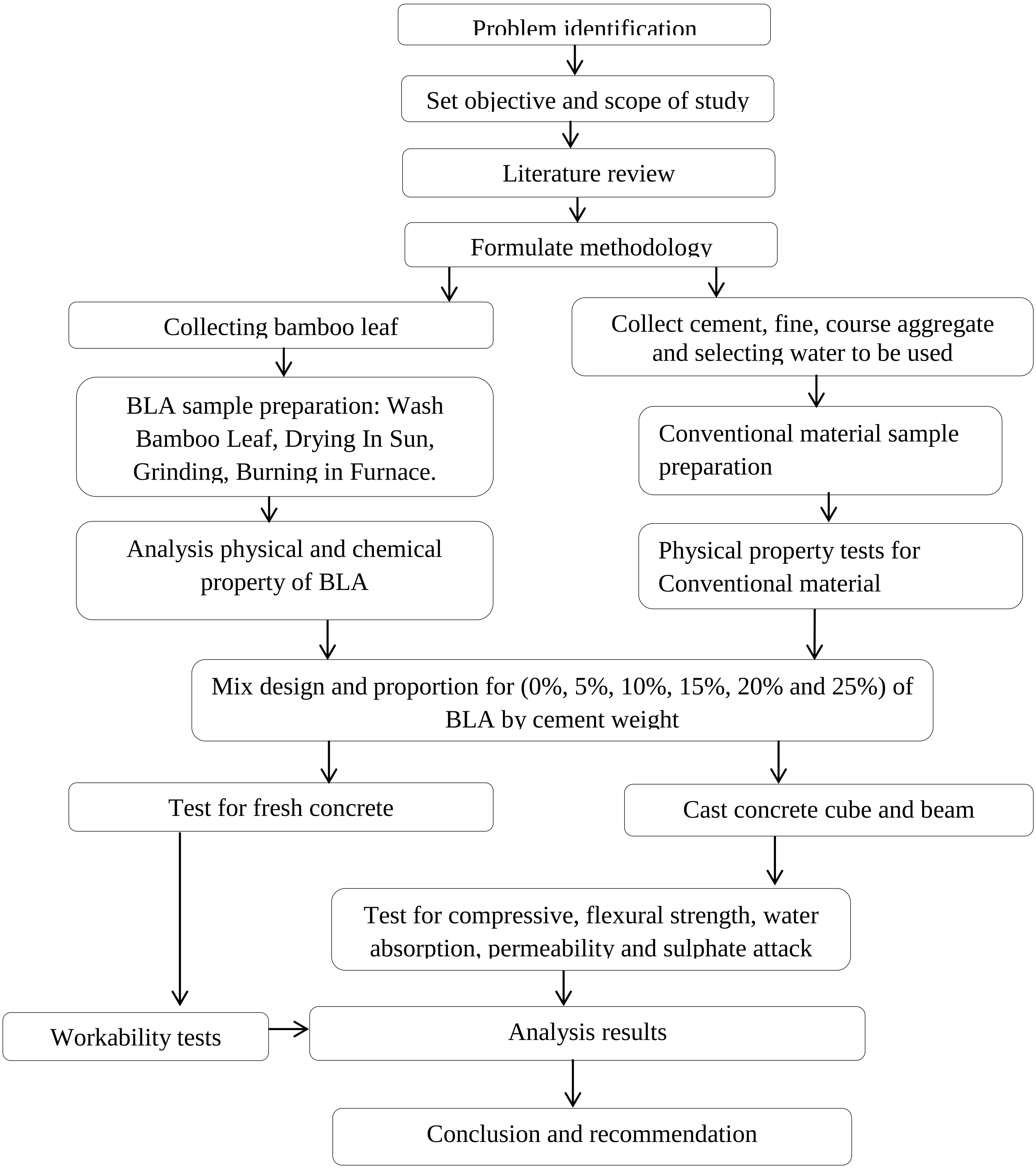


Figure 3.1 experimental frame work flow

3.1 Materials

3.1.1 Bamboo Leaf Ash (BLA)

Bamboo leaf used for this study was high land bamboo (yushania alpina) taken from Kokosa woreda, West Arsi zone, Oromia Regional State; south east Ethiopia. Eight Bags of bamboo leaf was collected from source and washed by tap water then dried in sun. Grinding machine (Wofco) was used for grinding the washed and dried bamboo leaf. Combustion of the grinded bamboo leaf powder was conducted in the Geological Survey Center of Ethiopia, by using furnace under controlled Temperature of $600C^0$ for two hours.

3.1.2 Cement

The type of cement used for this experiment was ordinary Portland (OPC), Strength Class CES 28, CEM I 42.5 R. Which manufactured from National cement factory and available at local market Adama, Ethiopia.

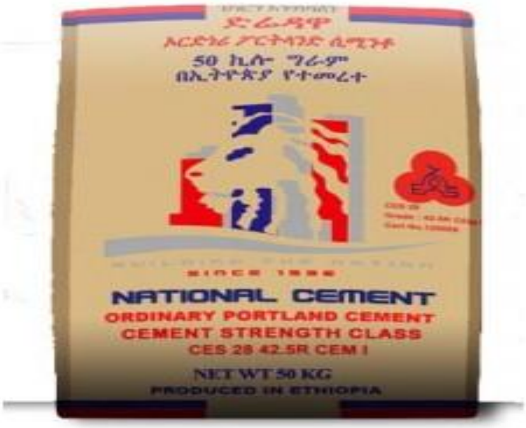


Figure 3.2 National OPC cement

3.1.3 Fine Aggregate (Sand)

For this study, Natural sand obtained from Adama center was used. The quality conforming was approved standards of American Society for Testing and Materials (ASTM).

3.1.4 Coarse Aggregate

For this specific work, the crushed basaltic rock course aggregates obtained from Adama town was used. The size of the maximum aggregate 25mm. Quality approved conforming standards of American Society for Testing and Materials (ASTM).

3.1.5 Water

For this study, Available Potable water obtained from Adama sience and Technology University was used in making concrete. According to (Oromia water works design & supervision enterprise, 2022) Adama town water including Adama sience and Technology University is PH. (7.06 - 7.47) in boundary that specified by IS: 3025 which is PH (6-8) for construction of concrete.

3.2 Methods

The experimental program was conducting a thorough laboratory experiment. The main objective of the experimental program is to investigate the effect of Bamboo leaf ash in concrete as a cement replacing material. The methodology includes the selection of raw materials, method of analyzing physical and chemical properties of Bamboo Leaf Ash (BLA), sample preparation, mix designing and casting concrete cubes, conducting tests, and finally methods of analyzing the experimental result. Then conclusions and recommendations were drawn based on the findings.

3.2.1 Bamboo Leaf Ash (BLA) Production Process

Bamboo leaf used in this investigation was collected, washed, dried in sun and grinded using local grinder (Wofco). During grinding bamboo leaf: fist the grinder is divorce, second internal of grinder cleaned by clean clothes, third half quintal bamboo leaf added to grinder and grinded to clean privies grinded material from grinder and finally complete bamboo leaf was grinded. 35.25 Kg of grinded bamboo leaf obtained taken to Geological Survey Center of Ethiopia and heated in muffle furnace under controlled Temperature of $600C^0$ for two hours and obtained 20 kg bamboo leaf ash (BLA). This was to found amorphous material containing amorphous silica and remove extra carbon in the ash. The ash generated was taken and used as bamboo leaf ash sample after sieved on 45 µm (No. 325) and checked the percent of passed BLA as per ASTMC 618 Specification.

A. Bamboo leaf at source

B. Collected Bamboo Leaf

Bamboo Leaf washed by tap water

C. Sun-dried Bamboo leaf

D. Grinded bamboo leaf

E. Furnace burned Bamboo Leaf ash

Figure 3.3 Process of Bamboo leaf ash (BLA) preparation

3.2.2 Physical Properties of the BLA

All the laboratory investigations on physical property such as Colour, Specific gravity, Fineness, Density were conducted in the Adama science and Technology University, laboratory.

3.2.3 Chemical Properties of the BLA

The chemical properties investigation Bamboo leaf ash samples was taken to the Geological Survey of Ethiopia laboratory and perform complicate silicate analysis of the ash.

3.2.4 Scanning Electron Microscopy (SEM):

The Scanning Electron Microscopy (SEM) was carried out to find the shape and size of concrete with bamboo leaf ash particles in dry form. The samples were taken to Adama science and Technology university laboratory to perform SEM analysis.

3.2.5 Batching

Batching by weight method was used for this specific work, because it was found more accurate than batching by volume. Bamboo leaf ash was used to replace OPC at dosage of 5%, 10%, 15%, 20% and 25% by weight of binder (cement). Additionally, 0% of BLA was used as a control mix.

3.2.6 Mix Design

In this specific study, the mix design of concrete with determined right proportions of cement, sand, course aggregates, water and BLA were proportioned for a C-25 concrete grade based on the ACI mix design method, while the water to cement ratio was 0.49 and Ordinary Portland cement content of 365kg/m3 used.

Table 3.1 Mix code explanation.

No	Mix code	Description
1.	BLA0	Control mix or no addition of BLA (Only OPC)
2.	BLA5	95 % OPC and 5% BLA
3.	BLA10	90% OPC and 10% BLA
4.	BLA15	85% OPC and 15% BLA
5.	BLA20	80% OPC 20% BLA
6.	BLA25	75% OPC 25% BLA

3.2.7 Concrete Mixing and Sample Preparation

For preparing concrete specimens, samples of aggregates for physical property tests were taken after sieving according to ASTM C39 sampling techniques for each property test. Samples for cement test taken from national OPC cement. For physical characteristics and concrete specimen casting, bamboo leaf ash powder partially replaced the cement. Activities of cleaning of the mold, oiling the surface, casting after thoroughly mixing the quantities of the trail mix, trimming the extra concrete above the mold with a sharp edge, coding the sample with identification, removing the mold after 24 hours, and curing samples in a water tank until crushing was undertaken carefully. Specimens for each duration and mix type were tested for compression and flexural strength of concrete. Three (150mmx150mmx150mm) concrete cube samples for each percentage addition of BLA by weight of cement (0%, 5%, 10%, 15%, 20% and 25%) were casted and test for compression strength of concrete. Also three (500mmx100mmx100mm) concrete beam samples for each percentage addition of BLA by weight of cement (0%, 5%, 10%, 15%, 20% and 25%) concrete specimens were cast and cured in the open tank for 7^{th} and 28^{th} days and test for flexural strength of concrete. One concrete cube samples for each percentage addition of BLA were casted then cured in the open tank for 28th day and tested for water absorption and permeability of concrete separately. Finally, concrete cube and concrete beam samples for each percentage addition of BLA were cast cured in the open water tank for 7 day. Then socked in 10% sodium sulphate up to 28^{th} curing age and tested for effects of BLA on concrete sulphate attack resistance analysis. Generally 54 concrete cubes and 42 concrete beams was prepared, totally 96 concrete sample was prepared.

3.3 Test on Fresh Concrete

3.3.3 Slump test

For this specific study, the concrete slump tested to determine the consistency of fresh concrete before it sets and identify the influence of BLA on the workability of concrete as per (ASTM C 143) procedure. The slump test is carried out by filling the cone and Place the filled cone (cup) upside-down on a flat, rigid surface, compaction is carried out by the rod penetrates the full depth to be compacted. Each three layers was compacted in the same manner, After compaction of the top layer, the cone filled up to the top and leveled using a hand trowel then it was removed, finally the height difference of the cone to concrete is measured with ruler and slump value of the mix is taken.

3.3.4 Curing

In this specific study, to ensure that hydration continues, curing concrete cube and beam performed in water tank. Tap water was used for curing purpose.

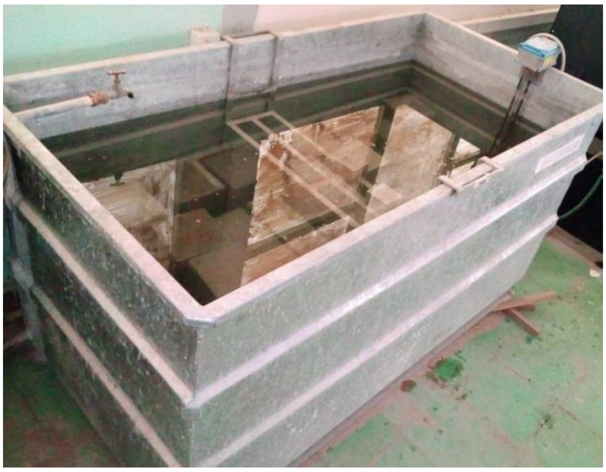


Figure 3.4 Curing

3.4 Test on Hardened Concrete

Mechanical property of concrete analyzed by conducting Compressive and flexural strength test on hardened Concrete.

3.4.3 Compressive Strength Test

The compressive strength test is the most significant experiment for determining all of the qualities of concrete. For this study, Compressive strength test was conducted on hardened concrete at varies curing age (7th and 28th day). Concrete cubes of 150mmx150mmx150mm sizes were preferred due to the ASTM C109 description. The specimens are gradually loaded in Compression Testing Machine till specimen fails.

3.4.4 Flexural Strength Test

The flexural strength test was carried out on the concrete beams as ASTM D790 description, at varies curing age (7^{th} and 28^{th} day) to determine the flexural strength. The specimens are tested in a flexural testing machine at standard loading rates. Concrete beam of 500mmx10mmx10mm sizes was used.

3.4.5 Durability Test for Concrete

In this specific study, Durability of concrete examined by water absorbance, permeability and sulphate attach resistance.

3.4.1 Water Absorption Test

Water absorption test is measures the amount of water that penetrates into concrete samples when submersed under specified conditions which indicates the degree of absorbency of a concrete. The water absorption test was conducted based on BS 1881: Part

122. The specimen was dried in the oven in which the temperature was controlled at 110 °c for 72 hours, then Cool the dried specimen for 24 hrs. Before measuring the weight of specimens. The dried specimen was soaked in water for 24hrs, and then removed from the water and the weight of the specimen measured again. This gives the percentage of water absorbed. It was conducted at the curing age of 28 days. The water absorption expressed in percentage, then computed using the following equation (Umoh & Odesola, 2015)

Water absorption (%) = $\frac{Mw-Md}{Md}$ ____________Equation 3.1

Where: Mw the mass of wet specimen after immersion in water for 72 hours, and Md: is the mass of oven drayed specimen before immersion in water.

3.4.2 Water permeability test

Water permeability test determines the resistance of concrete against water under hydrostatic pressure. The Water permeability test was conducted based on BS EN 12390-8. The pressure of the water is then adjusted to 5 bar (0.5MPa) for 72 hours. At the end of the 72 hours period, all the valves supplying water and compressed air to the specimens were closed and the cubes were removed from the permeability rig and split. Upon visual examination, the portion of the specimen into which water has penetrated appears darker than the rest, and immediately after splitting, this zone was marked and measurements were taken.

3.4.3 Concrete Sulphate Attack Resistance Analysis Test

To examine the sulfate attack (durability) through testing the compressive and flexural strength loss, the casted concrete cubes and beam cured in water tank for 7 days , then the sample are taken from pure water thank and soaked in 10% Na2.SO4 up 28 days (for 21 days). Then concrete cube cured in potable water and 10% Na2.SO4 are compared and losses due to sulphate attack are determined (Abebaw et al., 2021),(Rambabu et al., 2016) and (Abiodun, 2019).

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter deals with results and discussion. The chapter containing a description about the main findings of a research and interprets the results.

4.1 Physical and Chemical Properties of Bamboo Leaf Ash

4.1.1 Physical Properties of Bamboo Leaf Ash

The physical characteristics of bamboo leaf ash such as Colour, Specific gravity, Fineness, Density were evaluated. The result of the physical characteristics of bamboo leaf ash is shown in table 4.1

Table 4.1 Physical properties of Cement and Bamboo Leaf Ash

S. N0	Physical Characteristics	Cement	BLA
1.	Color	Light gray	White gray
2.	Specific gravity	3.15g/cc	2.24g/cc
3.	Fineness (% Retained on 45 µm)	$\leq$ 34%	30%
4.	Density	1400Kg/m3	1294.67 kg/m3

Bamboo leaf ash has dark Gray colour after burned up to 600^{o}C for 2 hours in the furnace. Observed Dark Gray colour of BLA meets the color requirement investigated by various researchers Oladunmoye & Olutoge, (2017), Umoh & Odesola, (2015). The fineness of the ash retained on 45 µm (No. 325) sieves is 30% and 70% passed which is less than the maximum value of 34% retain as specified per ASTMC 618. Increasing the fineness of BLA increases the amount of mixing water required to achieve a given consistency and reduces the amount of bleeding by the concrete. BLA has specific gravity of 2.24g/cc, that less value than specific gravity of OPC which is (3.15g/cc). The density of BLA is 1294.67kg/m3, that less value than the density of cement (1400kg/m3). The smaller values recorded in terms of the specific gravity of BLA could yield a reduced density of concrete. Reduction of fresh and hardened concrete density of BLA has positive impact on structure. Reduction in dead loads save foundations and minimize amount of reinforcement bar because it depends on dead load (density) of concrete.

4.1.2 Chemical Properties of Bamboo Leaf Ash

Combustion of bamboo leaf ash was conducted in the Geological Survey Center of Ethiopia, by using a muffle furnace under controlled Temperature of 600^0C for two hours. The analytical result shows the percentage element by mass of major and minor oxides present in BLA. The result of the chemical composition of BLA is shown in Table 4.2

Table 4.2 Chemical Composition of BLA (%)

Oxide	SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	H2O	LoI
BLA composition	71.1	1.08	1.80	5.08	1	<0.01	2.96	1.55	13.85

The combined chemical composition for BLA at 600^0C; SiO2 + Al2O3 + Fe2O3 = 73.98 > 70% that categorized under Class F pozzolanic materials as per ASTM C- 618 specifications. LoI value not conforms to the ASTM standard, which Class F pozzolan containing up to 12.0 % (6^A) loss on ignition. Chemical composition values are varying from those studied previously with different countries bamboo leaf ash by different researchers. These differences would be related to the different species of bamboo leaf in different country. But based on this finding no one checks the chemical composition and pozzolanic properties of Ethiopian high land bamboo leaf ash.

4.2 Cement and BLA Blended Paste

4.2.1 Cement

Ordinary Portland (OPC), Strength Class CES 28, CEM I, 42.5 R. Which manufactured from National cement factory was used for this specific study. The consistency, setting time, and soundness for cement and BLA blended paste was conducted in the Adama science and technology university laboratory.

4.2.2 Consistency Of Cement And BLA Blended Paste

Consistency of the paste was measured using the Vicat equipment by following the ASTM C-187 standard. Cement pastes of OPC (control mix) and partial replacement of OPC with BLA (5%, 10%, 15%, 20% and 25%) were prepared.

Table 4.3 Consistency (%) of blended cement paste

S. No	Designation code	Results (%)	Consistency (%)	Remark
1	BLA0	26	26-33	Ok
2	BLA5	27	26-33	Ok
3	BLA10	29	26-33	Ok
4	BLA15	31	26-33	Ok
5	BLA 20	32	26-33	Ok
6	BLA 25	33	26-33	Ok

As table 4.3 shows, the Cement pastes of OPC (control paste) had 26% consistency. The blended cement paste with BLA had a greater consistency than the control paste. Consistency of paste increases with BLA increase in mix. According to Ethiopian standard typical range of water percentage for cement consistency is between 26% and 33% of cement. Therefore: Consistency of BLA blended cement paste was within the normal range.

4.2.3 Setting Time of Cement and BLA Blended Paste

For this specific study procedure (technique) specified under ASTM C-191 was used to test the Cement and BLA blended paste setting time.

Table 4.4 Setting time of Cement and BLA blended paste

code	(Setting time (min))		Setting time (min) (ASTM C-191)		Remark
	Initial	Final	Initial	Final	
BLA0%	125	278	49 - 202	185-600	Ok
BLA5%	142	295	49 - 202	185-600	Ok
BLA10 %	160	327	49 - 202	185-600	Ok

BLA15 %	166	335	49 - 202	185-600	Ok
BLA 20%	167	336	49 - 202	185-600	Ok
BLA25%	169	339	49 - 202	185-600	Ok

Ethiopian standard recommends that the initial setting time for cement not to be less than 45 minutes and the final setting time not to exceed 600 minute. As table 4.4 shows, the setting time was within the specified limit and therefore it is acceptable to use. Based upon the result, the setting time of cement paste increase as the BLA replacement level increase; this is due to the effect of lower cement content and fineness of BLA. to improve this argument, as the BLA replacement level increase the setting time of BLA blended paste increase due to the water absorption of BLA over its surface and lower cement content in the paste.

4.2.4 Soundness of Cement and BLA Blended Paste

For this specific study; procedure (technique) specified under ASTM C-151 standard was used to test the Cement and BLA blended paste soundness.

Table 4.5 Soundness of Cement and BLA blended

S.No	code	Result (Expansion (mm))	Ethiopian Standard (Expansion (mm)) not exceed 10mm	Remark
1	BLA0 %	0.9	$\leq$10mm	Ok
2	BLA5 %	1.4	$\leq$10mm	Ok
3	BLA10 %	1.8	$\leq$10mm	Ok
4	BLA15 %	2	$\leq$10mm	Ok
5	BLA 20%	3.1	$\leq$10mm	Ok
6	BLA25%	3.3	$\leq$10mm	Ok

According to Ethiopian standards, the expansion of hydraulic cement shall not exceed 10mm therefore the result obtained is acceptable for use in concrete manufacturing based on this standard.

4.3 Physical Properties of Fine Aggregate

Physical Properties of Fine Aggregate such as Silt Content, Gradation, and Moisture Content were conducted in the Adama science and technology university laboratory.

4.3.1 Silt Content

Silt content test was conducted in laboratory According to Ethiopian standards which silt concentration not exceed than 6%. The sand silt content was found 3.25% which is less than 6% and suitable for use.

4.3.2 Gradation of Fine Aggregate

Grading of fine aggregates is aimed at determining the mean size of the particle in a given batch of aggregates and found by the method of fineness modulus. The gradation of the sand was done per ASTM-C 136 standard and the grain size distribution of the fine aggregate is shown in table 4.6

Table 4.6 Fine aggregate gradation

sieve size (mm)	weight of sample retained	cumulative weight retained	cumulative % retained	cumulative % pass	Min (%)	Max (%)
9.5	0	0	0	100	100	100
4.75	10	10	2.04	97.95	95	100
2.36	55.9	65.9	13.48	86.51	80	100
1.18	105.65	171.55	35.11	64.88	50	85
0.6	125	296.55	60.69	39.30	25	60
0.3	111	407.55	83.41	16.58	5	30
0.15	64.25	471.8	96.56	3.43	0	10
Pan	16.77	488.57	100	0		
Total	488.57		291.32			

Fineness Modules of sand = summation of cumulative % weight retained/100 = 2.91

Fineness modulus of fine aggregate is generally ranges between 2.3 to 3.1 used in concrete as per ASTM C 33.

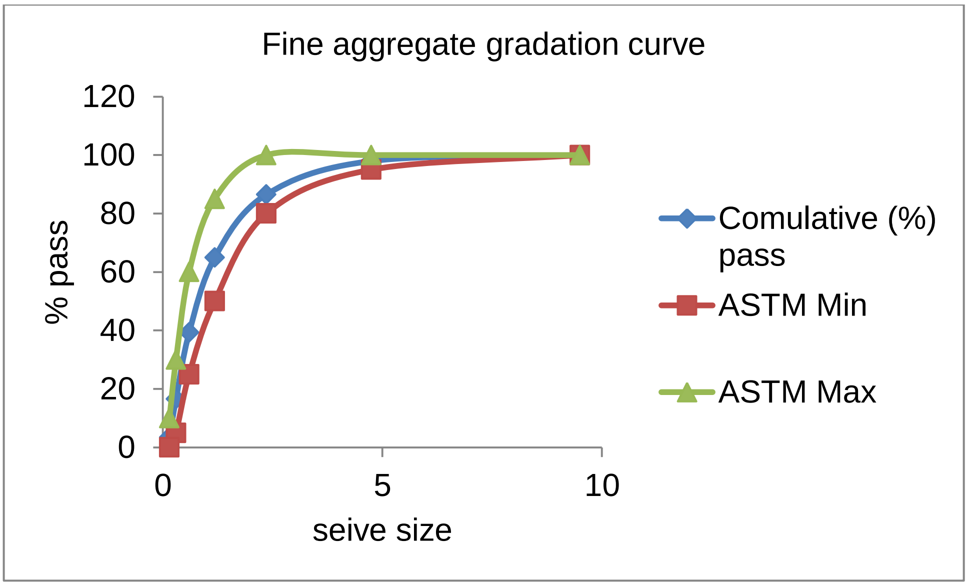


Figure 4.1 Fine Aggregate Gradation Curves

4.3.3 Unit Weight of Fine Aggregate

Unit weight can be defined as the weight of a given volume of graded aggregate. It effectively measures the volume that the graded aggregate that occupy in concrete and includes both the solid aggregate particles and the voids between them. The unit weight is simply measured by filling a container of known volume and weighing it. The mass of the instrumentation is deducted to allow the mass of the fine aggregate, from which the bulk density is the fine aggregate mass divided by the quantity of the container. The unit weight of fine aggregate was done in was done accordance with ASTM-C 29 standard and also the sample result was found to be 1825kg/m^3. Here the result satisfied the ASTM minimum and maximum of 1280kg/m3 and 1920 kg/m3 respectively. Hence, the sample is accepted for use.

4.3.4 Specific Gravity and Absorption Capacity

Specific gravity is an expression of the density of an aggregate. It is the ratio between the weight of the substance and that of the same volume of water. Aggregates contain pores in their structure, therefore the specific gravity depends on whether the pores are included in the measurement or not. Apparent specific gravity of an aggregate refers to the solid materials excluding the pores and bulk specific gravity refers to total volume i.e. including pores of the aggregate. The specific gravity and absorption of fine aggregate were done in accordance with ASTM-C 128 standard. The following results are found for the fine aggregate:

Bulk specific gravity = 2.67, Bulk specific gravity (SSD basis) = 2.69, Apparent specific gravity = 2.72 and Absorption capacity = 0.65%

The specific gravity of proper fine aggregates ranges between 2.6 to 2.8. Hence, the sample having the bulk specific gravity of 2.67 is appropriate for concrete production. Absorption is an amount of the total opening volume accessible to water. It was also useful for a mixed design moisture adjustment. The absorption of 0.65% % is well within the maximum limit of 4%.

4.3.5 Moisture Content of Fine Aggregate

The moisture content of fine aggregates was determined by oven drying a sample of fine aggregate (500gm) in an oven at a temperature of 110 0c for 24 hrs and dividing the weight difference by the oven dry weight. The moisture content of fine aggregate was conducted based on ASTM-C 566 standard and the sample results were found 1.01% meet the standard and suitable for use .Physical properties of fine aggregate results are summarised in Table 4.7

Table 4.7 Summary physical properties of fine aggregate

No.	Types of Tests	Test Result	Test Standard
1.	Finesse modulus	2.91	ASTM -C136
2.	Bulk unit weight	1825kg/m3	ASTM -C29
3.	Bulk Specific gravity	2.69	ASTM -C128
4.	Absorption	0.65%	ASTM -C128
5.	Moisture content	1.01%	ASTM -C566

4.4 Physical Properties of Coarse Aggregate

4.4.1 Gradation of Coarse Aggregate

The coarse aggregates used for this research were crushed rock. A maximum aggregate size of 25 mm was used in all the concrete work. In a similar manner like the fine aggregate, laboratory tests were carried out gradation of the coarse aggregate using sieve analysis based on the ASTM C-136 standard. The results are shown in Table 4.8 below and figure 4.2 respectively.

Table 4.8 Sieve analysis result in reference to standard for coarse aggregate

sieve size (mm)	weight of sample retained	cumulative weight retained	cumulative % retained	cumulative % pass	Min (%)	Max (%)
37.5	0	0	0	100	100	100
25	140	140	6.99	93.00	90	100
19.5	773.25	913.25	45.64	54.35	4 0	85
12.5	611.5	1524.75	76.2	23.8	10	40
9.5	440.15	1964.9	98.20	1.796	0	15
4.75	35.95	2000.85	100	0	0	5
pan	0	2000.85	100	0		
Total	2000.85		327.043392			

Fineness modules of coarse aggregate = summation of cumulative % weight retained /100 = 327.04/100 = 3.27

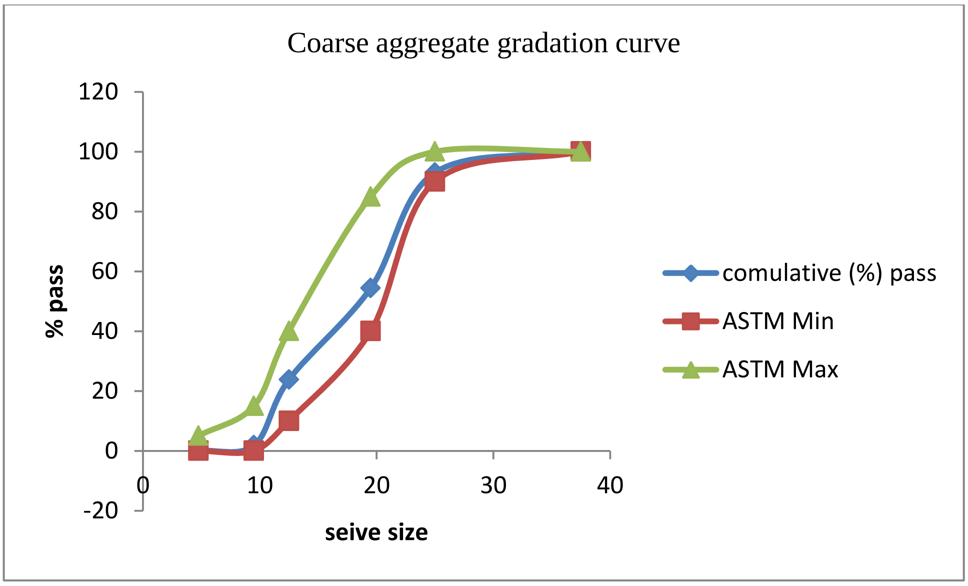


Figure 4.2 Course Aggregate Gradation Curves

4.4.2 Unit Weight of Coarse Aggregate

The unit weight of coarse aggregate was carried out based on ASTM-C 29 standard and the sample result was found to be 1,658kg/m3. Here the result satisfies the ASTM minimum and maximum limit of 1280 and 1920 kg/m3 respectively. Hence, the sample was within the range and accepted for use.

4.4.3 Specific Gravity and Absorption Capacity of Coarse Aggregate

ASTM C-127 standard was used to calculate the Specific gravity and absorption Capacity of coarse aggregate and the following results are found for the coarse aggregate:

Bulk specific gravity = 2.54, Bulk specific gravity (SSD basis) = 2.57, Apparent specific gravity = 2.63 and Absorption capacity = 1.4%

4.4.4 The Moisture Content of Coarse Aggregate

The moisture content of coarse aggregate is determined in the same way as for fine aggregate; using the ASTM-C 566 standard, the sample value was 0.68%. The summary of the physical properties of coarse aggregate is shown below in Table 4.9

Table 4.9 Summary of physical properties of coarse aggregate

No.	Types of tests	Test result	Test standard
1.	Nominal maximum aggregate size	25mm	ASTM -C33
2.	Bulk unit weight	1611.5 kg/m3	ASTM -C29
3.	bulk Specific gravity	2.54	ASTM -C127
4.	Apparent Specific gravity	2.63	ASTM -C127
5.	Absorption	1.4%	ASTM -C127
5.	Moisture content	0.46%	ASTM -C5

4.5 Mix Proportion of Concrete

In this specific study, the mix design of concrete with determined right proportions of cement, sand, course aggregates, water and BLA were proportioned for a C-25 concrete grade based on the ACI mix design method, while the water to cement ratio was 0.49 and Ordinary Portland cement content of 365kg/m3 used.

Table 4.10 Final Mix proportion summery

Mix Designation	Quantity of material per cubic meter (kg/m^3)				W/C Ratio
	Cement	BLA	Fine Aggregate	Coarse Aggregate	
OPC Control	365	0	775.1	1066.9	0.49
BLA5	346.5	18.25	775.1	1066.9	0.49
BLA10	328.5	36.5	775.1	1066.9	0.49
BLA15	310.25	54.75	775.1	1066.9	0.49
BLA 20	292	73	775.1	1066.9	0.49
BLA 25	273.75	91.25	775.1	1066.9	0.49

4.6 Properties of Fresh Concrete with BLA

Fresh properties of was conducted when the setting and hardening process has not yet started immediately after mix.

4.6.1 Workability

The concrete slump test or slump cone test was tested for workability of freshly mixed concrete which can be performed in the laboratory to analysis the effect of bamboo leaf ash on workability and quality of fresh concrete.

Table 4.11 Slump value

Mix code	Observed slump (mm)	Reduction (%)
BLA0	30.00	0.00
BLA5	27.50	-8.33
BLA10	26.00	-13.33
BLA15	25.75	-14.17
BLA 20	25.25	-15.83
BLA 25	24.00	-20.00

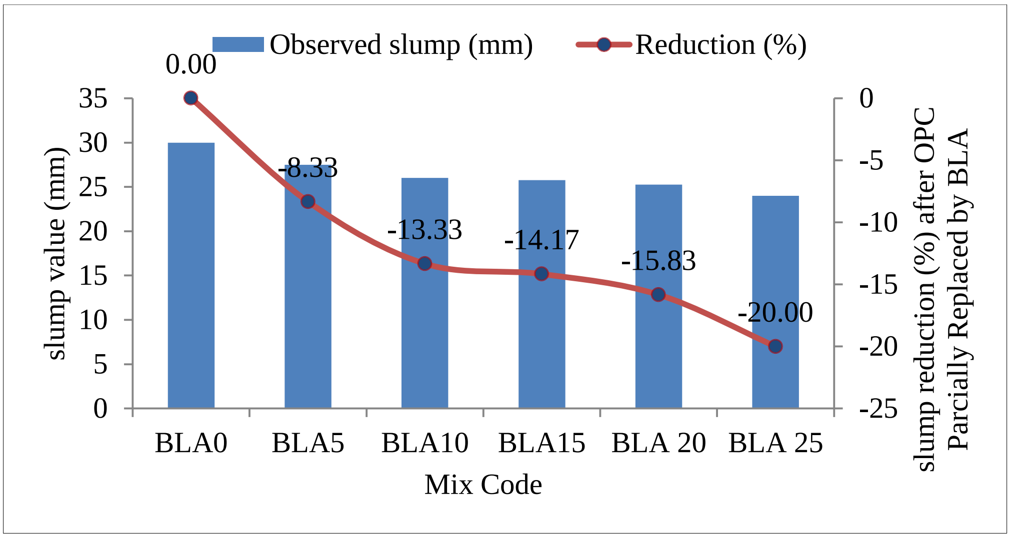


Figure 4.3 Slump Test Results

As shown in Table 4.11 and figure 4.3 respectively, as the replacement percentage of BLA increases, the slump value goes down. Therefore, the probable reason was due to fineness of BLA and their large specific surface area though all other factors are constant. Finer particle requires more water to wet their larger specific surface area. Up to 20% replacement level, the slump is still in the range of 25mm to 50mm for C25. However, at 25% replacement level, the slump was found less slump value than targeted range.

Figure 4.4 checked Concrete slumps

4.7 Test on Hardened Concrete

The Mechanical property of concrete, density, water absorption, permeability and sulfate attack resistance of hardened concrete are discussed and analyzed in this section. The Mechanical property of concrete analyzed by conducting Compressive and flexural strength test on hardened Concrete cube and beam.

4.7.1 Compressive Strength of Concrete

The compressive strength was measured by breaking concrete cube specimen in a compression testing machine. During this research, total numbers of 36 cubes of concrete were prepared for compressive strength test. Figure 4.5 below shows a compressive strength test under progress.

Figure 4.5 Compressive Strength of Concrete Is Being Tested

Three specimens casting cube were cured and crushed in the testing machine for each replacement at each interval of ages of 7^{th} and 28^{th} days. The specimens were tested for compressive strength by applying increasing compressive load as shown in figure 4.5 until failure occurs and reported in MPa. A valid test result for compressive strength was taken the mean of the results of tests carried out on three specimens that sampled from the same batch of concrete and cured under standard conditions at any particular age (7^{th} and 28^{th} days).

Table 4.12 Result of compressive strength value of the concrete cubes

Mix code	compressive strength result (Mpa)									
	Each cube test result (7^{th} day)			Average (7^{th} days)	Mean standard deviation $\pm$15%	Each cube test result (28^{th} day)			Average (28days)	Mean standard deviation $\pm$15%
BLA (0%)	29.5	28.5	29.9	29.4	1.96	38.2	38.1	37.9	38.01	0.23
BLA5%	28.4	27.94	28.9	28.4	1.46	38.9	39.5	38.9	39.2	0.68
BLA10%	26.3	25.4	27.2	26.3	2.79	35.3	34.9	36.0	35.44	1.23
BLA15%	20.5	23	24.1	22.5	6.62	30.7	30.9	31.3	30.9	0.73
BLA 20%	19.5	22.76	21.4	21.2	6.28	29.1	29.5	29.3	29.3	0.57
BLA 25%	18.3	19.32	20.3	19.3	4.13	25.6	24.3	24.5	24.8	2.31

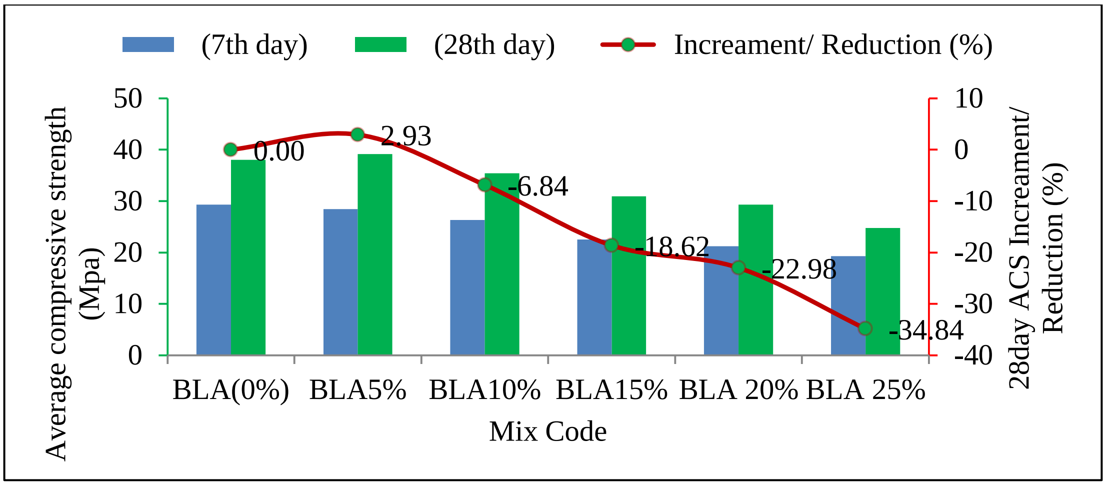


Figure 4.6 Compressive Strength Results for 7th and 28^{th}day

The results of the compressive strength of concrete produced during this research at various percentages of BLA at 7^{th} and 28^{th} days were showed in Table 4.12 and figure 4.6 respectively. It was observed that the compressive strength values increase with increase in curing days. The compressive strength value of control mix (OPC control), BLA5% and BLA10% are observed 38.05Mpa, 39.16Mpa, 35.44Mpa respectively and achieved the target mean strength of 33.5Mpa after 28 days. The mix designations for BLA15% and BLA20% are observed 30.96Mpa, 29.30Mpa respectively and did not achieved the target mean strength of 33.5Mpa after 28 days. However, they attain the characteristic strength of 25Mpa on the 28th day. Finally, the compressive strength value of BLA25% observed 24.79Mpa and did not achieved the target mean strength of 33.5Mpa, as well as the characteristic strength of 25Mpa on the 28th day for C25.

Table 4.13 Compressive strength increment and reduction value

Mix code	Compressive strength increment and reduction value (%)	
	7^{th} day	28^{th} day
BLA (0%)	0	0
BLA (5%)	-2.97	+ 2.93
BLA (10%)	-10.19	- 6.84
BLA (15%)	-23.03	- 18.62
BLA (20%)	-27.54	- 22.98
BLA (25%)	-34.14	- 34.84

From Table 4.13, the partial replacement of BLA5% had shown the compressive Strength incensement of (2.93%) as compared to the OPC control mix at 28th day. The increase in strength could be a result of the presence of a high amount of amorphous silica (SiO2) about (71.1) % in BLA which reacts with lime giving additional amount of Calcium Silicate hydrate (C-S-H) and reduces the amount of Ca(OH)2 which responsible for strength reduction of concrete (Oladunmoye & Olutoge, 2017). The partial replacement of BLA10% had shown the compressive Strength reduction of (6.84%) as compared to the OPC control mix at 28th day. But it achieved the target mean strength of 33.5Mpa after 28 days. Partial replacement of BLA 15% and BLA20% had shown the compressive Strength reduction of (18.62%), (22.98%) respectively as compared to the OPC control mix at 28th day and did not achieved the target mean strength. However, they attain the characteristic strength of 25Mpa on the 28th day. Partial replacement of BLA25% had shown the compressive Strength reduction of (34.84%) as compared to the OPC control mix at 28th day and did not achieved the target mean strength as well as characteristic strength of 25Mpa on the 28th day. This indicates that the compressive strength of BLA blended concrete decrease with an increase in BLA content. The reason for compressive strength reduction is due to the high replacement of BLA and cement content reduction per cubic meter of concrete by 5%, 10%, 15%, 20% and 25% from the normal concrete mix, and also the pozzolanic reaction takes a long time, this leads to compressive strength reduction (Abebaw et al., 2021). The optimum strength was recorded at BLA 10% replacement at 28th days curing age. It could be that C-S-H is effective at 10% BLA replacement and any further increase beyond 10% BLA replacement would lead to series strength reduction. The compressive strength obtained from this study confirm with privies study (Abebaw et al., 2021) and found better results when compared with those of earlier studies(Oladunmoye & Olutoge, 2017) and (Onikeku et al., 2019).

4.7.2 Validity of Compressive Strength Result

A valid test result is the mean of the results of tests carried out on three specimens which are sampled from the same batch of concrete, and which are made and cured under standard conditions at any particular age (7 and 28 days). This is with the condition that the range of strengths between the highest and lowest individual result does not exceed 15% of the mean according to Indian Standard (IS 2006). There is no detailed information about this in any Ethiopian concrete standard. An invalid result, or a series of them, indicates one or more problems with the testing procedure. An invalid result is rejected from a quality control viewpoint and the cause of the invalidity must be investigated. Typical causes include poor sampling and cube making, mislabeling of cubes, out of tolerance cube molds, operator error, and malfunctioning compression machine.

Table 4.14 Mean standard deviation from the compressive strength average value

Mix code	Mean standard deviation value (%)	
	7th day	28th day
Control OPC	1.96	0.23
BLA5%	1.46	0.68
BLA10%	2.79	1.23
BLA15%	6.62	0.73
BLA20%	6.28	0.57
BLA25%	4.13	2.31

Referring table 4.14 for all concrete mixture of BLA with their respective curing ages, the mean standard deviation is less than 15%. This indicates that, the concrete mix was done according to the mix design procedures and techniques, per validity analysis.

4.7.3 Flexural Strength of Concrete

The flexural strength was measured by breaking concrete beam specimen in a flexural strength testing machine. During this research, total number of 36 beam of concrete prepared for flexural strength test. Figure 4.6 below shows a flexural strength test under progress.

Figure 4.7 Flexural Strength of Concrete Is Being Tested

Three specimens casting beam were cured and crushed in the testing machine for each replacement at of ages of 7th and 28th days. The specimens were tested for flexural strength by applying increasing flexural load as shown figure 4.7 until failure occurs and reported in MPa. A valid test result for flexural strength was taken the mean of the results of tests carried out on three specimens that sampled from the same batch of concrete and cured under standard conditions at any particular age (7and 28 days).The results of Flexural strength of concrete obtained during this research at various percentages of BLA at 7th and 28th days were as showed in Table 4.15 and figure 4.8 respectively.

Table 4.15 Result of flexural strength value of the concrete beam

Mix code	Average flexural strength result (Mpa)	
	(7th day)	(28th day)
Control (OPC)	2.74	3.89
BLA5%	2.56	4.28
BLA10%	2.57	3.95
BLA15%	2.02	3.15
BLA 20%	1.56	2.41
BLA 25%	1.35	1.93

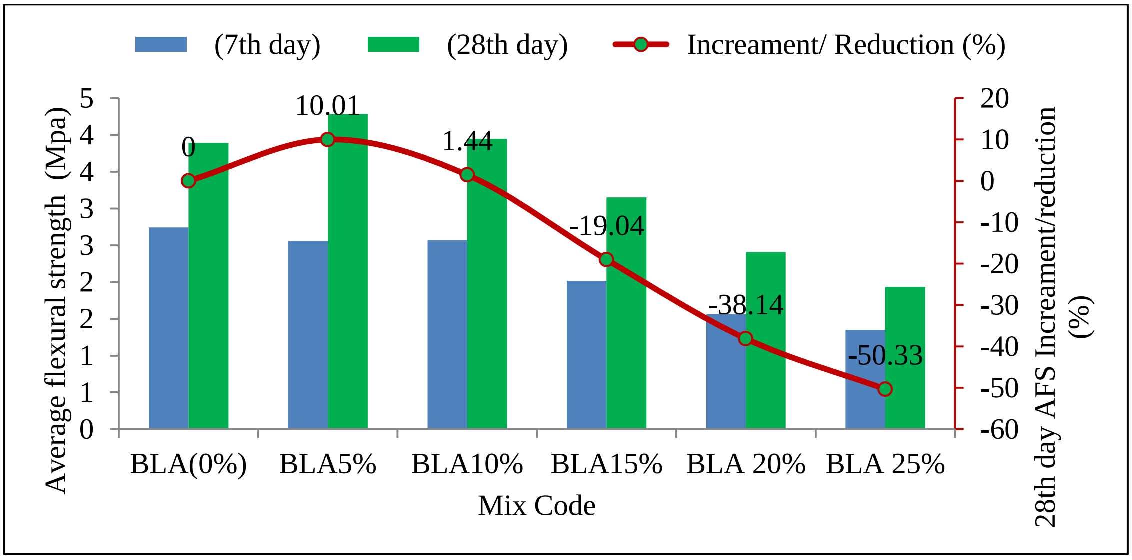


Figure 4.8 Flexural Strength Results for 7th and 28thday

The results of the flexural strength of concrete produced during this research at various percentages of BLA at 7th and 28th days were showed in Table 4.15 and figure 4.8 respectively. It was observed that the flexural strength values increase with increase in curing days. The flexural strength value of control mix (OPC control), BLA5%,and BLA10% are observed 3.89 Mpa, 4.28Mpa, 3.95Mpa respectively and satisfied the required strengths 3.5Mpa for C25 as per IS 5860 - 2000. The mix designations for BLA15%, BLA20% and BLA25% are observed 3.15Mpa, 2.41Mpa, 1.93 Mpa respectively and did not achieved the required strengths 3.5Mpa for C25 as per IS 5860 – 2000 on 28th day.

Table 4.16 Flexural strength reduction and increment value

Mix code	Flexural strength increment value (%)	
	7th day	28th day
BLA (0%)	0	0
BLA (5%)	- 6.76	+ 10.01
BLA (10%)	- 6.32	+ 1.44
BLA (15%)	- 26.49	- 19.04
BLA (20%)	- 43.05	- 38.14
BLA (25%)	- 50.79	- 50.33

Based on above Table 4.16 , flexural strength increased as the percentage replacement of BLA increased for BLA 5% and BLA10% . It had shown the flexural Strength incensement of (10.0%) and (1.44%) respectively as compared to the OPC control mix at 28th day. The increase in strength could be as a result of the presence of high amount of amorphous silica (SiO2 = 71.1%) present in the ash and high amount of CaO (5%) which was responsible for the formation of tri calcium silicate and di calcium silicate which both oxidises with water to form calcium silicate hydrate which was the determining factor for strength gain. There was a drastic (extreme) reduction in flexural strength at BLA15%, BLA20 % and BLA 25%) and Its had shown the flexural Strength reduction of (19.04%, 38.14%, 50.33%) respectively as compared to the OPC control mix at 28th day. The maximum flexural strength increment was found at BLA5% replacement. The maximum flexural strength reduction was found at BLA25% replacement. The optimum strength was recorded at BLA 10% replacement at 28th days curing age. It could be that C-S-H is most effective at 10% BLA replacement. Any further increase beyond 10% BLA replacement would lead to strength reduction. The flexural strength obtained from this study found better results when compared with those of earlier studies (Onikeku et al., 2019),

4.7.4 Validity of Flexural Strength Result

Table 4.17 Mean standard deviation from the Flexural strength average value

Mix code	Mean standard deviation value (%)	
	7th day	28th day
Control OPC	0.18	0.96
BLA5%	0.23	0.38
BLA10%	0.11	1.61
BLA15%	0.03	1.44
BLA20%	0.29	0.71
BLA25%	6.06	4.93

Referring table 4.17 for all concrete mixture of BLA with their respective curing ages, the mean standard deviation is less than 15%. This indicates that, the concrete mix was done according to the mix design procedures and techniques, per validity analysis.

4.7.5 Density of Hardened Concrete

The density of hardened concrete is determined based on the weight of the concrete cube. The weight of the specimens was measured just before the compressive strength testing had conducted. Here, the density of concrete specimens is calculated by using the 28th, day weight and the result is as shown below in Table 4.18.

Table 4.18 Density of hardened concrete

Mix code	The density of hardened concrete Cube on 28th days (kg/m3)	Reduction (%)
Control OPC	2373	0.00
BLA5%	2367	0.25
BLA10%	2361	0.51
BLA15%	2347	1.10
BLA20%	2345	1.18
BLA 25%	2341	1.35

As shown in table 4.18, The density of hardened concrete Cube value of control mix (OPC control), BLA5%, BLA10% BLA15%, BLA20% and BLA25% are observed (2373,2367,2361,2347,2345 and 2341) kg/m3 respectively.

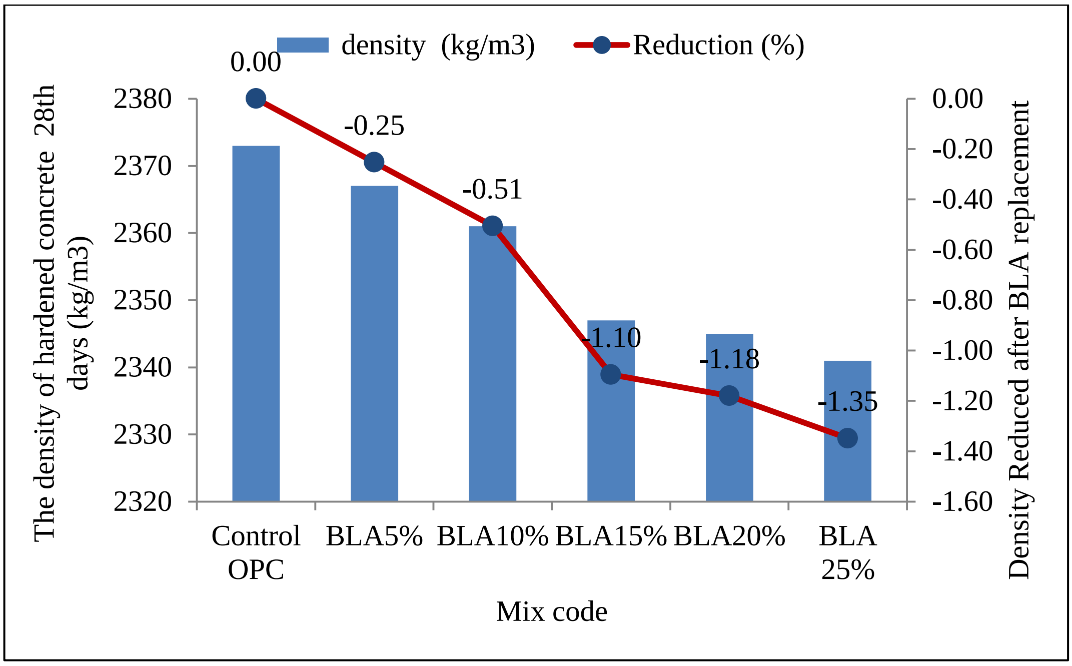


Figure 4.9 Density of Hardened Concrete

Referring to Table 4.18 and figure 4.9 the density of hardened concrete was decreased as the percentage of BLA replacement level increases. Partial replacement of BLA5%, BLA10 %, BLA 15%, 20% and BLA 25% had recorded density reduction of 0.25%, 0.51%, 1.10%, 1.18% and1.35% respectively as compared to the OPC control mix at 28th day. The probable reason is that the specific gravity of National OPC cement (3.15) is higher than Bamboo Leaf Ash specific gravity 2.15 and referring back to section 4.7.2, unit weight of BLA is 1,217kg/m3 lighter than OPC cement of 1400kg/m3. The reduction of concrete density is an important property of concrete to build high-rise buildings, consequently suitable for lightweight concrete construction. Therefore, the replacement of cement with BLA is very important to construct economical buildings and reduce building failures (settlement) due to heavy self-weight. This study conforms to the previous research (Oladunmoye & Olutoge, 2017), (Onikeku et al., 2019) and (Abebaw et al., 2021).

4.8 Durability Concrete with BLA

In this specific study, Durability of concrete was examined by water Absorption, permeability and sulphates attack resistance of hardened concrete.

4.8.1 Concrete Water Absorption

Water absorption is used to determine the amount of water absorbed under specified conditions which indicates the degree of absorbency of a concrete. The water absorption test was conducted based on BS 1881: Part 122. 1st the cube specimens was oven dried at 110^{o}C for 72 hours, 2nd the dried specimen was cool for 24 hrs and weight of specimens was measured (Md). 3rd the dried specimen was soaked in water for 24hrs, 4th the specimen removed from the water and the weight of the specimen were measured again (Mw). Finally water absorption of specimens was determined by using formula**:** water absorption (%) = $\frac{(Mw-Md)}{(Md)}$ to know the water absorption capacity and durability of concrete. The overall water absorption test result of each proportion of concrete cubes is as shown in Table 4.19 below.

Table 4.19 Water absorption of BLA blended cement concrete

Mix code	Water absorption (%)
Control OPC	3.85
BLA5%	3.71
BLA10%	3.43
BLA15%	4.18
BLA20%	4.64
BLA 25%	5.11

Referring table 4.19 Decreases in the weight of water absorbance was observed at the percentage of BLA substitution of 5% and 10% then starts increasing from 15% to 25%. The percentage water absorption ranges between 3.43% and 5.11% with the least value attained at 10% BLA (3.43%) content, and the greatest value of 5.11% attained at 25% BLA content at 28th day. The reduction in water absorption could be as a result of initial filling of the voids by BLA concretes there by acting as a water repellent. This study conforms to the previous research (Umoh & Odesola, 2015). However, at higher levels of BLA substitution, there was an insufficient quantity of calcium hydroxide to react with the excess BLA thus creating pores in the mixture and thereby increasing the water absorption.

4.8.2 Water permeability test

Water permeability test determines the resistance of concrete against water under hydrostatic pressure. The Water permeability test was conducted based on BS EN 12390-8**.** The specimens ready for test are as shown in Figure 4.10 below.

Figure 4.10 Specimens Ready for Water Permeability Test

The pressure of the water was adjusted to 5 bar (0.5MPa) for 72 hours. At the end of the 72 hours period, all the valves supplying water and compressed air to the specimens were closed and the cubes were removed from the permeability rig and split. Upon visual examination, the portion of the specimen into which water has penetrated appears darker than the rest, and immediately after splitting, this zone was marked and measurements were taken. Figure 4.11 shows a typical water penetrated sample just after splitting. To determine the average depth of penetration with more accuracy, measurements were taken at 10mm intervals.

Figure 4.11 Typical Concrete Samples Just After Splitting

Table 4.20 Results of the water penetration depth

Mix code	Average Penetration depth (mm)	maximum penetration depth (mm)
BLA 0	27.8	28
BLA 5	26	27
BLA 10	25.5	26
BLA 15	27	28
BLA 20	35.3	37
BLA 25	40	42

As shown in Table 4.20 above, the results of the water penetration test, i.e. the average depths of water penetration show some variation over the different types of concrete specimens with different percentage of BLA replacement. Decreases in Average Penetration depth was observed at the percentage of BLA substitution of 5%, 10% and 15% then starts increasing for 20% and 25%. The Average Penetration depth ranges between 25.5mm and 40mm with the least value attained at 10% BLA (25.5mm) content, and the greatest value of 40mm attained at 25% BLA content at 28th day. The concrete with BLA have shown some improvement on the average depth of penetration over the control concrete for BLA5%, 10% and 15%. The improvement on the average depth of penetration could be as a resulted by filling effect of BLA concretes there by acting as a water repellent. Figure 4.12 below shows the penetration depth as a function of concrete types.

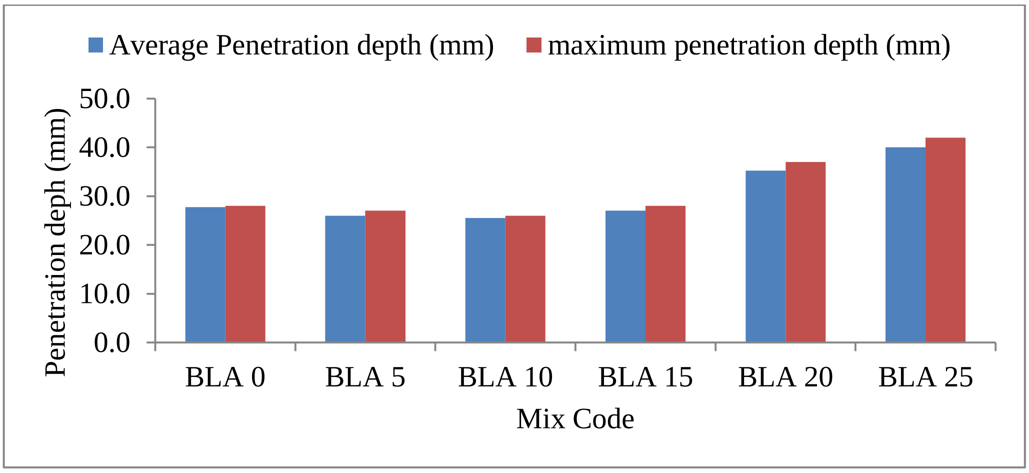


Figure 4.12 Water penetration depths in concrete

As figure 4.12 shows, the result observed that incorporation of BLA significantly amended the water impermeability of the pastes With the Increment in BLA fineness and supersession levels. It has been suggested that the presence of BLA leads to a more preponderant precipitation of cement gel products in comparison to that of OPC alone. This results in an efficacious blocking of pores and, thus, avails in reducing permeability. In addition, pozzolanic reaction of BLA engenders supplemental cementitious compounds that block channels, and fill pore space and, thus, further reduce the permeability of the hardened pastes. According to (Neville, 2010), it is possible to use the depth of penetration Of water as a qualitative assessment of concrete: a depth less than 50mm classifies the concrete as impermeable. In this regard it can be noted that all the concretes in this research are impermeable concretes.

4.8.3 Sulphate Attack Analysis on Concrete

BLA blended concrete sulfate resistance result is expressed in terms of compressive and flexural strength loss.

4.8.3.1 Effect of BLA replacement on sulphate attack resistance of concrete

The effect of BLA replacement on sulphate attack resistance of concrete result was expressed in terms of compressive strength loss at 28 curing age. The result is presented in and Table 4.21 and Figure 4.13 below.

Table 4.21 Concrete compressive Strength loss due to sodium sulfate (Na2SO4) attack

Mix code	Compressive strength at 28day (Mpa)		Strength loss (%)
	In Water	In 10% Na_2SO_4	
Control Mix	38.05	36.67	3.62
5% BLA	39.16	37.76	3.58
10% BLA	35.44	34.17	3.59
15% BLA	30.96	29.7	4.08
20% BLA	29.30	28	4.45
25% BLA	24.79	23.5	5.20

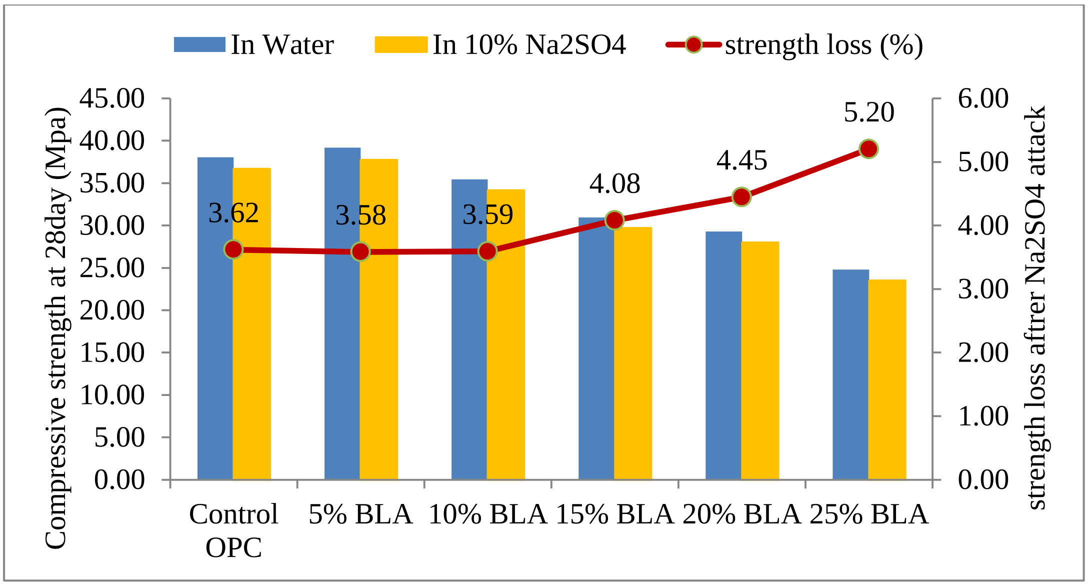


Figure 4.13 Concrete Compressive Strength Losses Due to (Na2.SO4) Attack

As Table 4.21 and Figure 4.13 shows , The compressive strength loss due to sodium sulfate attack after immersed the specimens in 10% sodium sulfate solution for control mix, BLA5%, BLA10% ,BLA15%, BLA20% and BLA25% are recorded 3.62,% 3.58%, 3.59%, 4.08%, 4.45% and 5.20% respectively. As referring, table 4.21 and figure 4.13 Resistance to sulphate attack is found more in concrete made with 5% and 10% Bamboo leaf ash due to rise in homogeneity and decrease in sorptivity (Abebaw et al., 2021). Mixes with 15%, 20% and 25% BLA observed more compressive strength loss when comparison to the control mixes. Loss of compressive strength due to Sodium sulphate reacts with calcium hydroxide and hydrated calcium aluminates. It decomposes the hydrated calcium silicates completely and makes the concrete a friable mass. (Acharya & Patro, 2016)

4.8.2.1 Effect of Sulphate Attack on Flexural Strength

To examine the sulfate attack (durability) through testing the flexural strength loss due to sulphate attack the casted concrete beam cured in water tank for 7 days , then the sample is taken from pure water thank and soaked in 10% sodium sulfate (Na2.SO4) up 28 days for (21 days). Then concrete beam cured in potable water and 10% Na2.SO4 are compared and losses due to sulphate attack are determined. The result is presented in and Table 4.22 and Figure 4.14 below.

Table 4.22 The effect of BLA replacement on sulphate attack resistance.

Mix code	Flexural strength at 28day (Mpa)		Strength loss (%)
	In Water	In 10% Na_2SO_4	
Control Mix	3.89	3.76	3.36
5% BLA	4.28	4.15	3.04
10% BLA	3.95	3.82	3.21
15% BLA	3.15	3	4.76
20% BLA	2.41	2.28	5.26
25% BLA	1.93	1.8	6.86

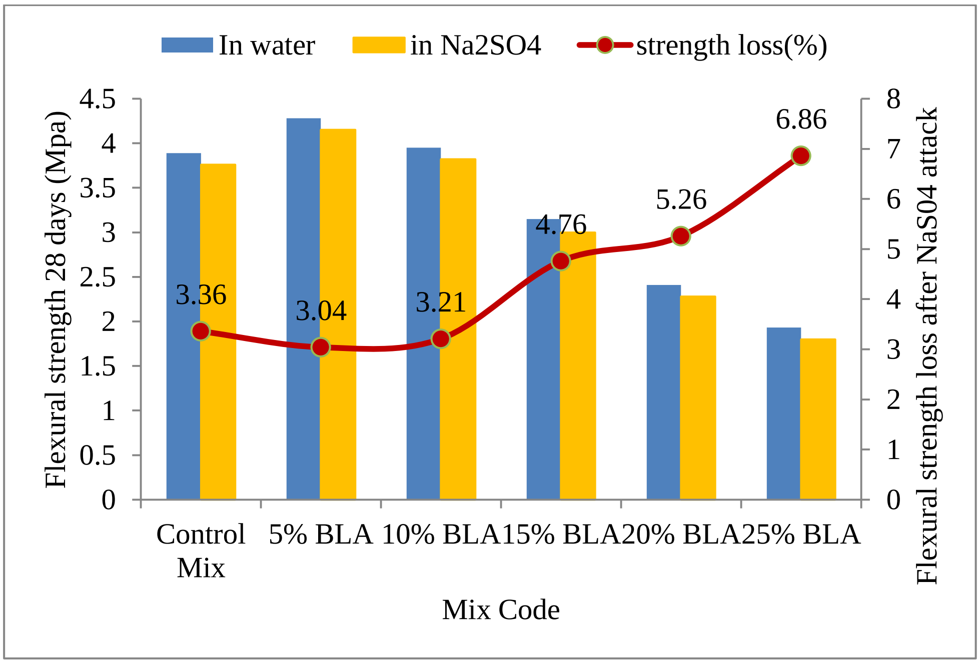


Figure 4.14 Concrete Flexural Strength Losses due to Sodium Sulfate Attack

As Table 4.22 and Figure 4.14 shows , The flexural strength loss due to sodium sulfate attack after immersed the specimens for 28 days in the 10% sodium sulfate solution for control mix, BLA5%, BLA10% ,BLA15%, BLA20% and BLA25% are recorded 3.36%,3.04%, 3.21%, 4.76%, 5.26% and 6.86% respectively. Similar for compressive strength loss concrete mixes with 5% and 10% BLA observed less flexural strength loss and Concrete Mixes with 15%, 20% and 25% BLA observed more flexural strength loss when comparison to the control mixes.

4.9 Regression and Correlation between Variables

The most commonly used techniques for investigating the relationship between two quantitative variables are correlation and linear regression. Correlation quantifies the strength of the linear relationship between a pair of variables, whereas regression expresses the relationship in the form of an equation. In regression analysis, the value of at least one independent variable is used to predict the value of a dependent variable. It explains how changes in an independent variable influence the dependent variable. The dependent variable in this case was compressive strength and flexural strength, while the independent variable was density. Excel 2016 was used to calculate the linear regression equation and correlation simultaneously. The sample correlation coefficient ‘r’ is a measure of the strength of the linear relationship between the sample observations. Pearson correlation coefficient(r) is unit free; it ranges between -1 and 1. Hence, -1 is negatively relationship, 0 is the weaker or no relationship, and 1 is positive liner relationship (Bewick et al., 2003).

4.9.1 Density and Compressive Strength

For three cube specimens, X is the average density of concrete. Under various BLA additions, Y represents the average compressive strength of concrete. The sample correlation coefficient is a measurement of the strength of the linear relationship between the experimental results.

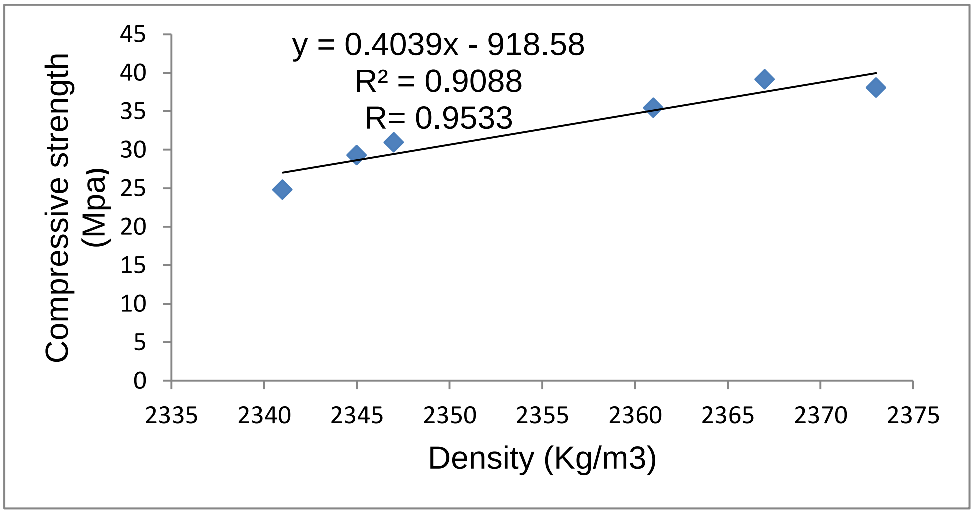


Figure 4.15 Relationships between Compressive Strength and Density of Concrete

Figure 4.15 Compressive strength and density regression at 28 Days shows that the compressive strength of concrete increases with curing age as the density of the concrete increases. It demonstrates that the compressive strength and density of concrete are directly proportional variables. The 28th day compressive strength has a significant positive correlation (0.9533) as related to the 28th day concrete density, as shown in Figure 4.15 In line with this, as stated in the previous sections, the Pearson correlation coefficient (r) is between -1 and +1. Based on this, the correlation (+ 0.9533), which is nearly positive one, arguing that the 28th compressive strength and 28th day density have direct relationship.

4.9.2 Density and Flexural Strength

It's drafted as a linear equation with two variables (X and Y). For three Concrete beam specimens, X is the average density of concrete. Under various BLA additions, Y represents the average flexural strength of concrete. The sample correlation coefficient is a measurement of the strength of the linear relationship between the experimental results.

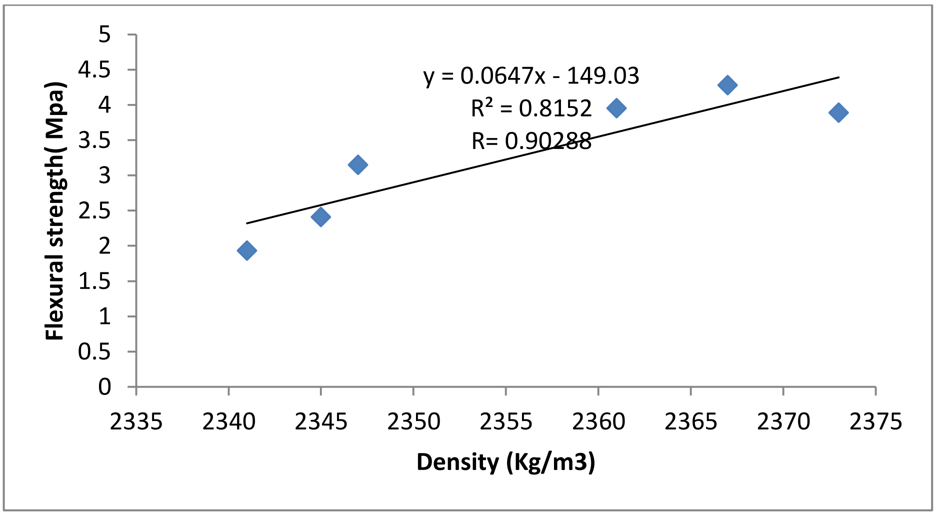


Figure 4.16 Relationships between Flexural Strength and Density of Concrete

Figure 4.16 Flexural strength and density regression at 28 Days shows that the Flexural strength of concrete increases with curing age as the density of the concrete increases. It demonstrates that the flexural strength and density of concrete are directly proportional variables. The 28th day flexural strength has a significant positive correlation (0.90288) as related to the 28th day concrete density, as shown in Figure 4.16 In line with this, as stated in the previous sections, the Pearson correlation coefficient (r) is between -1 and +1. Based on this, the correlation coefficient is + 0.90288, which is nearly positive one, arguing that the 28th flexural strength and 28th day density have direct relationship.

4.9.3 Permeability and Water Absorption

Relations between Water Absorption and Permeability of samples at 28 curing age were measured, and results were given in Figure 4.16

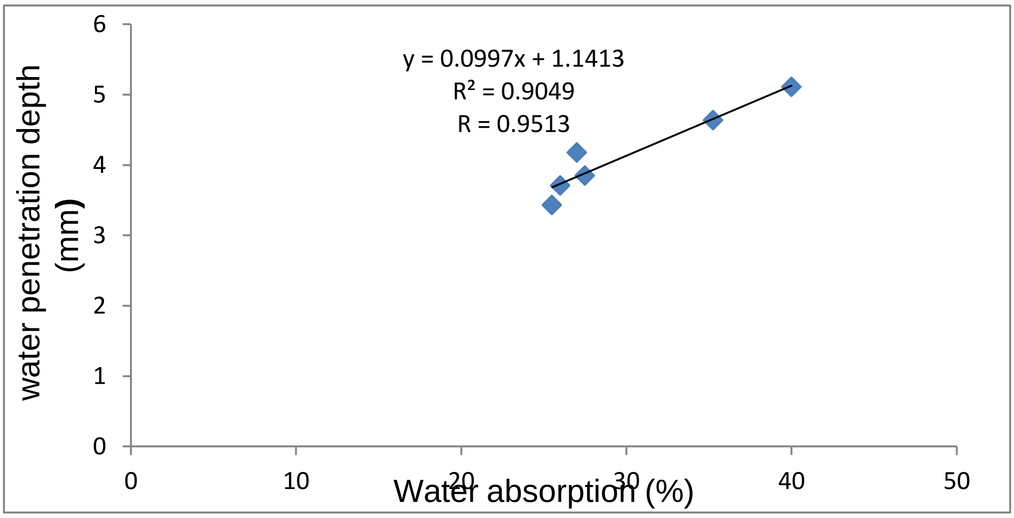


Figure 4.17 Relationships between Water Absorption and Permeability Of Concrete

As figure 4.17 shows, the permeability coefficient increased with the increase in surface water absorption. Both of permeability and water absorption were affected by the pore structure of cement paste, and liquid transfers from surface into interior. So, it indicated that surface water absorption provides great influence on permeability. In addition, the high correlation coefficients of 0.9513 indicated that there was a significant linear correlation between permeability and water absorption.

4.9.4 Compressive and Flexural Strength.

Relationship between the average compressive strength and flexural strength of the BLA mixed concrete at the age of 28 days are shown in the figure 4.18.

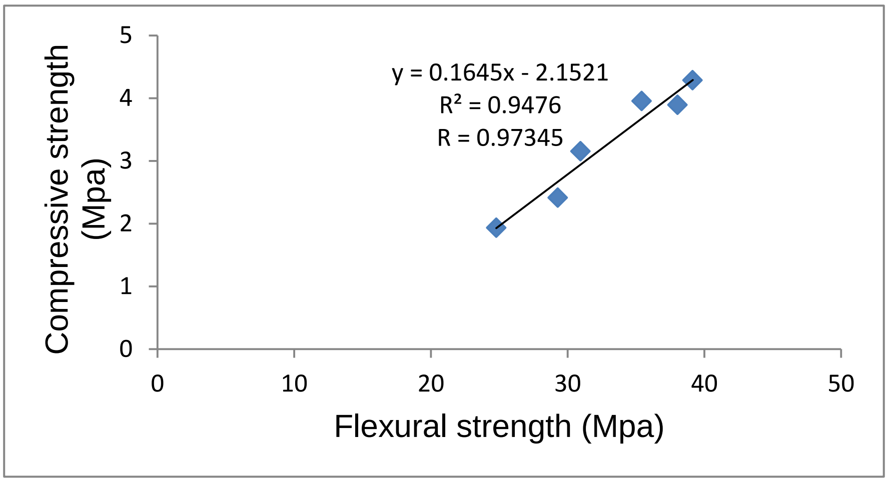


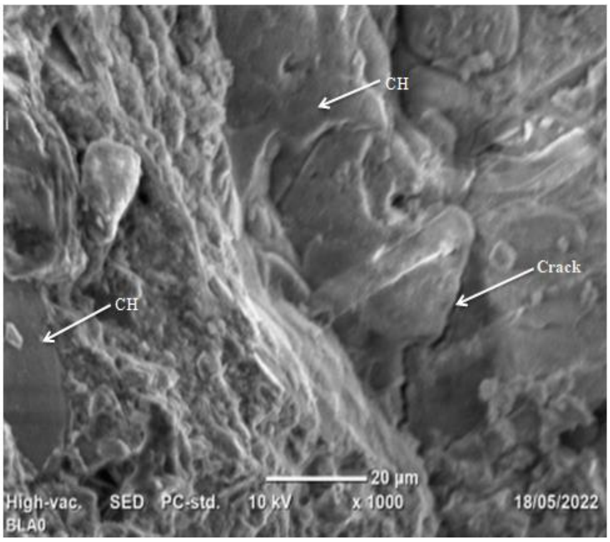
Figure 4.18 Relationships between Compressive Strength and Flexural Strength

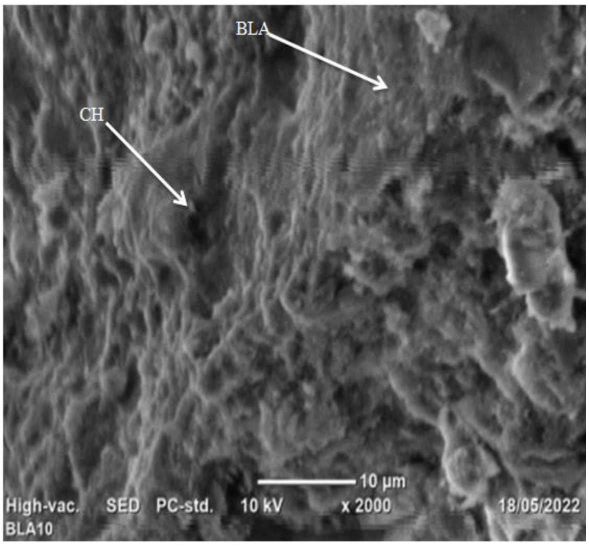
As referring figure 4.18 the high correlation coefficients of 0.97343 indicated that there was a significant linear correlation between compressive and flexural strength.

4.10 Micro Structure Analysis

4.10.1 Scanning Electron Microscopy (SEM):

The Scanning Electron Microscopy (SEM) was carried out to find the shape and size of concrete with bamboo leaf ash particles in dry form. The samples were taken to Adama science and Technology university laboratory to perform SEM analysis.





A. SEM picture for BLA0% (OPC)

B. SEM picture for BLA10%

Figure 4.19 SEM pictures for hydrated samples

The result of the SEM pictures for hydrated samples of OPC and BLA 10% at 28days curing are shown in Figures 4.19 A and B .The result shows that the image of BLA10% is tightly interlocked when compared with OPC. Gives a better mechanical interlocked than control mix. This result further supports that addition of pozzolanic material to concrete will improve the micro structural property of such concrete which in turn will improve the other properties like compressive strength and durability Based on the outcome of this research, it can be concluded that BLA are pozzolans which when partially replaced with OPC will affect the hydration products as well as the mechanical interlock or microstructure of such concrete. Crystalline silica is one of the main chief elements that contribute to pozzolanicity in pozzolans.

Also as observed by the SEM picture, the CH (Ca (OH)2) morphology in specimens with and without BLA are different from each other. Large and euhedral crystals of CH have accumulated in the fissures and large pores (Figure4.19A). This kind of large and euhedral CH crystals were observed in the specimen produced without any BLA. On the other hand, the CH crystals with smaller size are well dispersed into the matrix of the BLA added specimen (BLA 10%), (Figure 4.19B). This situation can be explained by the filler effect of BLA in the concrete (Turker et al., 2002). It can be stated that the usage of BLA effectively decreases the porosity in hardened concrete.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the experimental results, the following conclusions were drawn on Utilizing of BLA as cement replacement materials in concrete production.

- The chemical composition test of BLA satisfies class F pozzolana specification, as per ASTM C 618.
- The workability of concrete decreases as the BLA replacement amount increases, but the setting time, water percentage for consistency, and soundness of cement paste are increase.
- On the 28th day, the compressive strength of concrete made with partial replacement of cement by up to 10% attains the target mean strength (33.5Mpa), It could be that C-S-H is well effective at 10% BLA replacement. Any further increase beyond 10% BLA replacement would lead to strength reduction. While the density reduced as the BLA replacement increase.
- On the 28th day, the flexural strength of concrete made with partial replacement of cement by BLA up to 10% satisfied the required strengths 3.5Mpa for C25 as per IS 5860 - 2000. Similar to compressive strength results, any further increase beyond 10% BLA replacement would lead to flexural strength reduction.
- The water absorption of the BLA blended concrete was lower than the control at 5% ,10% BLA content, However, at higher levels of BLA substitution: (BLA15%, BLA20% and 25%) water absorption where observed higher than the control.
- Decreases in the weight of water permeability was observed at the percentage of BLA substitution of 5% , 10% and 15%, then starts increasing for 20% and 25% BLA replacement.
- Concrete mixes with 5% and 10% BLA observed less compressive strength and flexural strength loss in comparison to the control mix. Further increase beyond 10% BLA replacement would lead to more strength loss due to sodium sulphate attack in comparison to the control mix.

- The result SEM picture shows that the image of BLA10% is tightly interlocked when compared with OPC and gives a better mechanical interlocked than control.

5.2 Recommendation

Utilizing locally available Bamboo leaf ash as partially cement replacement material can significantly reduce natural resource exploitation while increasing bamboo plant cultivation. Planting bamboo plants reduces carbon emissions and increases farm profitability.

- To apply Alternative building material like BLA in construction sector there should be have locally recognized code and standards.
- In developing countries such as Ethiopia, housing affordability is a big problem, therefore using BLA as a cement alternative saves money. Universities, research communities, government, and non-governmental organizations should collaborate for further studies of bamboo leaf ash as a cement replacement material.

5.3 Areas for Future Study

Using modern methodologies like Fourier transforms infrared Spectroscopy (FTIR) and differential scanning calorimeter and thermo gravimeter (TG). Researchers need to explore Fourier Transform Infrared Analysis and obtain qualitative and quantitative details on the effects of various heat treatments on materials of all kinds, for example, the hydration of concrete. Can uses thermal analysis methods such as differential scanning calorimetry and thermogravimetry (TG).The impact of an admixture on the hardened and fresh qualities of BLA concrete could be investigated. The Studies should be made to check Economic advantages of using BLA as a cement replacing material.

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APPENDIXES

APPENDIX A: TEST FOR MATERIAL

1. **Normal Consistency of Hydraulic Cement**

General: normal consistency of the cement paste is the condition of the cement during finding of initial and final setting time of cement. For determine the exact initial and final setting time of cement it's necessary to determine the exact water quantity for the cement paste of normal consistency.

Objective: To regulate the quantity of water required to formulate the cement paste.

Tools, equipment and material : Vicat needle apparatus with all necessary accessary, bowl with trowel and spatula, Vicat mould , Glass plate, Mixing dish, watch,

Procedures:

1. Mix 500gm of cement with a measured quantity of clean water thoroughly for three minutes utilizing a paste mixer.
2. Fill the paste into the Vicat mould by using a trowel.
3. Immediately after filling the mould, level the paste and lower the plunger gently and take it in contact with the outward of the paste.
4. Tighten the plunger by the screw and move the indicator to the upper zero marks and put the plunger on the surface.
5. Thirty seconds subsequently liberating the plunger record its penetration.
6. The paste is thought to be standard to the rod settles 10±1mm underneath the original surface with 30 seconds.

Observation

1.1. Consistency of Cement Paste, Control OPC (BLA0%)

Calculation:

1. 1^{st} water taken for Start, 26% of cement by weight = (26*500)/100 = 130ml
2. 2^{nd} Water taken, 27% of cement by weight = (27*500)/100 = 135ml
3. 3^{rd} Water taken, 28% of cement by weight= (28*500)/100 = 140ml

Table A1. Normal Consistency of Hydraulic Cement

Trial	Percentage of water taken	Penetration depth from the surface (mm)	Remark
1.	26%	11	Ok!
2.	27%	13	--
3.	28%	15	--

1.2 Normal Consistency of Blended Cement (BLA5%)

Calculation:

1. 1^{st} Water taken, 27% of cement by weight = (27*500)/100 = 135ml
2. 2^{nd} Water taken, 28% of cement by weight = (28*500)/100 = 140ml
3. 3^{rd} water taken 29% of cement by weight = (29*500)/100 = 145ml

Table A2. Normal Consistency of Blended Cement (BLA5%)

Trial	Percentage of water taken	Penetration depth from the surface (mm)	Remark
1.	27%	10	Ok!
2.	28%	12	--
3.	29%	14	--

1.3 Normal Consistency of Blended Cement (10%)

Calculation:

1. 1^{sd} Water taken, 28% of cement by weight = (28*500)/100 = 140ml
2. 3^{nd} Water taken, 29% of cement by weight= (29*500)/100 = 145ml
3. 4^{th} Water taken, 30% of cement by weight= (30*500)/100 = 150ml

Table A3. Normal Consistency of Blended Cement (10%)

Trial	Percentage of water taken	Penetration depth from the surface (mm)	Remark
1.	28%	9	---
2.	29%	10	Ok!
3.	30%	13	--

1.4 Normal Consistency of Blended Cement (15%)

Calculation:

1. 1^{st} water taken for Start, 29% of cement by weight= (29*500)/100 = 145ml
2. 2^{nd} Water taken, 30% of cement by weight = (30*500)/100 = 150ml
3. 3^{rd} Water taken, 31% of cement by weight= (31*500)/100 = 155ml

Table A4. Normal Consistency of Blended Cement (15%)

Trial	Percentage of water taken	Penetration depth from the surface (mm)	Remark
1.	29%	8	---
2.	30%	9	--
3.	31%	11	OK!

1.5 Normal Consistency of Blended Cement (20%)

Calculation:

1. 1^{st} water taken for Start, 30% of cement by weight= (30*500)/100 = 150ml
2. 2^{nd} Water taken, 31% of cement by weight = (31*500)/100 = 155ml
3. 3^{rd} Water taken, 32% of cement by weight= (32*500)/100 = 160ml

Table A5. Normal Consistency of Blended Cement (20%)

Trial	Percentage of water taken	Penetration depth from the surface (mm)	Remark
1.	30%	7	---
2.	31%	9	--
3.	32%	10	OK!

1.6 Normal Consistency of Blended Cement (25%)

Calculation:

1. 1^{st} water taken for Start, 31% of cement by weight= (30*500)/100 = 155ml
2. 2^{nd} Water taken, 32% of cement by weight = (31*500)/100 = 160ml
3. 3^{rd} Water taken, 33% of cement by weight= (32*500)/100 = 165ml

Table A6. Normal Consistency of Blended Cement (25%)

Trial	Percentage of water taken	Penetration depth from the surface (mm)	Remark
1.	30%	6	---
2.	31%	8	--
3.	33%	10	OK!

NB. The penetration depth is within the ASTM C-187 limit of 10±1mm.

Table A7 Summary of Consistency (%) of blended cement paste

S. No	Designation code	Results (%)	Consistency (%) Ethiopian standard (26-33) (EN 196-3, no.5, 1994)	Remark
1	BLA0	26	26-33	Ok
2	BLA5	27	26-33	Ok
3	BLA10	29	26-33	Ok
4	BLA15	31	26-33	Ok
5	BLA 20	32	26-33	Ok
6	BLA 25	33	26-33	Ok

1.7 Determination of Initial and Final Setting Time of control and blended cement

Test Procedure:

1. Fit the plunger to the movable rod of the Vicat Needle Apparatus
2. Weigh 500 g of cement powder and transfer into the bow!
3. Find the water quantity as P (Norm Consistency) x 500 g /100 = milliliter of water. **P** is to be found with a separate test, see before
4. Mix the water with cement to form uniform paste (use stop watch)
5. Transfer the paste into the Vicat Mould kept on the glass plate

6. Shake the mould to relief entrapped air Step 4-6 to be completed within 3 minutes
7. Keep Vicat Mould with glass plate below the plunger attached to movable rod.
8. Release the movable rod to sink into the paste Initially the needle will completely penetrate into the paste
9. Repeat the steps 8 and 9 with time Intervals of 15 minutes until the needle penetration of 25 mm or less is obtained.
10. When step 10 is satisfying, observe stop watch, note time (Do not stop the watch)

Result: Initial Setting Time____________________ minutes at room temperature of °C

11. Replace the needle with the circular attachment
12. Adjust the circular attachment to touch the surface of the cement paste in the mold
13. Release the movable rod to sink into the paste Repeat the steps 13 and 14 until the center needle (of circular attachment) makes an impression, while the circular cutting edge (of the circular attachment) fails to do so Result: Final Setting Time__Minutes at room temperature of 27 $C^0 \pm 2$ The setting time test for blended cement was done based on the ASTM C-191 standard.

Table A8 Setting Time of Cement

code	Result (Setting time (min))		Setting time (min) (ASTM C-191)		Remark
	initial	Final	Initial	Final	
BLA0%	125	278	49 - 202	185-600	Ok
BLA5%	142	295	49 - 202	185-600	Ok
BLA10	160	327	49 - 202	185-600	Ok

%					
BLA15 %	166	335	49 - 202	185-600	Ok
BLA 20%	167	336	49 - 202	185-600	Ok
BLA25%	169	339	49 - 202	185-600	Ok

1.8 Determination of Soundness of Cement

The soundness test for cement was done based on the ASTM C-151 standard.

Objective: To determine the explanation of cement.

Apparatus: Le chatelier's apparatus, Glass plate

Procedure:

1. Prepare cement of normal consistency.
2. Fill the paste in the cylinder mold placed on the glass plate.
3. Cover the mold with another glass plate holding it down by a small weight.
4. Then submerge it in the water for 24 hours at a temperature of 27±2 ^{o}C and measure the distance between the indicator needles.
5. Then, Place it in the hot water of 100^{o}C for one hour.
6. Remove the mold from the water and allow it to cool and measure the distance between the needles again. Then The difference between step 4 and 6 represents the expansion of cement

Table A9 Soundness of Cement

S.No	code	Result (Expansion	Ethiopian Standard (Expansion (mm))	Remark

		(mm))	not exceed 10mm	
1	BLA0 %	0.9	≤10mm	Ok
2	BLA5 %	1.4	≤10mm	Ok
3	BLA10 %	1.8	≤10mm	Ok
4	BLA15 %	2	≤10mm	Ok
5	BLA 20%	3.1	<10mm	Ok
6	BLA25%	3.3	<10mm	Ok

According to the Ethiopian specification, the expansion of hydraulic cement shall not exceed 10mm. during this experiment, the change of expansion of the paste was less than 10mm and therefore, it's acceptable to use in concrete production.

1.9 Specific gravity of BLA

Objective: to determine BLAs specific gravity

Apparatus: Cement, Kerosene, Specific Gravity Bottle capacity of 250 ml with stopper, Specific Gravity Bottle capacity of 250 ml with stopper. To estimate the specific gravity cement and cement corresponding material, we use kerosene as like water because to stop the hydration reaction with react to water. Cement and pozzolanic material never react with kerosene. The specific gravity of Kerosene is 0.79 g/cc the specific gravity of water is 1g/cc.

Procedure:

1. The Lechatlier flask must be free from wetness.
2. Measure the weight of dried flask and note it as W_1.
3. Take 50gm of BLA and add it in Flask. Now weight the Flask with the stopper as W_2

4. Now pour kerosene in the sample up to the neck of the bottle. Mix thoroughly and see that no air bubbles left in the flask. Note down the weight as W3

5. Empty the flask and fill the bottle with kerosene up to the tip of the bottle and record the weight as W4.

Calculation: Specific gravity = $\frac{(W2-W1)}{(W2-W1)-(W3-W4)*0.79}$

Table A10: specific gravity of BLA

Trial	Weight by gram(g)				
	W1	W2	W3	W4	S.G BLA.
1	75	125	195	160	2.24
2	75	125	196	160	2.32

Average specific gravity = 2.28

Density of BLA

A = Weight of container = 1500g

B= Weight of BLA and container = 3442g

C = Volume of container = 0.0015

$$Density\ of\ BLA = \frac{Weight\ of\ BLA\ in\ (Kg)}{Volume\ of\ Container\ (m3)}$$

$= \frac{B-A}{C}$ = 1294.67 kg/m3

2. Test for water

potable water is used as mixing water for concrete production. Consequently, there is no essential water test for mixing concrete in laboratory.

3. Test for Fine Aggregate

a. Silt Content of sand

Objective: The objective of the test is to regulate the quantity of silt content in sand.

Apparatus: Glass jar, The Dish for taking a sample Spoon, Sand (fine aggregate)

Procedure: Observation and calculation

A = amount of silt deposited above the sand=0.95ml

B = amount of clean sand =29.05ml

Silt content (%) = $\frac{A}{B} * 100 = \frac{0.95}{29.05} * 100 = 3.25\%$

According to Ethiopian standards which silt concentration not exceed than 6%. The sand silt content was found 3.25% which is less than 6% and suitable for use.

A. Fine Aggregate/Sand Gradation

Objective The objective of the gradation test is to examine the particle size distribution of fine aggregate.

Apparatus: Digital balance, Series of sieves, Shovel and Sieve brush

1. Take a jar having a capacity of greater than 100ml.
2. Pour 30ml of sand into the cylinder.
3. Fill approximately ¾ of the jar with water.
4. Shake the trial dynamically for about a minute.
5. Leave the cylinder for about an hour to allow the silt to settle on above.
6. Measure the number of fines forming a separate layer on the top of the washed sand.

Procedure:

1. Take 2kg of sand and quarter it using a riffle box and then take 500gm from the Quartered sample.

2. Measure the empty sieves weight and record the figures.

3. Put the pan to the bottom and put the other sieves into the pan by increasing the opening size of the sieves.

4. Place the 500gm. of sample on the topmost of sieve

5. Shake the sample for about 2 minutes in a sieve shaker.

6. Weigh each sieve together with the sand retained on it.

7. Calculate the weight reserved on each sieve.

8. The weight of retained aggregates was measured and registered recorded as indicated in the table below.

Table A11: Fine aggregate Sieve analysis result

sieve size (mm)	weight of sample retained	cumulative weight retained	cumulative % retained	cumulative % pass	Min (%)	Max (%)
9.5	0	0	0	100	100	100

4.75	10	10	2.04	97.95	95	100
2.36	55.9	65.9	13.48	86.51	80	100
1.18	105.65	171.55	35.11	64.88	50	85
0.6	125	296.55	60.69	39.30	25	60
0.3	111	407.55	83.41	16.58	5	30
0.15	64.25	471.8	96.56	3.43	0	10
Pan	16.77	488.57	100	0		
Total	488.57		291.32			

Fineness modules (FM) of sand = (summation of cumulative % weight retained)/100 = 2.91

ASTM approved that the fine aggregate intends to have not more than 45 % fleeting any sieve and reserved on the succeeding sieve of those shown in table A8 and its fineness modulus intend to be not less than 2.3 not above 3.1. The sand fineness modules was found 2.91 which in standard range and suitable for use.

Bulk Unit Weight Fine Aggregate

Objective: The test aims to examine the bulk density of fine aggregate. Apparatus: A cylindrical metal container of known volume, Temping rod and Balance.

Procedure: First, the weight of an empty container having a volume of 0.003m3 is noted. Then, the Container is filled in three layers, each layer being tamped with 25 blows using a standard tamping rod. Finally, the excess layer is trimmed off and weighed with a balance

Calculation:

Volume of container = 0.00303m3

Weight of container = 3000 gm.

Weight of fine aggregate + container = 8530 gm.

Unit weight of fine aggregate = $\frac{Weight\ of\ fine\ aggregate}{Volume\ of\ container}$ = $\frac{5530}{0.00303}$ = 1825kg/m3

B. Specific Gravity and Absorption of Fine Aggregate

Objective: To determine bulk, apparent specific gravity, and absorption capacity of fine aggregates.

Apparatus:

Balance: a balance or a scale capacity of 1kg or more.

Pycnometer: a flask or another suitable container into which the fine aggregate test sample can readily be introduced.

Mold: a metal mold in the form of a frustum of a cone 38mm in top diameter, 89mm in bottom diameter, and 74mm in height with the metal was having a minimum thickness of about 0.9mm.

Tamper: a metal device weighing 340±15g and having a flat circular tamping face 25±3mm in diameter.

Preparation of test sample: Take the test sample employing the riffle box. Using a suitable pan, the sample was dried in an oven. Then the dried sample was covered with water for about 15 hr. after cooling. Until the sample was approached to free-flowing conditions, it was spread on a flat surface and exposed to gently moving warm air. Next, the partially dried sample was placed loosely into the mold and tamped 25 times with the tamper. Finally, the mold was lifted vertically. The drying process was repeated until the sample partially flows when the mold is lifted vertically. This indicates that the sample has reached a surface dry condition.

A= Mass of oven dray sample = 496.75gm

B= Mass of pycnometer + water = 1479gm

C = Weight of water + sand + pycnometer = 1793gm

S = Weight of sample at, SSD = 500.00gm

1. Bulk specific gravity = $\frac{A}{B+S-C}$ = 2.67
2. Bulk specific gravity at SSD basis = $\frac{S}{B+S-C}$ = 2.69
3. Apparent specific gravity = $\frac{A}{B+A-C}$ = 2.72

4. Absorption = $\frac{S-A}{A}$ *100 = 0.65%

Conclusion: The specific gravity of proper fine aggregates ranges between 2.6 to 2.8. Hence, the sample having the bulk specific gravity of 2.67 is appropriate for concrete production. Absorption is an amount of the total opening volume accessible to water. It was also useful for a mixed design moisture adjustment. The absorption of 0.65% % is well within the maximum limit of 4%.

C. Moisture Content of Fine Aggregate

Objective: The objective of this test is to determine the moisture content of fine aggregate.

Apparatus: Balance, Dish, Oven, Trowel

Procedure:

1. Take and weigh a sample of 500gm fine aggregate from the sample splitter.
2. The sample was then oven-dried for 24hrs with a temperature of 105^{o}C to 110^{o}C.
3. Remove the sample from the oven and cool for about an hour without absorbing water from the atmosphere.
4. Then measure the over dried weight after cooling.

Observation and calculation:

A = weight of original sample = 5000g

B = weight of oven-dry sample = 4950g

Moisture content = $\frac{A-B}{B} * 100 = 1.01\%$

2 Test for Coarse Aggregate

2.2 Gradation of Coarse Aggregate

Objective: the aim of this test is to govern the particle size distribution of coarse aggregate.

Apparatus: Digital Balance, Sieve brush, quartering box, Sieve (ASTM standard), Electronic shaker.

Procedures:

1. Take 20 kg of sample and choose a representative sample by a quartering and take 2kg.

2. Weigh the sieve without sample and also record data.

3. Sit 2kg of sample on the top sieve and shake the sample about 2 min using a sieve shaker.

4. Weigh each sieve together with the sample aggregate retained.

5. Calculate the weight retained on each sieve.

6. The weight of retained aggregates was measured and registered recorded as indicated in the table below.

Observation and Calculation: Initial sample weight = 2000 gram

Table A 12: Sieve analysis of coarse aggregate

sieve size (mm)	weight of sample retained	cumulative weight retained	cumulative % retained	cumulative % pass	Min (%)	Max (%)
37.5	0	0	0	100	100	100
25	140	140	6.99	93.00	90	100
19.5	773.25	913.25	45.64	54.35	40	85
12.5	611.5	1524.75	76.2	23.8	10	40
9.5	440.15	1964.9	98.20	1.796	0	15

4.75	35.95	2000.85	100	0	0	5
pan	0	2000.85	100	0		
Total	2000.85		327.043392			

Fineness modules of Coarse aggregate = $\frac{\text{Asummation of cumulative \% weight retained}}{100}$ = 3.27

2.3 Bulk Unit Weight of Coarse Aggregate

Objective: The objective of the test is to determine the unit weight of coarse aggregate.

Apparatus: Balance, Tamping rod, cylindrical metal container capacity 0.00303m3

Observation and calculation

Volume of container =0.00303m^3

Weight of container = 3000 gm.

Weight of coarse aggregate + container = 7882.75 gm.

Weight of coarse aggregate = 7882.75 gm. - 3000 gm. = 4882.75

Unit weight of fine aggregate = $\frac{Weight\ of\ coarse\ aggregate}{Volume\ of\ container}$ = 4882.75/0.00303 = 1611.5kg/m3

A. Specific Gravity and Absorption of Coarse Aggregate

Scope: Determination of bulk, apparent specific gravity and absorption of course aggregate.

Apparatus: Balance, Sample container, Oven.

Test Sample: Material passing the 4.75mm. (No - 4) Sieve shall be discarded. The test sample shall weigh approximately 5kg.

Procedure:

1. After thoroughly washing to remove dust or other coatings from the surface of the particles dry the sample to constant mass at a temperature of 110$\pm$5^{0}c cool in air at room

And then immerse in water at room temperature for a temperature for 1 to 3 hour. Minimum time of 15 hours.

2. 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 weight the sample in the saturated surface dry condition. Record this and all subsequent weights to the nearest 1.0 gm.

3. After weighing immediately place the saturated surface dry sample in the sample container and determine its mass in water 23+1.7 °c, Take care to remove all entrapped air before weighing by shaking the container while immersed.

4. Dry the sample to constant mass at temperature of 110 ± 5^0c, cool in air at room temperature 1 to 3 h and weight.

1. A= mass of oven- dry sample in air (g) = 5Kg
2. B = mass of saturated-surface dry (g) = 5.07kg
3. C = mass of saturated sample in water (g) = 3.1

Bulk specific gravity = $\frac{A}{B-C}$ = 2.54

Bulk specific gravity (SSD basis) = $\frac{B}{B-C}$ = 2.57

Apparent specific gravity = $\frac{A-C}{B-A}$ = 2.63

Absorption capacity = $(\frac{B-A}{A}) * 100$ = 1.4%

B. **Moisture Content of Coarse Aggregate**

Objective: The objective of this test is to determine the moisture content of coarse aggregate.

Apparatuses: Balance, Dish, Oven

1. A sample of 2kg coarse aggregate was measured and taken (A).
2. The sample was oven-dried for about 24 hrs. With a temperature of 105 ^{0}C – 110^{0}C.

3. The samples were removed from the oven and placed on the table for about an hour to cool without absorbing water from the atmosphere. The aggregate was then measured after cooling (oven-dry weight, B).

Observation and calculation: The moisture content of the coarse aggregate is then calculated as shown below.

A = Weight of the original sample = 5000gm

B = Weight of sample under SSD condition = 4977gm

Moisture content = $\frac{\boldsymbol{A-B}}{\boldsymbol{B}} * \mathbf{100}$ = 0.46%

APPENDIX B: CONTROL MIX PROPORTION

1. Mix Design for C-25 Non-Air-Entrained Concrete

In this particular research, the ACI mix design is selected and done as per ACI 211.1. Mix

Table B1: Course aggregate test results

No.	Types of tests	Test result	Test standard
1.	Nominal maximum aggregate size	25mm	ASTM -C33
2.	Bulk unit weight	1611.5 kg/m3	ASTM -C29
3.	bulk Specific gravity	2.54	ASTM -C127
4.	Apparent Specific gravity	2.63	ASTM -C127
5.	Absorption	1.4%	ASTM -C127
5.	Moisture content	0.46%	ASTM -C5

Table B2: Fine aggregate test result

No.	Types of Tests	Test Result	Test Standard
1.	Finesse modulus	2.91	ASTM -C136
2.	Bulk unit weight	1825kg/m3	ASTM -C29
3.	Bulk Specific gravity	2.69	ASTM -C128
4.	Absorption	0.65%	ASTM -C128
5.	Moisture content	1.01%	ASTM -C566

Computing required average compressive strength from the given characteristic strength of 25MPa According to ACI-318.

Table B3: From ACI 318 Required average compressive strength f`cr (Mpa).

Specified compressive strength f'c (Mpa)	Required average compressive strength f`cr
21 to 35	f `c + 8.5

Therefore; for 25Mpa specified compressive strength, the average compressive strength can be calculated as; f'c + 8.5 = 25 + 8.5 = 33.5Mpa

Step 1: Choice of Slump: 25-50 mm slump is selected

Step 2: Maximum Aggregate Size Selection

According to ACI 211.4R-93, for concrete strength greater than 9000Psi (62Mpa), the recommended maximum size of coarse aggregate is between 9.5 mm to 12.5mm whereas, for concrete strength, less than 9000psi (62Mpa), the recommended maximum size of coarse aggregate is between 19 mm to 25mm. C-25Mpa less than 62Mpa and therefore 25mm nominal maximum coarse aggregate is selected.

Step 3: Estimating Mixing Water and Air Content

Approximate mixing water (kg/m^3) for indicated nominal maximum sizes of aggregate								
Slump (mm)	9.5 mm	12.5 mm	19 Mm	25 Mm	37.5 Mm	50 mm	75 mm	150 Mm
25 to 50	207	199	190	179	166	154	130	113
Approximate amount of entrapped air in non-air-entrained concrete (%)								
Slump (mm)	9.5 mm	12.5 mm	19 Mm	25 Mm	37.5 Mm	50 mm	75 mm	150 Mm
All	3	2.5	2	1.5	1	0.5	0.3	0.2

Table B4: Approximate mixing water and air content requirements.

For slump 25-75mm and nominal maximum size of aggregate of 25 mm and non-air-entrained concrete, the mixing water requirement can be calculated as:

Mixing water amount = 179 kg/m³, The air content is= 1.50%

Step 4: The Selection of the Water-Cement Ratio.

Table B5: The relationship between water to cementitious material ratio and compressive strength of concrete.

Compressive strength at 28	Water-cement ratio by weight non-air-
40	0.42
35	0.47
30	0.54

By using interpolation, the water-cement ratio of concrete with 28days compressive strength of 33.5Mpa is 0.49.

Step 5: Cement Content

Weight of cement = (weight of water/ Water−cement ratio) = (179kg /m^3)/0.49 = 365kg/m^3

Step 6: The Coarse Aggregate Amount

Table B. 6: coarse aggregate amount

The Volume of oven-dry-rodded coarse aggregate per unit volume of concrete for different fineness modulus of fine aggregate				
Nominal maximum size of aggregate (mm)	2.4	2.6	2.8	3
9.5	0.5	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19	0.66	0.64	0.62	0.6
25	0.71	0.69	0.67	0.65

From the above table the volume of coarse aggregate = 0.659m^3 by interpolation

Bulk density of coarse aggregate = 1611.5 kg/m^3

Weight of coarse aggregate = 0.659 × 1611.5 = 1069.99Kg air dry mass, but 0.659m3 is dry volume allowing for 1.4% absorption and 0.46% of moisture content.

Step 7: Fine Aggregate Amount

By using absolute volume methods Water = (179 /1000) = 0.179m^3

Cement = (365/3.15*1000) = 0.116m^3

Coarse aggregate = 1061.99/2.63*1000 = 0.404m^3

Air = 1.5% = 0.015m3

Total volume of fine aggregate = 1m3 – (0.179+ 0.116 + 0.404+ 0.015) = 0.286m^3

The mass of fine aggregate is 0.286x 2.69 x 1000 = 767.34 kg/m^3

Step 8: Adjustment for Moisture

Their moisture in both coarse and fine aggregate, so their batch must be adjusted as follows. Weight of coarse aggregate (wet) = 1061.99kg/m^3 (1+0.0046) = 1066.9kg/m^3 Weight of fine aggregate (wet) = 767.34 kg/m^3 (1+ 0.0101) = 775.1kg/m^3

Step 9 Adjustment for water absorption:

Water absorbed by coarse aggregate = 1061.99kg/m^3x (0.46%-1.4%) = -9.982kg/m^3

Water absorbed by fine aggregate = 767.kg/m^3x (0.65%- 1.01%) = -2.76 kg/m^3

The adjusted amount of water for one cubic meter of concrete can be calculated as 179+9.98+2.76 = 191.74kg/m^3

The Proportion of ingredients for trail mix in 9 cubes and 7 concrete beams is calculated below for control mix (BLA 0%): Trial mix volume = ((0.15*0.15*0.15)*9+ (0.5*0.1*0.1)*7 + 20% wastage = 0.07845m3

Table B. 7: Final mix proportion for control mix (BLA0%)

Amount of mix	Cement (kg)	BLA (0%) (kg)	Coarse aggregate (kg)	Fine aggregate (kg)	Water (kg)
Per cubic meter	365	0	1066.9	775.1	191.74
Trial mix = 0.07845m^3	28.6	0	83.7	60.81	15.05

Table B8: Final mix proportion for (BLA5%)

Amount of mix	Cement	BLA (5%)	Coarse aggregate	Fine aggregate	Water
Per cubic meter	346.75	18.25	1066.9	775.1	191.74
Trial mix = 0.07845m3	27.2	1.43	83.7	60.81	15.05

Table B 9: Final mix proportion for (BLA10%)

Amount of mix	Cement	BLA (10%)	Coarse aggregate	Fine aggregate	Water
Per cubic meter	328.5kg	36.5	1066.9kg	775.1kg	191.74
Trial mix = 0.07845m3	25.8	2.86	83.7	60.81	15.05

Table B9: Final mix proportion for (BLA15%)

Amount of mix	Cement	BLA (15%)	Coarse aggregate	Fine aggregate	Water
Per cubic meter	310.25kg	54.75	1066.9kg	775.1kg	191.74
Trial mix = 0.07845m3	24.34	4.3	83.7	60.81	15.05

Table B10: Final mix proportion for (BLA20 %)

Amount of mix	Cement	BLA (15%)	Coarse aggregate	Fine aggregate	Water
Per cubic meter	292kg	73kg	1066.9kg	775.1kg	191.74
Trial mix = 0.07845m3	22.9	5.73	83.7	60.81	15.05

Table B11: Final mix proportion for (BLA25%)

Amount of mix	Cement	BLA (15%)	Coarse aggregate	Fine aggregate	Water
Per cubic meter	273.75 kg	91.25	1066.9kg	775.1kg	191.74
Trial mix = 0.07845m3	21.48	7.2	83.7	60.81	15.05

Table B10. Final mix proportion Summary

Mix Designation	Quantity of material per cubic meter (kg/m^3)				W/C Ratio
	Cement	BLA	Fine Aggregate	Coarse Aggregate	
OPC C	365	0	775.1	1066.9	0.49
BLA5	346.5	18.25	775.1	1066.9	0.49
BLA10	328.5	36.5	775.1	1066.9	0.49
BLA15	310.25	54.75	775.1	1066.9	0.49
BLA 20	292kg	73kg	775.1	1066.9	0.49
BLA 25	273.75 kg	91.25	775.1	1066.9	0.49

APPENDIX C: SAMPLE PHOTO TAKEN DURING LABORATORY TEST

1. Process of Bamboo leaf ash (BLA) production

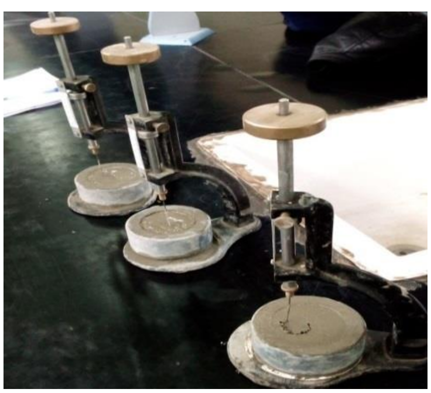


A. Bamboo leaf at source B. Collected Bamboo Leaf C. BL washed by tap water



D. Sun-dried Bamboo leaf E. Grinded bamboo leaf G. Furnace burned BLA

3 Physical properties of cement and BLA blended taste




A. Test for Consistency of Cement and BLA blended paste B. Tests for soundness

4 Fine and Coarse Aggregate Physical Properties Test

A .Tests for fine and coarse aggregate physical properties

5 Fresh concrete

A. Mixing concrete ingredients by Mixer

B. Casting Concrete

C. Test for fresh concrete

6 Tests on hardened concrete

A. Concrete curing B. cube prepared for transport C. Beam prepared for transport

C. Transporting to Compressive & flexural strength testing machine D. concrete after tested.

E. Compressive strength test

F. Flexural strength test

G. Sample in oven

H. permeability test

I. samples after splitting

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

Customer Name:- Sadam Gudeto Bedaso

Issue Date:- 31/03/2022

Request No:- GLD/RQ/850/22

Report No:- GLD/RN/349/22

Sample type :- Ash

Sample Preparation: - 200 Mesh

Date Submitted:-22/03/2022

Number of Sample:-One (01)

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

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

Collector's code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI	Weight Of Sample
BLA-12	71.10	1.08	1.80	5.08	1.00	<0.01	2.96	0.12	0.96	<0.01	1.55	13.85	900.00gm

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

Analysts	Checked By	Approved By	Quality Control
Elisa Fiseha Lidet Endeshaw Nigist Fikadu Yirgalem Abraham	Tizita Zemene	Yohannes Getachew	Gosa Haile

J. Bamboo leaf ash chemical composition