Experimental Study on Mechanical Property of Enset Fiber Reinforced Concrete with Partial Replacement of Cement by Cow Dung Ash

Beza Meskele Kefa

A Thesis Submitted to

The Department of Construction Engineering and Management

School of Civil Engineering and Architecture

Presented in Partial Fulfilment of the Requirements of Masters of Science in Civil Engineering (Specialization in Construction Engineering and Management)

Office of Graduate Studies

Adama Science and Technology University

June, 2023

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DECLATARION

I declare that this thesis entitled "**Experimental Study on Mechanical Property of Enset Fiber Reinforced Concrete with Partial Replacement of Cement by Cow Dung Ash**" is my own work and has not been submitted to any university for a similar purpose. The references used in this thesis are duly recognized by proper citations.

Beza Meskele Kefa ____________________ ________________

Signature Date

RECOMMENDATION OF ADVISOR

I, the major advisor/supervisor of this research thesis, hereby certify that I have closely advised/supervised the student while developing this study and read the draft thesis/dissertation proposal entitled "**Experimental Study on Mechanical Property of Enset Fiber Reinforced Concrete with Partial Replacement of Cement by Cow Dung Ash**" prepared under my guidance by Beza Meskele Kefa. Therefore, I recommend the submission of the thesis to the department for further review and evaluation.

Bahiru Bewket (PhD)	____________________	________________
Major Advisor	Signature	Date

APPROVAL PAGE

I, the principal advisor of this thesis, hereby certify that the recommendations and suggestion given by the thesis review Committee are appropriately incorporated into the final thesis entitled **"Experimental Study on Mechanical Property of Enset Fiber Reinforced Concrete with Partial Replacement of Cement by Cow Dung"** by Beza Meskele.

Major Advisor	Signature	Date

APPROVAL OF BOARD OF REVIEWERS

We, the undersigned members of the board of reviewers of the research open defence by Beza Meskele Kefa, have read and evaluated the thesis entitled "**Experimental Study on Mechanical Property of Enset Fiber Reinforced Concrete with Partial Replacement of Cement by Cow Dung**" and assessed the understanding of the candidate about the proposed research. This is, therefore, to certify that the thesis is accepted and we recommend the implementation of the thesis.

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LIST OF ACRONYMS

Acronyms	Full name
ACI	American Concrete Institute
ASTUM	American Society for Testing and Materials
CDA	Cow dung ash
EDS	Energy Dispersive Spectroscopy
EF	Enset fiber
ETB	Ethiopian birr
FM	Fineness modulus
FRC	Fiber reinforced concrete
GDP	Gross Domestic Product
GFRC	Glass Fibers Reinforced concrete
GHG	Green House Gas
IS	International Standard
Kg	Kilogram
LOI	Loss of Ignition
MPa	Mega Pascal
NC	Normal concrete
NFRC	Natural Fibers Reinforced Concrete
OPC	Ordinary Portland Cement
PC	Portland Cement
PPC	Portland Pozzolana Cement
RHA	Rice Husk Ash
RHC	Rapid Hydration Cement
SCM	Supplementary Cementitious Material
SEM	Scanning Electron Microscope
SFRC	Steel Fibers Reinforced Concrete
SFRC	Synthetic Fibers Reinforced Concrete
SSD	Saturated Surface Dry
W/B	Water to bidder ratio
XRD	X-Ray Diffraction

LIST OF CHEMICAL FORMULAS

Al	Aluminum	C_4AF	TetraCalcium Alumino Ferrite
Al_2O_3	Aluminum Oxide	C-S-H	Calcium Silica Hydrate
$Al_2\ Si_2O_5\ (OH)_4 2H_2O$	Halloysite		
Ca	Calcium	CH	Calcium Hydroxide
CaO	Calcium Oxide	CO_2	Carbon Dioxide
$CaCO_3$	Calcium Carbonate	Fe	Iron
Ca_3SiO_5	Alite	Fe_2O_3	Iron Oxide
Ca_2SiO_5	Belite	K_2O	Potassium Oxide
Ca_2AlFeO_5	Ferrite	MgO	Magnesium Oxide
$Ca_3Al_{12}O_6$	Aluminate	Na_2O	Sodium Oxide
C_2S	Dicalcium Silicate	Si	Silicon
C_3S	Tricalcium Silicate	SiO_2	Silicon Oxide
C_3A	Tricalcium Aluminate	SO_3	Sulfur Trioxide

ABSTRACT

Concrete is one of the world's most versatile and widely used construction material due to its superior ability to be Mould into any desired shape and strength. But concrete has relatively low tensile strength, weak in tension and poor resistance to expansion cracking. Thus, addition of enset fiber composites as reinforcement has been introduced to improve the properties of concrete such as, tensile strength, flexural strength, toughness and also it reduces crack formation. Cement, which is an essential concrete material that takes up 10%–15% of the volume of the concrete. Its production is an environmentally unfriendly process due to release of CO2 gas to the atmosphere. In addition to this, it is the most expensive material when compared to the other components of concrete. Hence, alternative cheap natural pozzolanic cementing materials are of great interest to deal with in such a situation. Cow dung ash (CDA) is cheap cattle farming by-products and possess pozzolanic properties. The primary goal of this study was to conduct an experimental study of the combined effect of the partial replacement of cement by cow dung ash and addition of enset fiber in concrete production. The study examined the chemical composition and physical properties of cow dung ash and enset fiber on the workability of fresh concrete, the mechanical properties, the microstructural analysis of hardened concrete and on the environmental and economic analysis of using CDA as a cement replacing material. The chemical composition of cow dung ash was examined, and the summation of SiO_2, Al_2O_3 *and* Fe_2O_3 *was 81.08% and classified as class F pozzolanic material. The consistency and setting time increase as the CDA replacement amounts increase, but workability decreases as replacement increases. The compressive strength, flexural strength and tensile strength of concrete for C-3 (10% CDA with 0.5% EF) shows less strength at 7th day curing age but shows better improvement on the 28th day. Microstructure tests (SEM and XRD) analysis including environmental and economic analysis shows improved performance for replacement of cow dung ash at 10% with 0.5 % addition of enset fiber. Therefore, the maximum amount of replacement is 10% CDA with 0.5% addition of EF, which gives better strength properties of the concrete.*

Key words: Cow dung ash, Enset fiber, Microstructure, *Scanning Electron microscopy,* X-Ray Diffraction.

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

Now a day's sustainable development is a major issue in the modern world. It involves the development of community with comfort without consuming all available resources. Concrete is the most useful construction material for the construction industry which is used for making shelters, bridges, high rise buildings and so on. Due to the increasing of populations in the world, there is increasing of demands to use concrete for constructing homes and buildings, industries, and other infrastructures i.e., bridges, roads, dams and so on. But these increasing demands to use concrete as a construction material is affecting the environment and the available resources adversely. Therefore, the world is looking green materials which can replace the concrete materials at list partially and make the building green and cost effective. (Venkatasubramanian et al., 2017)

Concrete is man-made product made by hardening a specific mixture of binding material (cement), fine aggregate (sand), coarse aggregate (gravel), admixtures in some situations, and water. Concrete is classified as a combined material for the reason that it is prepared from many different components that are used to build different parts. Cement and water combine to produce an adhesive that hardens and binds the particles. The volume of aggregates, both fine and coarse, constitutes around 65–75% of the volume of the concrete, and they are essential parts in its production (Mindess et al., 2003). The amounts of these components paste and aggregate have an impact on the concrete's strength, planned concrete's lifetime, fresh concrete's workability, and cost (Mindess et al., 2003)

Concrete, on the other hand, is a brittle material with high compressive strength and low tensile strength, which makes it susceptible to cracks. Therefore, in order to reduce these cracks or to increase its tensile strength reinforcement is used and the combination of these two materials is called reinforced concrete (RC). But to increase the tensile strength of plane concrete and to reduce cracks different fibers i.e., synthetics and natural fibers, has been used by adding in the concrete mix (Wijatmiko et al., 2019).

Cement which is one of the component of concrete is a finely ground inorganic material with adhesive and interconnected properties that make it capable of uniting or bonding together fragments or particles of solid matter into a compact whole. For the reasons of increasing population and industrialization, the amount of cement utilized in concrete production has been progressively increasing to meet the requirements. This rises the price of cement and makes the manufacturing process environmentally undesirable (Asfaw et al., 2022a). Also, cement is one of the components of concrete which plays a great role for production of concrete, but it is the most expensive material and affects the environment adversely because its production requires more energy which emits CO2 and other greenhouse gases that leads to environmental pollution. It has been estimated by World Health Organization (WHO) that about 5% of total CO2 released into the heat energy consumed for the production of cement is about 1500 °C (Venkatasubramanian et al., 2017).

The cement industry is one of the major contributors for greenhouse gases (GHG) emissions, specifically CO2 emissions (Kim & Worrell, 2002). This is due to the calcinations of raw materials for the production of cement and burning fuels needed to maintain high temperatures in a kiln (Ali M.B et.al., 2011). In 2000, the cement industry sector in the world released 2.37 Gt air pollutants to the environment (Kim & Worrell, 2002). Regarding CO2 emissions, the global emissions of CO2 reached approximately 28.3 Gt in 2005, of which the cement industry generated approximately 1.8 Gt CO2 (Kim & Worrell, 2002), indicating that the cement industry contributed approximately 6% of the total global CO2 emissions. Some measures have been considered in order to reduce the CO2 emissions of cement industry.

Cement consumption in Ethiopia has increased by an average growth rate of 30%, far exceeding the growth rates observed during this period for both overall GDP growth (11%) and the construction industry (10%) (Gashahun, 2020). This is due to Ethiopia's rapid economic growth in general and construction activities in particular. Large-scale private sector investments from both domestic and international sources have been made to build cement manufacturing enterprises as a result of the growth in cement demand that is brought on by massive construction projects (Gashahun, 2020). Cement is a costly material to produce because it requires a lot of energy at extremely high temperatures and produces a lot of carbon dioxide. Compared to 30 to 40% of worldwide standards, the energy cost of Ethiopian cement companies accounts for close to 50–60% of the overall production structure (Aklilu, 2016).

According to (Lemma & Saradhi, 2021), Ethiopian cement production were evaluated and the result on the energy use intensities showed that, 3.74, 3.67 and 2.64GJ/ton of clinker, ordinary Portland cement (OPC), Pzzolana Portland cement (PPC) respectively. The result on the greenhouse gas emission were 0.87,0.84 and 0.59 tons of CO2 equivalent ton of clinker OPC, and PPC, respectively. As a result, cement production uses a lot of energy and pollutes the environment by releasing hazardous gases. Partially replacing cement with locally available materials will reduce energy consumption and environmental impact.

Utilizing plant residue, an industrial by-product, and agricultural waste in the designated area of cement is a successful method of reducing the consumption of raw materials, protecting the environment, enhance concrete strength and improving the value of cement. It is common practice throughout the world to partially replace cement in the production of concrete with waste materials that have pozzolanic qualities. Due to their pozzolanic content, various agricultural wastes and by-products are currently the subject of extensive investigation for use as additives in commercial Portland cement (Ma et al., 2012).

Cattle which are one of the main livestock production components in Ethiopia hence 70 % of its populations are engaging in traditional cattle production. Next to coffee export, cattle substantially contribute to Ethiopian foreign currency exchanges (Melaku, 2019). Cow dung ash, which is a by-product of cattle manure which was used as fuel in the form of dried cake for cooking and heating as well as for production of bio- gas energy in Ethiopia. Cattle dung ash have been tested in some parts of the world for its pozzolanic property and has been found to improve some of the properties of the paste, mortar and concrete like compressive strength, low thermal conductivity and water tightness in certain replacement percentages (Tefera, 2018).

Fibers are small discrete reinforcing inputs produced from various materials like steel, glass, carbon and natural sources in various shapes and sizes. The application and uses of fiber reinforced concrete (FRC) is continuously growing in various application fields for structural and non-structural purposes, because of their significant effects on the mechanical properties of concrete (Madhavi et al, 2014). The basic importance of adding fibers into a concrete mix is to improve its tensile and flexural strength and decrease the deformation which causes cracking. This means, addition of fibers into the concrete mix decreases cracking of concrete by increasing its flexural strength. Enset ventricosum (EV) fiber is one of the type of natural fiber which is an agricultural waste obtained from enset plant. This natural fiber has the potential to improve the mechanical strength of the concrete. Additionally, it is also environmentally sustainable, easily accessible and cheap material. Therefore, it is very important to give due attention and study the potential of Ensete fiber addition in the improvement of mechanical strength of cow dung ash concrete.

Therefore, the study has been conducted on the effects of using cow dung ash as a partial replacement of cement and addition of enset fiber for C-25 concrete by investigating the chemical composition of cow dung ash, fresh properties of concrete, mechanical properties and microstructure of the concrete.

1.2 Statement of the problem

A wide range of creative designs can be made with cement concrete as it can be cast to any desired shape. It also possesses many desirable properties like high compressive strength and stiffness and low thermal and electrical conductivity. However, it has low tensile strength, limited ductility and little resistance to cracking have limited its use for various applications. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete. Consequently, natural fibers have been used in order to overcome the shortcoming of tensile strength of concrete (Khaliq & Ehsan, 2016). Also, the availability of materials is limited and in order to overcome this problem replacing of cement with pozzolanic binder and addition of coconut fiber found an improvement on the engineering properties of the concrete. (Venkatasubramanian et al., 2017).

In Ethiopia, the construction sector is growing rapidly, and concrete is mostly utilized in construction industry. As a result, the consumption of concrete is increasing, and cement is the most important ingredient in the concrete. while, production of cement consumes a lot of natural resources, and the factory's raw material processing stages release pollutants that worsen climate change, including carbon dioxide, dust, noise, and greenhouse gases. In addition to the CO_2, the Ethiopian Ministry of Trade reported that all cement manufacturers are raising production costs because the price of imported coal, which the factories rely on heavily, has risen, as have transportation costs (Abebaw et al., 2021), (Lemma & Saradhi, 2021). As a consequence, there is a shortage of cement in Ethiopia, and it is expensive. Producing one ton of Portland cement releases roughly one ton of CO2 to the atmosphere, and sometimes much more, and the cement industry accounts for 7-8 percent of the planet's human produced CO_2 emissions (Best & Lane, 1980).

For this reason, various researchers have undertaken several investigations on the applicability of various agricultural waste products as supplementary cementitious materials in the production of concrete. However, the use of CDA as a partial replacement of cement with addition of EF in concrete has not been studied yet. Therefore, this study investigates the effect of CDA and EF on concrete production.

1.3 Objectives

1.3.1 General objective

The general objective of the study is an experimental investigation on the mechanical property of concrete where cement is partially replaced by cow dung ash and also reinforced with enset fiber for C25 grade of concrete.

1.3.2 Specific objective

- To characterize the physical properties and chemical composition of cow dung ash.
- To determine the effect of CDA with addition of enset fiber on the workability and mechanical properties of concrete.
- To examine the morphological structure (SEM and XRD) of concrete made by partially replacing of cement by CDA and reinforced with EF
- To estimate the environmental and economic implications of using cow dung ash as a partial replacement of cement.

1.4. Research questions

- What are the physical properties and chemical composition of CDA?
- Can CDA concrete with addition of enset fiber to cement mix proportion have effect on workability and mechanical properties of concrete?
- How does morphological structure of concrete change that made with cement replaced by CDA and reinforced with enset fiber?
- What are the environmental and economic implication of using cow dung ash as a partial replacement of cement in concrete production?

1.5. Significance of the study

The overall aim of this study is to investigate the influence of cow dung ash and enset fiber on the mechanical properties of concrete and to improve its weakness. Experimental test will be performed to investigate the behavior of enset fiber reinforced concrete with partial replacement of cement with cow dung ash. The study may benefit the public, the construction industry, farmers, and other stakeholders that are directly and indirectly involved by the sector. The discovery is significant in that it provides alternative replacement materials for the manufacture of concrete that meet the properties of the concrete while consuming less cement. This helps to reduce the volume of cement produced by factories, which indirectly reduces the CO2 emissions and incurred energy produced during the manufacturing of Portland cement. Partially replacing cement with renewable materials like CDA can save a substantial quantity of virgin material, cost, and improve the properties of concrete.

1.6. Scope of the study

This research addressed the chemical composition of CDA, physical properties of fine aggregate, coarse aggregate, CDA and Enset fiber. After that an optimization test of enset fiber reinforced concrete were determined. It also studied combined effect of CDA and enset fiber on the mechanical properties like, (compressive strength, split tensile strength, flexural strength and workability). In this study, the microstructural performance was evaluated by X-ray diffraction (XRD) and scanning electron microscopy (SEM) analysis for C-25 grade of concrete. Finally, the study considered the environmental and economic implications of CDA concrete.

1.6 Limitation of the study

Due to a lack of data, it is impossible to calculate the actual energy consumption intensity and carbon dioxide emissions during CDA production and optimisation models cannot be employed because of time constraints.

1.8. Organization of the Study

The current study was organized mainly into five chapters. The first chapter is an introductory section that covers the study's background, statement of the problem, objectives, scope, significance, and limitations. The second chapter provides a concise review of concrete, cement, aggregate, sand, cattle waste products used as supplementary cementitious materials, which is Cow dung ash as a pozzolanic material and enset fiber. The third chapter discusses experimental methodologies used to conduct various experiments. The fourth chapter relied on the presentation, analysis, and interpretation of results. This chapter covered all the findings of the experimental investigation, like gradation curve, silt content, workability status, compressive strength, flexural strength and split tensile strength including concrete characterization to determine the morphology were analyzed. Based on the result, finally, the fifth chapter was concerned with the conclusion and recommendations.

CHAPTER TWO

2. REVIEW OF RELATED LITERATURE

2.1 General Overview

During the past years, concrete and cement technology have attained a lot of achievements. One of the achievements is the incorporation of industrial wastes as filler or additive in cement and concrete production with technical, economic and environmental advantages (Robalo et al., 2021). The economic usage of mineral admixtures by the cement and concrete industries has increased since the turn of the twentieth century. The rising demand for cement and concrete is met by partially substituting cement. Using by-products to partially replace cement can result in substantial cost reductions. The use of by-products reduces pollution and has proven to be an environmentally friendly way to dispose of tons of waste that would otherwise pollute the land, air, and water (Varshney, 2016).

Ecological concern has resulted in a profound interest in renewable materials. Lignocellulose natural fibers such as hemp, sisal, banana, jute and flax are interesting, environmentally friendly, alternative synthetic polymeric fibers for application in engineering composites (Nahiyan Al-Azad et al., 2021). The natural fibers are biodegradable, recyclable, nonabrasive, environmentally friendly, and contribute to a reduction of waste and environmental pollution (V. Manikandan, P. Amuthakkannan, 2015). They also exhibit excellent mechanical properties, low density, and they are available in fibrous forms at low cost (Teli & Terega, 2017b). This excellent price-performance ratio at low density in connection with the environmentally friendly character is very important for the acceptance of natural fibers in large volume engineering applications such as the automotive and construction industry (Aaliya et al., 2021).

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a rock-like structure formed by the chemical reaction of cement and water. This rock-like material is a brittle material with very high compressive strength but very low tensile strength (Mazizah et al., 2016). Concrete is very strong against compression, but weak against tension. Propagation of micro cracks present in stressed concrete reduces the tensile strength of concrete (Huda et al., 2017)

2.2 Theoretical Review

2.2.1 General concepts about Concrete and its Ingredients

Concrete is One of the most frequently used building materials. The Portland cement and water paste hardens as a result of the chemical reaction between the cement and the water, binding the aggregates (often sand and gravel or crushed stone) into a mass that resembles rock (Markos Makebo, 2019). It is the most commonly used construction material and is mainly composed of cement, fine aggregates, coarse aggregates, and water.

2.2.1.1 Aggregates

Aggregates are essential components in concrete because they give it body and decrease shrinkage. Aggregates are now acknowledged as chemically active elements that demonstrate chemical interaction at the aggregate-paste contact, unlike in the past when they were regarded as inert materials. Because aggregates comprise the majority of concrete, they must be properly examined in order for the research on concrete to be comprehensive. Aggregates account for about 60 to 75 percent of the total size of concrete, or 70 to 85 percent by mass, implying that selecting the proper one is crucial. Aggregate particles should be resistant to exposure and free of any components that might damage the concrete. For the effective use of the slurry, a consistent grading of the granular size of particles is required (Steven H ,et al., 2002).

2.2.1.2 Water

Due to its role in cement's chemical reaction, water is an essential component of concrete. Water quality is important since it aids in the development of the cement paste, which provides strength. Water must be potable in order to be used in concrete mixing, but this does not appear to be the case in all circumstances (Silva & Naik, 2010).

2.2.1.3 Cement

Cement is a binding substance that, when combined with water, forms a paste that is temporarily plastic and can be molded or deformed. However, it eventually sets and hardens into a rigid mass. Calcareous cement, which contains lime, is the name for this type of cement. Non-hydraulic calcareous cement and hydraulic calcareous cement are the two kinds. Non-hydraulic cement is cement that cannot set and harden in water (for example, non-hydraulic lime) or is not stable in water (e.g., gypsum plasters). Hydraulic cement is the type of cement that can set and harden in water, resulting in a solid mass that does not disintegrate (e.g., Portland cement) (Nel, 2003).

Types of cement

There are diverse types of cement based on chemical composition, method of manufacture (grinding, burning, etc.), and the varying compounds' proportional ratios. Among the different types of cement, the most commonly used one is Portland cement, which in turn is divided into many types. These are ordinary Portland cement and Portland pozzolana cement, which contain some percentage of pozzolanic materials (Asfaw et al., 2022) .

A) Ordinary Portland cement

Ordinary Portland Cement (OPC) is by far the most important member of the hydraulic cement family, which is composed of cement that hardens through chemical interaction with water. According to (Tennis & Standards, 2018), Joseph Aspdin obtained the first patent for "Portland" cement in England in 1824, though it was most likely not a true Portland cement; the first true Portland cement was produced about 20 years later. Since then, remarkable improvements in the production of cement have tended to result in sophisticated, yet widely available cement. The ingredients used to make modern Portland cement must include the right amounts of lime (CaO), silica ($SiO2$), alumina ($Al2O3$), iron ($Fe203$), and only trace amounts of magnesia and sulphur trioxide. Because they make up over 90% of Portland cement, these four principal compounds govern the hydraulic characteristics of cement.(Goshu, 2019).

B) Portland pozzolana cement

It is made by combining OPC clinker with 15 to 35% pozzolanic materials. Siliceous or aluminous materials with little to no cementitious characteristics on their own are called pozzolanic materials. However, in the presence of water, they combine with the calcium hydroxide that is released during the hydration of cement to generate a substance having cementitious properties. There are several benefits to PPC over OPC as a result of the pozzolanic materials' reaction with calcium hydroxide (Abebe dinku, 2012).If these pozzolanic elements hadn't reacted with the calcium hydroxide, there would have been free calcium hydroxide in the concrete, increasing its permeability and making it more vulnerable to subsequent attacks. By generating cementitious compounds, the pozzolanic reaction lowers the concrete's porosity. It is appropriate for mass concrete buildings because it minimizes the hydration heat and has a slower rate of strength than OPC due to its slower reactivity.

2.2.2 Supplementary cementitious materials

Supplementary Cementitious Materials (SCMs) are widely used mineral admixtures as partial replacements for Portland cement. The proper use of SCMs has an improvement in the reduction of the heat of hydration, economy, and workability. The Pozzolanic reaction produces less heat than Ordinary Portland cement as the reaction is very similar to a C_2S reaction (Mackechnie & Alexander, 2009). SCMs are materials that contribute to the properties of concrete through hydraulic activity, pozzolanic activity, or both when combined with Portland cement (Liu et al., 2019).

Hydraulic activity occurs when phases in the SCM chemically react with water, forming cementitious hydration products similar to those formed through hydration of Portland cement. This is in contrast to pozzolanic activity, which is characterized by the reaction between, siliceous or alumina silicates material in the SCM with calcium hydroxide (a reaction product from the hydration of Portland cement), forming calcium silicate hydrate and other cementitious compounds (Cabrera & Plowman, 1980). The performance of SCMs in mortar and concrete is strongly dependent on their physical and chemical characteristics, which vary depending on the nature and source of the SCM. Some of the factors affecting the replacement potential of SCM are fineness, the ratio of SCM over Portland cement and burning temperature (Bouchikhi et al., 2022) (Cordeiro et al., 2008). Pozzolanic materials are grouped into two categories as natural pozzolans and artificial pozzolans (by-product materials) (Mindess et al., 2003).

Natural pozzolan is a raw or calcined natural material (such as volcanic ash), which has a little or no cementitious value by itself but in finely divided form and in the presence of moisture, has a chemical reaction with calcium hydroxide to form compounds which have hydraulic and cementitious properties. Pozzolan contains high amounts of silica and alumina and small amounts of iron oxide, magnesium oxide, and calcium oxide. There are different usages of natural pozzolan like producing portland-pozzolan cement, usage as admixtures in concrete and direct usage by combining lime, natural pozzolan, and water together (Olubajo et al., 2014).

Artificial pozzolans are generally industrial by-product materials. Some examples are fly ash,silica fume, ground granulated blast furnace slag and rice husk ash. They are finely divided particles, so they reduce the size and volume of the voids and improve the workability of the fresh concrete mixture. Blast furnace slag and fly ash have very fine particles and they have glassy textures that allow a reduction of water for required consistency. Not to mention the improvement in durability that can be obtained when these by-products are used properly in concrete mixtures (Wesche, 1991)

The physical and chemical requirements of pozzolanic materials are outlined in ASTM C618. The most common by-product material is fly ash, which is classified as either Class F or Class C due to differences in chemical composition. The majority of Class F fly ashes have pozzolanic properties. Class C fly ashes frequently have cementitious and pozzolanic characteristics. Based on the sums of SiO2, Al2O3, and Fe2O3, ASTM C618 divides fly ashes into Classes C and F. SiO2 + Al2O3 + Fe2O3 must be at least 50% in Class C fly ash. SiO2 + Al2O3 + Fe2O3 must be at least 70% for Class F fly ash. Class C fly ashes operate differently than a low-calcium Class F fly ash because they contain 15 to 25% more calcium (Olagunju & Olanrewaju, n.d.)

Table 2. 1 Chemical requirements of supplementary cementitious materials (ASTM C618)

Chemicals	Pozzolana class		
	Class N	Class F	Class C
SiO_2+Al_2O_3+Fe_2O_3 (min %)	70	70	50
SO_3 (max %)	4	5	5
MgO (max %)	5	-	5
Moisture content (max %)	3	3	3
Loss of ignition (max %)	10	12	10
Available alkalis as Na_2O (max %)	-	1.5	1.5
Amount of weight retained when wet sieved on 45 micro meter (max %)	34	34	34
Strength activity index(min%)for 7th and 28th days	75	75	75
Soundness when measured by autoclave	0.8	0.8	0.8

2.2.3 Cement Hydration

Hydration is the term used to describe the chemical and physical processes that occur between cement and water. Cement hydration is critical because it is responsible for the setting and hardening of concrete. The chemical reaction converts the cement from a powder to a cohesive matrix with high strength that binds the aggregate particles together. The reaction between Portland cement and water is an exothermic chemical reaction which needs higher amount of heat energy (Bullard et al., 2011). Tricalcium silicate (C3S) ,Dicalcium silicate (C2S),Tricalcium aluminate (C3A), Tetracalcium aluminoferrite (C4AF) and Gypsum(C$\underline{S}$H2) are major compounds of cement. Both C3S and C2S react with water to form an amorphous calcium silicate hydrate known as C–S–H gel, which serves as the primary 'glue' that binds sand and coarse aggregate particles together in concrete. When water and Portland cement are combined, the constituent compounds of the cement and water undergo a chemical reaction that causes the concrete to harden. Each substance found in cement reacts with water at a different rate. The most reactive compounds are C3S and C3A, whereas C2S reacts more slowly (Goshu, 2019). The C3S is hydrated to produce calcium silicate hydrates, lime, and heat, while the C2S also hydrates to form calcium silicate hydrates and heat. Hydration of both are shown in equation 2.1 and equation 2.2

2C3S + 6H = C3S2H3+ 3CH…………………………………..Equation 2.1

C2S + 4H = C3S2H3 + CH…………………………………...Equation 2.2

Calcium silicate hydrate (C-S-H) gel generated by hydration of C3S and C2S in equation (1) and (2) is the main strengthening concrete. Calcium hydroxide which is the final product of hydration reaction form the frame of the gel-like product which provides crystalline structure of the concrete. The tricalcium aluminate –hydrate react with water to produce C-A-H and this product react with gypsum to form ettringite which is essential for stability of the concrete.(Sarath, et al.2011).

2.3 Cow dung ash as cementitious material

2.3.1 Cow Dung Ash

Cow dung is used to make cow dung ash, which is produced when cow dung is burned after being dried by sunlight. It is hefty and contains a lot of ash, which is made up of calcium, potassium, phosphorus, and a compound that is rich in nitrogen. (Ramachandran, George, et al., 2015).

Cow dung is essentially the waste products of herbivorous materials that are processed by symbiotic bacteria living in the rumen of the animal. The majority of the animals in Ethiopia are cows or cattle. Cow dung is made up of organic waste, including fibre material that was digested by the cow and liquid digest that was left over after fermentation, absorption, and filtration before being acidified and then reabsorbed. Exact chemical composition consists primarily of carbon, nitrogen, hydrogen, oxygen, phosphorus, and other elements, along with salts, cells that were shed as the digester passed through the digestive tract, some urea, mucus, cellulose, lignin, and hemicellulose. (Ojedokun et al., 2014). Cow dung was frequently utilised in concrete, leading one to believe that there were special advantages to its addition. Dung may increase workability and durability, or it may serve as an extra binder, according to recent publications. It is also unknown if fresh, used, or aged dung was employed. It is probable that this is a recent concept brought about by contemporary views towards smell and hygiene since there is no historical reference to the waste being old or worn. In any case, the main difference between dried and fresh dung is how much water they contain. This means that they are likely to only have an impact on the water that is added during the concrete's mixing process, if any. According to (Venkatasubramanian et al., 2017) Cow dung ash has been obtained from villages are dried under sunlight, burnt at a temperature of 450 to 500 °C and cooled. The summation of chemical composition cattle dung ash $SiO_2 + Al_2O_3 + Fe_2O_3$ was 73.39%, which was greater than 70% specified as class F in ASTM C-618.

2.3.2 Physical and Chemical Properties of Cow Dung Ash

Cow dung ash has chemical characteristics that are high in nitrogen, potassium, and calcium. It has a rather high carbon to nitrogen ratio (Ojedokun, 2014). According to (Thakur et al., 2019) CDA is a good binding material reducing voids in concrete and the physical properties such as it is bulky, it has large ash content, It has low volatile content after burning, Carbon content is low and the burning ratio is less. The dung is exposed to sunlight to dry to have dung makes which are then subjected to burning after it is dried to have the dung ash which is obtained in black color.

Table 2. 2 Physical Properties of Cow Dung Ash

Parameter	Physical properties of CDA by different researchers						
	(Samson & Tope, 2014)	(Ramachandran, George, et al., 2015)	(Omoniyi et al., 2014a)	(Deshpande et al., 2018)	(Ramachandran, Vishwakarma, et al., 2015)	(Venkatasubramanian et al., 2017)	(Adewuyi & Ramahobo, n.d.)
Specific gravity	2.55	1.865	2.55	2.59	2.39	2.55	2.48
Colour	-----	Grey	-------	grey	-------	Dark grey	Dark grey
Particle size	212 mic	------	-----		425mic	300mic	---

2.3.3 Chemical properties of dung ash

Several investigations into the use of ash from cow dung as a pozzolanic component in concrete manufacturing have been conducted internationally. The researchers discovered that more than 70% of the oxides in cow dung ash were (SiO_2 + Al_2O_3 + Fe_2O_3), followed by a substantial proportion of CaO, SO_3, and LOI. According to (Samson et al., 2014) the constituents of CDA are similar to those of Ordinary Portland cement but with varying quantities of the compound. PC contained more of the main oxides of CaO, Al_2O_3, and Fe_2O_3 than CDA, and the increasing of CDA in the blend with cement, there will be a reduction in tricalcium silicate (C3S), tricalcium aluminates (C3A), and Tetracalcium Aluminoferrite (C4AF). The chemical composition of CDA is summarized table 2.3 below based on different researchers.

Table 2. 3 Chemical composition of CDA

Chemical composition	(Fredrick et al., 2018)	(Nyagah, 2022)	(Venkatasubramanian et al., 2017)	(Tefera, 2018)	(Ramachandran, George, et al., 2015)
SiO_2	9.75	69.65	65.77	59.44	----
Al_2O_3	4.74	4.27	4.46	8.45	1.45
CaO	13.25	4.56	12.99	8.60	7.30
Fe_2O_3	3.17	5.05	3.16	4.90	---
MgO	2.11	12.55	2.02	2.74	3.05
SO_3	0.89	2.99	0.94	---	---
K_2O	2.70	2.94	---	9.18	1.62
Na_2O	0.61	0.57	0.511	0.64	---
P_2O_5	1.37	1.48	1.38	0.50	1.49
Mn_2O_3	0.62	0.63	0.59	---	---
TiO_2	0.38	0.33	0.368	0.83	---

2.3.4 Effects of cow dung ash on consistency

The paste consistency was determined using Vi-cat equipment. The following percentages of OPC substitution in cement pastes were used: 0% (reference mix), 5%, 10%, 15%, and 20%. The water content of each paste was varied until a standard consistency was achieved. The normal control paste had a consistency of 26%. The mixed cement paste had a more uniform consistency than the control paste. According to (Tefera, 2018), The consistency rises from 7.69 percent to 53.85 percent as the CDA content rises from 5% to 20%. The amount of water needed to attain a regular consistency was found to increase as the CDA content increased (Samson & Moses, 2014).The consistency value increased as more cement was substituted with CDA in percentage terms. This could be due to the particle size of the ash, which requires more water for better lubrication consequently increase the surface area available for contact with water thereby increasing the water demand of the OPC/CDA blended Paste.

2.3.5 Effects of cow dung ash on setting time

Setting time was measured in accordance with BS EN-196-3. (2005). Setting time increased as the percentage replacement for CDA increased with cement. This means that the addition of CDA causes a retardation of the setting times of the blended cement. This trend may be attributed to the ability of CDA to delay the hydration of cement and consequently prolong the setting times (Samson & Moses, 2014). This could be owing to the high amount of potassium oxide (9.18 percent) found in CDA, which reduces the heat of hydration (Onikeku et al., 2019). A research done by (Tefera, 2018), also comes to the conclusion that as the CDA replacement level rises, so does the cement paste's setting time; this is because of the impact of the CDA's fineness and reduced cement content. The findings indicate that OPC mixed with CDA had a longer start and final setting times than OPC alone. Initial and final setting times rise along with replacement.

2.3.6 Effects of cow dung ash on workability of concrete

One of the characteristics of new concrete is its workability. The most fundamental and often used workability test on construction sites is the slump test. Scholars have investigated how cow dung ash affects the concrete's workability. According to (Tefera, 2018) as the replacement percentage of CDA increases, the slump value decreases. As a result, the most likely reason was due to the fineness and their large specific surface area. However, up to 5% replacement level, the slump remains in the estimated range of 25mm to 50mm and above 10% replacement the workability became harsh.

2.3.7 Effects of cow dung ash on compressive strength

One of the mechanical characteristics of hardened concrete is its compressive strength. It is influenced by a number of factors, including the water-cement ratio, compaction, cement quantity, and curing temperature. The addition of pozzolanic components to cured concrete also affects its strength. Researchers are looking at how CDA affects the compressive strength of concrete. Reference (Rayaprolu & Raju, 2012) studied the effect of cow dung ash in cement paste and concrete. Their results reveal a decrease in compressive strength with increasing ash content of 10%, 20% and 30% CDA replacement. Another study also investigated the possibility of using CDA as partial cement replacement material in the production of concrete (Ojedokun, 2014). Their findings showed that cement replacement with CDA beyond 10% adversely affected its compressive strength. All the aforementioned study did not cure concrete specimens beyond 28days which is essential for assessing the pozzolanic potentials of CDA. According to (Tefera, 2018) as concrete's compressive strength was examined after 28 days cow dung ash (CDA) used as a partial replacement for cement up to 10%, both the control mix and the replaced concrete up to 10% met the desired mean strength of 33.5 MPa, but the mix designations for CDA15% and CDA20% did not.

2.4 Chemical characterization of Cow Dung Ash replaced concrete

According (Zerihun et al., 2022), X-ray diffraction (XRD) and scanning electron microscopy(SEM) are the standard and most often used methods for examining the mineralogical and morphological behaviour of pozzolanic materials.

2.4.1 SEM of cow dung ash replaced concrete

According to (Ramachandran & Vishwakarma, 2015), the information on the shape, texture, and chemical makeup of the hydrated phases was obtained by the use of FESEM and EDX methods. The FESEM analysis of OPC and CDA powder explains the change in the morphology, size and chemical composition in both OPC and CDA particles. OPC analysis image shows presence of bigger size particles and some voids between the grains, whereas CDA is closely filled and packed by small grains. The Figure 2.1 below shows the FESEM micrographs which reveal the better structures in all the mix ratio of concrete modified with CDA (5.0, 7.5, 10.0, 12.5 and 15.0 %) compared to NC. 28 days of curing. This finding supports the notion that adding pozzolanic material to concrete improves its microstructural qualities, improving other attributes like compressive strength and durability. The weight percentage of OPC and CDA was analysed by EDAX which showed different elements. It was found that basic nature of CDA had more silica content than OPC.

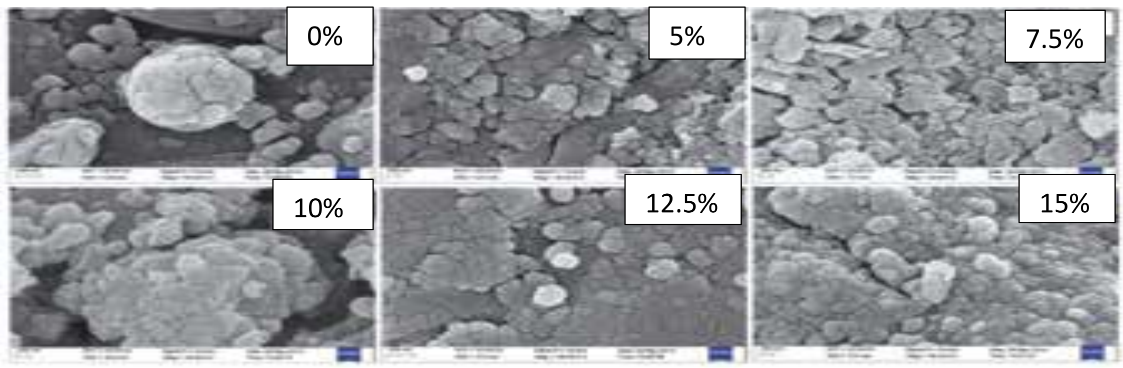

Figure 2. 1:FESEM pictures of CDA blended cement paste (Ramachandran & Vishwakarma, 2015)

2.5 Fiber reinforced concrete

Fiber reinforced concrete (FRC) is concrete made primarily of hydraulic cements, aggregates, and discrete reinforcing fibers. Fibers suitable for reinforcing concrete have been produced from steel, glass, and organic polymers (synthetic fibers). Naturally occurring asbestos fibers and vegetable fibers, such as sisal and jute, are also used for reinforcement. The concrete matrices may be mortars, normally proportioned mixes, or mixes specifically formulated for a particular application (Madhavi et al, 2014).

Based on the terminology adopted by the American's Concrete Institute (ACI) committee 544, there are four categories of fiber reinforced concrete particularly Steel Fibers Reinforced Concrete (SFRC), Glass Fibers Reinforced concrete (GFRC), Synthetic Fibers Reinforced Concrete (SNFRC) and Natural Fibers Reinforced Concrete (NFRC).

2.5.1 Steel fibers

Steel fibers are short, discrete lengths of steel with an aspect ratio (ratio of length to diameter) from about 20 to 100, and with any of several cross sections. Some steel fibers have hooked ends to improve resistance to pull out from a cement-based matrix. Steel-fiber volumes used in concrete typically range from 0.25% to 2%. Volumes of more than 2% generally reduce workability and fiber dispersion and require special mix design or concrete placement techniques. Steel fibers have a relatively high modulus of elasticity. Their bond to the cement matrix can be enhanced by mechanical anchorage or surface roughness and they are protected from corrosion by the alkaline environment in the cement matrix (Kosmatka et al., 2002) .

2.5.2 Synthetic fibers

Synthetic fibers are man-made fibers resulting from research and development in the petrochemical and textile industries (Kosmatka et al., 2002). These fibers are derived from organic polymers which are available in a variety of formulations. Fiber types that have been tried in Portland cement concrete based matrices are: acrylic, aramid, carbon, nylon, polyester, polyethylene and polypropylene. Synthetic fibers can reduce plastic shrinkage and subsidence cracking and may help concrete after it is fractured. Problems associated with synthetic fibers include: low fiber-to-matrix bonding; inconclusive performance testing for low fiber-volume usage with polypropylene, polyethylene, polyester and nylon; a low modulus of elasticity for polypropylene and polyethylene; and the high cost of carbon and aramid fibers (Kosmatka et al., 2002).

2.5.3 Glass fibers

The first research on glass fibers was in the early 1960‟s used as conventional borosilicate glass (E-glass) and soda-lime-silica glass fibers (A-glass). Glass fibers have high modulus and high strength to develop strong bond with the concrete. The test results showed that alkali reactivity between the E-glass fibers and the cement-paste reduced the strength of the concrete. Glass fibers that are used in concrete must contain minimum of 16% of zirconia for alkali resistance. Fiber content in glass fiber reinforced concrete is about 4% to 6% by volume (Kosmatka et al., 2002)

2.5.4 Natural fibers

Natural fibers are fibers that are found in nature. Natural fibers can be classified as organic or inorganic fibers. Natural organic fibers are fibers that are obtains from either plant or animal sources. The majority of useful natural textile fibers are plant derived with the notable exceptions of wool and silk fibers. Natural-inorganic fibers are discontinuous short fibers widely used to reinforce concrete. Many natural reinforcing materials can be obtained at low levels of cost and energy using locally available manpower and technical know-how. They have long served many useful purposes but the application of materials technology for the utilization of natural fibers as the reinforcement in concrete has only taken place in comparatively recent years (Shah et al., 2022).

The distinctive properties of natural fiber reinforced concretes are improved compressive, tensile and bending strength, greater ductility, and greater resistance to cracking and hence improved impact strength and toughness. Natural fibers reinforced concrete highly fascinated designers by their several advantages such as low weight, low cost, high availability, easy productivity, their friendly to environment and high specific mechanical performance. Natural fibers confirm advanced mechanical properties like stiffness, flexibility and modulus composite to glass fibers. Their availability, renewability, low density, and price as well as acceptable mechanical properties make natural fibers more attractive ecological alternative to glass, carbon and manmade fibers (Machaka et al., 2014).

The natural fibers have been tried as reinforcement for concrete matrices typically to produce less costly skinny factors for use in housing schemes. For their production, vegetable fibers need only a low industrialization diploma and in an equal weight assessment of the most common synthetic reinforcing fibers, the energy needed for their manufacture is small and the cost of manufacturing these composites is therefore also low. These plant fibers, herein referred as natural fibers, include coir, sisal, jute,enset fiber and others. Natural fibers also abound in large quantities in developing countries, for example in Nigeria; there are research works where the performance of natural fibers in concrete have been investigated exploiting the advantage of the economical and abundant availability of materials such as Kenaf fiber akwara, palm nut fiber and bamboo strips (Akubueze et al., 2014).

According to (Namango, 2006),fiber are generally classified as natural and synthetic (manmade). Natural fibers can be further split up in to vegetable, animal or mineral fibers. Further categorization of fibers is illustrated in Figure 2.2 provides a comprehensive discussion on the type and uses of fibers;

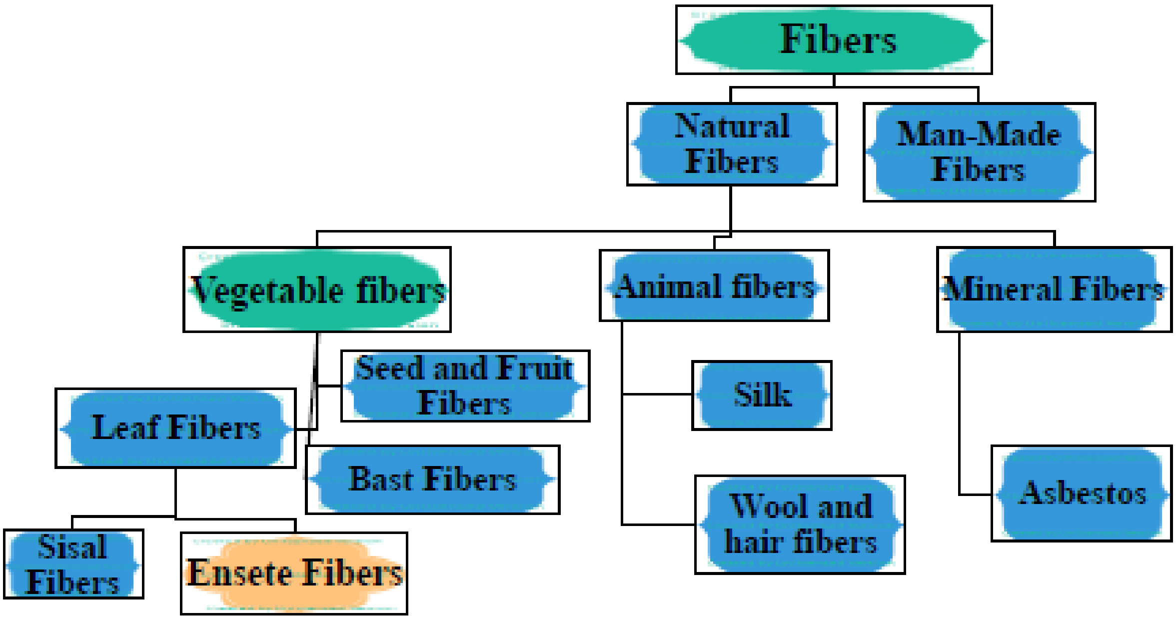

Figure 2. 2 Fiber Family (Namango, 2006)

2.5.4.1 Enset plant

Ensete (Ensete ventricosum Welw. Cheesman) is a major food crop which is indigenous to Ethiopia. Enset ventricosum is a monocarp perennial crop, located under the same genus Enset and have close similarity with the domesticated banana. It has the capacity to face up to drought condition and use as a substantial food item for many hundreds of thousands of people in Ethiopia. Records show that Enset has been cultivated for over 10,000 years in Ethiopia. It is renewable and eco-friendly, as it consumes nitrogen which may want to be a part of huge effort to prevent air pollution. This plant grows and reaches its maximum strength in simply few years. A fiber of enset is a natural organic fiber which serves to make stronger concrete materials and improves tensile energy of a concrete. Under tensile loading, concrete is fundamentally brittle. Enset (Enset ventricosum) is a multipurpose crop that offers a variety of products such as food, forage, medicine, rituals, soil protection and construction. The different uses are attributed to the existence of different Enset varieties (Tsehaye & Kebebew, 2006).

Enset is distributed in the wild throughout much of central, eastern and southern Africa. Ensete has several uses including food and non-food applications, and is highly integrated in the economic, social and cultural life of Ensete-growing societies. It is a major staple or co-staple crop for over 15 million people (20% of the Ethiopian population). Ensete plant is main source of food in the southern region of Ethiopia especially the" Guarage" people. One of the well-known foods is "kocho", a solid staple a bit like heavy bread, which is eaten with milk, cheese, cabbage, meat and/or coffee. This plant is also a major source fiber; the people call the fiber as "kancha". The fiber obtained from this plant has whitish in color, in average 1 m to 1.50 m long and it is a strong fiber. They use it to make rope and a mat (Yemane Tsehaye and Fassil Kebebew, 2006).

2.5.4.2 Extraction of Ensete vegetable

The fibre was extracted from the pseudostem (stalk) part of EV plant by using hand decortication (scrapping) method. Naturally, the stalk was built with several layers of sheathes which were tightly overlapped. After dismantling, every sheath was slitted in to 2-4 stripes of width 10-15cm each. The pulpy tissues were scraped out, traditionally, by using a sharp-edged blade (of bamboo) against bed plate (of flat wood) along the fibre length. The fibres were then sun dried in the open air (Teli & Terega, 2017) . The fiber, the leaf and inner part of pseudo stem are the main solid residues which are not utilized for Ensete. The main reason for extraction process is searching food. The fiber obtained from this plant has white color, in average 1 m -2.5 m long and good strength. (Sirany et al., 2022). The physical and chemical properties of enset fiber are illustrated in the table below.

2.6 Physical and chemical properties of enset fiber

2.6.1 Physical properties of enset fiber

According to (Bekele et al., 2022) physical and mechanical properties of enset fiber have been determined with the diameter, density, elongation, moisture content, tensile strength and tensile module as shown in the table below.

Table 2. 4 physical and chemical properties of enset fiber

Physical and mechanical properties	Diameter (μ m)	Moisture (%)	Density (g/cm3)	Tensile strength (Mpa)	Tensile module (GPa)	Elongation (%)
Un treated enset fiber	334.97 ± 0.11	13.91 ± 0.16	1.52 ± 0.09	15.81 ± 0.16	2296.95 ± 0.17	2.11 ± 0.29

2.6.2 Chemical properties of enset fiber

The cellulose, lignin, hemicellulose and wax are the most common fiber chemical compositions that affect the physical, chemical and mechanical properties of the fibers. Un treated Enset fiber have wax (5.13 ± 0.09), cellulose (80.88 ± 0.09), hemicellulose (10.90 ± 0.09), lignin (10.43 ± 0.05) and ash content of (2.67 ± 0.1). A higher cellulose content ensures good mechanical properties, while high levels of hemicellulose decreases the fiber strength by causing disintegration of cellulosic micro fibrils.(Bekele et al., 2022). The main chemical constituents of enset fiber are cellulose, hemi-cellulose and lignin. Enset fiber has 64.46 % cellulose, 22.47% Hemi cellulose and considerably about 6.88% of lignin. The enset fiber is often high tensile strength compared with other natural fibers, this is because Strong intermolecular forces (like hydrogen bonding within polyamides) lead to close packing of chains and increase the crystalline character, hence, provide high tensile strength .(Teli & Terega, 2017). The following summary of table shows different studies using cow dung ash as a supplementary material with different natural fiber.

Table 2. 5 Literature Review Summary of Works Related to cement replacement with cow dung ash and cow dung ash with different natural fiber

Year	Title	Author	% of dung ash Replacement	Experimental Test conducted	Findings
2014	Compressive strength Characteristic of Cow dung ash blended cement Concrete	(Omoniyi et al.,)	5% - 30% 5% interval	✓ slump test ✓compressive strength	✓ The workability and compressive strength concrete decreased as the cow dung ash. content increases ✓ CDA increases, the initial and final. setting times increased by 12.2%-59.3% and 2.74%-43.90% respectively ✓ A replacement of no more than 15%.
2015	Studies of Strength, Durability and Microstructural Properties of Cow Dung Ash Modified Concrete	(Ramachandran et al.,)	5.0, 7.5, 10.0, 12.5 and 15.0% CDA by weight	✓ X-Ray diffraction (XRD) ✓ compressive strength ✓ tensile strength ✓ Rapid chloride Penetration Test (RCPT) ✓ FSEM analysis for morphological structure determination	✓ CDA replaced concrete show lower and equivalent compressive strength at early and 28d curing periods ✓ CDA has increased in tensile strength for a 15% CDA replacement. ✓ CDA modified concretes are low in permeability. ✓ XRD analysis showed concrete modified with CDA contains more $SiO2$ compound and CaO (lime) than normal concrete ✓ The FESEM analysis confirmed smaller particle size in 15% replaced concrete which may fill the air voids. ✓ TG/DTA examined that after 650oC heat; concrete

					modified with 15% CDA was thermally stable compared to NC.
2014	Cow Dung Ash (CDA) as Partial Replacement of Cementing Material in the Production of Concrete	(Ojedokun et al.,)	10%, 20% and 30%by weight	✓ slump test ✓Compressive Strengths ✓Bulk density	✓ Cow Dung Ash concrete is recommended for use only when a ten percentage (10%) of Cow Dung Ash is added ✓ CDA requires more quantity of water ✓ CDA concrete is not to be used in a water accumulated area or for structures that are related to water and high structural strength
2015	Utilization of fly ash and cow dung ash as partial replacement of cement in concrete	(Roy, 2019)	10%, 20%, 30%of cow dung and 10%, 20%, 30% of Fly ash	✓ compressive strength ✓ slump test	✓ compressive strength at 21 and 28 days has no significant differences in compressive strengths of cubes prepared by cement and 10% of fly ash plus 10% cow dung ash. ✓ fly ash and cow dung ash being waste materials can be utilized for the concrete preparation. ✓ will also protect the environment by controlling the emission of CO2 from the cement industry as well as providing a technique for the safe disposal of solid wastes
2017	An Experimental Investigation on Strength of Concrete Made with Cow Dung Ash and Glass Fibre	(Sruthy B et al., 2017)	6%, 8%, 10%, 12% and 14% replacement of CDA and addition of 0.5% glass fiber	✓Workability test ✓compressive strength	✓Maximum strength is attained at 8% CDA and 0.5% of glass fibre, after that strength starts decreasing thus the optimum content is 8%. ✓The workability of concrete had been found to be decrease with increase of cow dung ash and glass fibre

2017	Experimental studies on the effect of cow dung ash (pozzolanic binder) and coconut fiber on the strength properties of concrete	(Venkatasubramanian et al.,)	2.5, 3 & 3.5 % by weight and with 1% of coconut fiber	✓Compressive strength ✓ Tensile strength test	✓compressive and tensile strength of the concrete with CDA and coconut fiber were improved. ✓Replacing of CDA reduction of environmental impact caused by land filling or dumping of these materials and cost of concrete. ✓ reducing the environmental risk, maintaining the ecological balance
2018	Permeability properties of concrete produced with ordinary portland cement (OPC) blended with cow dung ash (CDA	(Fredrick et al.,)	0, 10, 20 and 30% replace OPC content	✓slump test compressive strength ✓ flexural strength ✓ water permeability ✓ Septicity test (absorption and adsorption considered as a single process)	✓Lower early strength development is observed as a result of the presence of pozzolanic CDA as filler in the concrete that reduce the early strength of concrete. ✓ Flexural strength decrease as CDA percentage content was increased. CDA ✓ CDA increases the which could affect the durability of the concrete negatively. ✓ The optimum replacement was 10%, CDA is a very good pozzolana that can attain up to 93.64% design strength at 28 days concrete when used at 10% partial replacement cement.
2021	Investigate the effects of NaOH treated teff straw as fiber and cow dung ash on	(Tesfaye et al., 2021)	✓ with 10% replacement of CDA and 0.5%, 1% , and 1.5% treated teff straw fiber	✓water absorption ✓Compressive strength ✓Tensile strength ✓Flexural strength	✓ workability decreases as % of fiber increases ✓The mechanical properties of plain concrete show higher improvement than the treated teff straw fiber reinforced concrete containing 10% of cow

	mechanical and water absorption properties of concrete			✓workability	dung ash. ✓water absorption also increases with increasing of the fiber
2022	Durability assessment of Cow dung ash modified concrete exposed in fresh water	(Mathur & Chhipa, 2022)	✓ Replace CDA at 2% interval till 10%	✓Compressive strength ✓Tensile strength ✓Flexural strength ✓Abrasion ✓Durability	✓The increment in the compressive strength, Flexural strength and tensile strength are achieved at the optimum value of CDA replacement that is 6% ✓The CDA concretes pH value compared to conventional concrete has less pH reduction in all the days of curing. Volume of voids, ✓Permeability and water absorption for CDA modified are lower when compared to the control specimen.

2.6 Summary of Research Gaps

There have been many researchers who studied on the potential use of cow dung ash in concrete. also they conducted different researches on different types of natural fibers such as, enset fibers, sisal fiber, coconut fiber and so on, in the concrete mix. But, the studies on dual use of cow dung ash as a partial replacement of cement and enset fibers as fiber reinforcement is not studied yet. Hence, using CDA as a partial replacement of cement to minimize the consumption of non-renewable materials and environmental pollution is crucial. To use CDA as a partial cement replacement in concrete production, an initial investigation of the CDA properties and its effect on the properties of fresh and hardened concrete should be needed. Due to this, the current study focused on the combined effect of cow dung ash as partial replacement of cement and enset fibers as fiber reinforcement for C-25 grade of concrete.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Introduction

This chapter deals with the descriptions of all materials used, the experimental test carried out to determine materials physical and chemical properties, various experimental investigations and microstructure of concrete were conducted. The materials used in this specific study include cement, sand, coarse aggregate, cow dung ash and enset fiber. An experiment was planned and conducted to investigate the effect of addition of enset fiber with Cow Dung Ash as cement replacement on fresh properties of concrete like workability, mechanical properties like compressive strength, split tensile strength, flexural strength, and microstructural analysis of hardened concrete. In-depth discussions are also had on the experimental design, mix proportioning, sample preparation methods, experimental process and analysis method used in this study.

3.2 Experimental design

Materials research methods refer to the logical and consistent schemes by which experimental studies are carried out. The current study uses both qualitative and quantitative research methods to interpret and discuss the findings. This research was conducted and divided into several activities. Assessing different journals, previous studies, books, and related papers to achieve the specified objectives. Studying the properties of materials such as cement, sand, coarse aggregate, enset fiber and cow dung ash in the laboratory using different standards was takes place. Then after, optimization test was conducted in order to find the optimum amount of enset fiber that could give good strength. After getting the optimum amount of enset fiber and the chemical composition of cow dung ash from Ethiopian Geological survey the main research to study the combined effect of cow dung ash and enset fiber in the concrete was started. Finally, the combined effects of partial replacement of cement by cow dung ash and addition of enset fiber were studied for the 7 and 28 days curing time. The tests were conducted to examine the physical and mechanical properties of concrete such as, compressive strength, tensile strength, flexural strength and microstructure (SEM and XRD). Lastly, conclusion and recommendation was drawn.

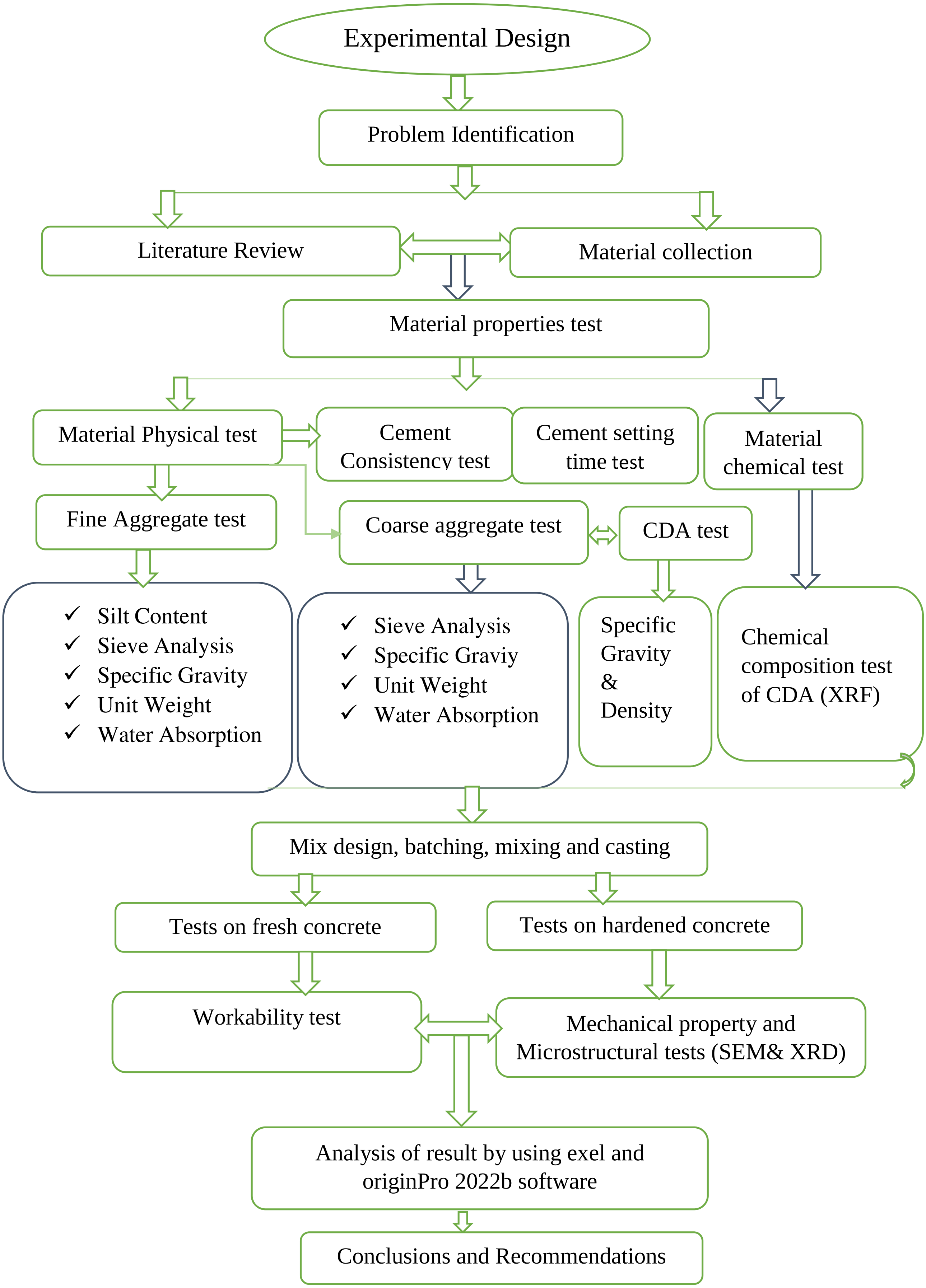

Figure 3. 1: Flow chart of research design

3.3 Materials

3.3.1 Cement

The cement used in this investigation was Ordinary Portland Cement (OPC) of grade 42.5 N CEM I, manufactured by National Cement of Ethiopia. It complied with ES 1177 and ISO 9001:2015 standards.

Figure 3. 2 : National OPC

3.3.2 Coarse aggregate

According to ASTM C-125 standard, coarse aggregates are mainly retained on 4.75mm sieve size. For this study, basaltic crushed rock coarse aggregate was used, and it was purchased from a nearby material provider. The coarse aggregates that used for this investigation have an aggregate size in between 4.75 mm 20 mm accordance with ASTM C 33. The physical properties of coarse aggregate were summarized in tables 3.1 shown below based on laboratory results and gradation test is given in table 3.1 and figure 3.3 and detail calculations are given in appendix.

A) Physical properties of Coarse aggregate

Table 3. 1 Physical properties of coarse aggregate with respective ASTM test standards

No	Description of tests	Test results	Standard limits	ASTM test standards	Remark
1	Unit weight	1680.5Kg/m^3	1245-1825kg/m^3	ASTM C29	✓
2	Moisture content	1.6%	0.5-2%	ASTM C566	✓
3	Water absorption	1.6%	0.2-2%	ASTM C127	✓
4	Fineness modulus	7.2	5.5-8.5	ES.C.D3.201	✓
5	Specific gravity (SSD)	2.85	2.4-3.0%	ASTM C127	✓
✓ Sign indicates the result is acceptable according to specified standards					

B) Gradation of coarse aggregate

The coarse aggregate was graded using sieve analysis in accordance with the ASTM C-136 standard. ASTM sieve sizes were 37.5mm, 19mm, 9.5mm, and 4.75mm were used. Table 3.2 and figure 3. 3 show the sieve analysis results and the gradation curve of crushed coarse aggregate, respectively.

Table 3. 2 Sieve analysis results and ASTM standard limit for coarse aggregate

Sieve size (mm)	Weight retained (gm.)	Percentage retained (%)	Cumulative retained (%)	Cumulative passing (%)	ASTM C-33 standard passing range (%)
37.5	269.99	2.7	2.7	97.3	95-100
19	4249.66	42.5	45.2	54.8	35-70
9.5	3202.74	32.03	77.23	22.77	10-30
4.75	1833.85	18.34	95.57	4.43	0-5
pan	442.96	4.43	100	0	0

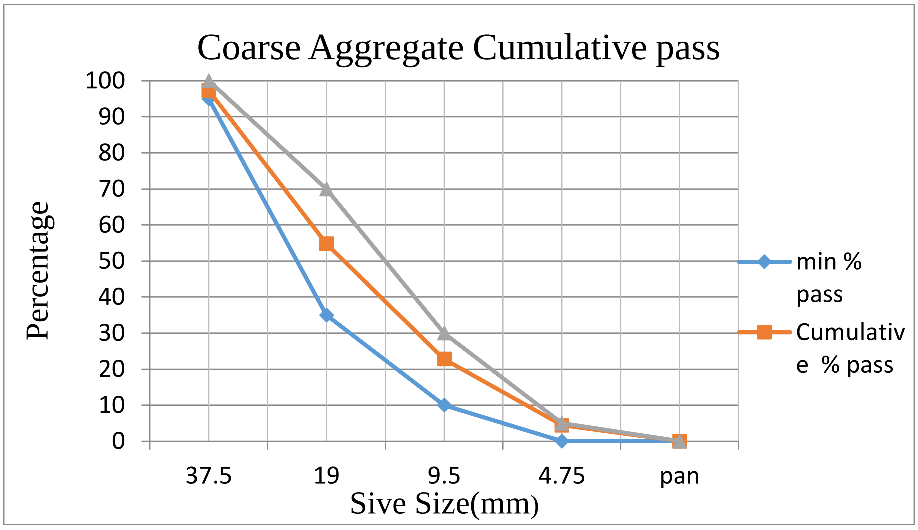

Figure 3. 3: Gradation curve for coarse aggregate

As shown in figure 3.3 above, the coarse aggregate particle size distribution and table 3.1 all physical properties of coarse aggregate are passed the requirement specified in the standards. This indicates that the coarse aggregate is an appropriate to use for concrete production.

3.3.3 Fine aggregate

A) Physical properties of fine aggregate

Natural sand is the fine aggregate used in the making of concrete in this study. Different tests, including fineness modules, specific gravity, absorption capacity, moisture content, silt content, and unit weight, were conducted to examine its qualities for the needed application. River sand that had been sieved through a 9.5 mm sieve and retained at 150 microns was utilized in this experiment. Silt, clay, and other organic contaminants should be absent from the sand. And detail calculations are given in appendix.

Table 3. 3 Physical properties of fine aggregate with respective ASTM test standards

No	Description of tests	Test results	Standard limits	Standard	Remark
1	Unit weight	1515.5Kg/m^3	1200-1750 kg/m^3	ASTM C29	✓
2	Moisture content	2.04 %	0-10%	ASTM C566	✓
3	Water absorption	2.04%	0.2%-4.0%	ASTM C128	✓
4	Silt content	4.08%	≤ 6%	ES.C.D3.201	✓
5	Fineness modulus	2.98	2.3-3.5	ES.C.D3.201	✓

6	Specific gravity(SSD)	2.6	2.4-3.0	ES.C.D3.201	✓
✓ Sign indicates the result is acceptable according to specified standards					

B) Gradation of fine aggregate

Sieve analysis is used to determine the fine aggregate gradation. A technique called sieve analysis uses a number of sieves to examine the distribution of particle sizes in aggregates. The sand was graded in accordance with the ASTM-C 136 standard, and table 3.4 and figure 3.5 show the sand's grain size distribution.

Table 3. 4 Sieve analysis results and ASTM standard limit for fine aggregate

Sieve size (mm)	Weight retained(gm)	Percentage retained (%)	Cumulative retained (%)	Cumulative passing (%)	ASTMC33 standard passing range (%)
9.5	0	0	0	100	100
4.75	50	5	5	95	95-100
2.36	110	11	16	84	80-100
1.18	190	19	35	65	50-85
0.6	270	27	62	38	25-60
0.3	250	25	87	13	5-30
0.15	90	9	96	4	0-10
pan	40	4	100	0	0
Total			298		
FM			2.98		

$$Fineness\ modules = \frac{\sum Cumulative\ fine\ retained\ \%}{100}$$

$$= \frac{298}{100} = 2.98$$

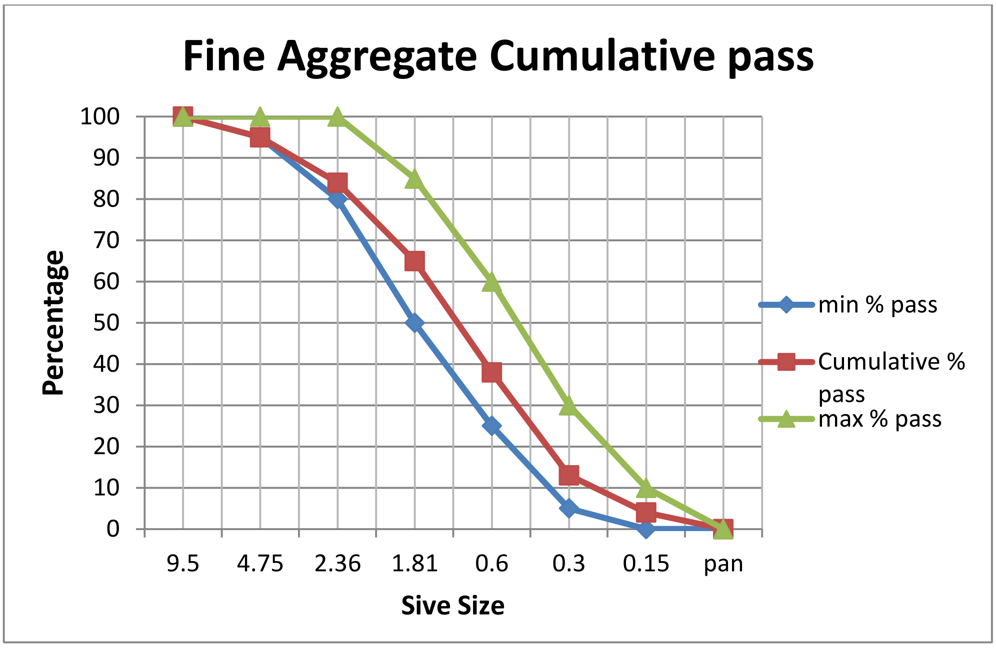

Figure 3. 4: Gradation curve for fine aggregate

As presented in figure 3.4 above, the fine aggregate particle size distribution and table 3.4 all physical properties of fine aggregate are passed the requirement specified in the standards. This indicates that the fine aggregate is an appropriate to use for concrete production.

3.3.4 Water

Water is an important component of concrete because it strongly plays part within the reaction with cement. The water should be free from impurities, alkalis, suspended solids, silt and dissolved solids which will degrade its quality. The water used for this study was H_2O from the construction material laboratory of Adama science and technology university.

3.3.5 Cow dung ash

Cow dung ash was collected from the Oromia region of Ethiopia in the Woliso zone, and it was exposed to the sun to eliminate surface moisture before it is burned. After eliminating surface moisture, it was calcined in furnace at a controlled temperature of 600^oC (Zaffar et al., 2022) to produce cow dung ash at Ethiopian Defence university, college of Engineering material laboratory. After cooling, the resultant ash was grinded into finer particles and was sieved using a 75µm ASTM sieve in order to remove larger size particles before it is used in the concrete mix. The chemical composition of the ash was determined using XRF in the Geology Survey Laboratory of Ethiopia in Addis Ababa, and physical properties such as consistency, specific gravity, and fineness were determined in the construction material laboratory of ASTU Civil Engineering Faculty. Figure 3.5 (a) shows Cow dung and (b) shows cow dung ash.

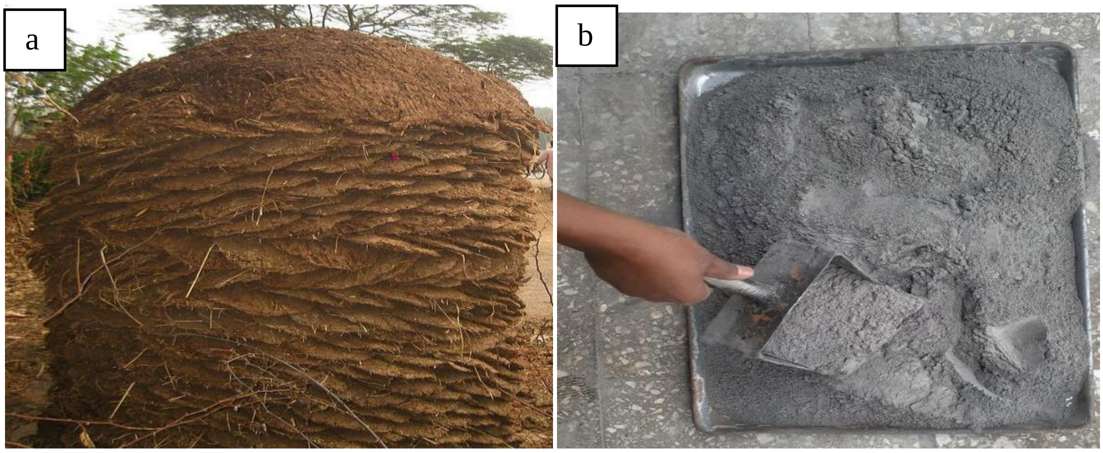

Figure 3. 5: (a) Cow dung and (b) Cow dung ash

3.3.6 Enset fiber

The Ensete (ventricosum) fiber used in this study was bought from a market found in woliso zone. The physical and mechanical properties of the fiber were studied including its aspect ratio which is important characteristics of the fiber. The tensile strength of enset fiber was 172.61MPa and It was used directly by cutting it using clippers with a constant length of 150 (Negash, 2021). The chopped fiber by weight of concrete were used with percentage range 0.5%, 1.0% and 1.5%. The figure below shows the important length and diameter of the fiber for determination of its aspect ratio. The length and diameter of the fiber was determined by using optical microscope.

Figure 3. 6 : (a) Enset ventricosum fiber and (b) copped enset fiber

3.4 Sample preparation and Determination of sample size

The sample size was determined by the number of test specimens required to conduct compressive strength, split tensile strength and flexural strength tests for concrete to meet the objectives of the study with CDA and enset fiber matrices. But primarily an optimization test for enset fiber reinforced concrete was conducted.

3.4.1 Sampling method of enset fiber reinforced concrete

optimization test with different percentage addition (0.5%, 1% and 1.5%) of enset fiber by the weight of concrete mix were used and the following concrete samples were casted for 7 and 28-day compressive strength test, splitting tensile strength test and flexural strength test.

Table 3. 5 Mixing of concrete to determine the optimum percentage value of enset fiber.

Types of test	**Sample size (mm)**	**% of enset fiber for 7 and 28 days of curing time**				**Total No. of specimens for 7 & 28 days**
		0%	0.5%	1%	1.5%	
Compressive	Cube (150*150*150)	6	6	6	6	24
Split tensile	Cylinder (300*150)	6	6	6	6	24
Flexural	Beam of 100*100*500	6	6	6	6	24

Table 3. 6 Mixing method and sampling of specimen for different types of concrete tests

Types of test	**Sample size (mm)**	**OPV of Enset fiber**	**% of CDA and curing time for 7 and 28 days**				**Total No. of specimens for 7 and 28 days**
			5%	10%	15%	20%	
Compressive	Cube of 150*150*150	0.5%	6	6	6	6	24
Split tensile	Cylinder of 300*150	0.5%	6	6	6	6	24
Flexural	Beam of 100*100*500	0.5%	6	6	6	6	24

3.5 Mix Design for C-25 Grade Concrete

Table 3. 7 Table Calculated Batch for 1 m^3 of Concrete

Water	184.19 kg/m^3
Cement	377.55 kg/m^3
Coarse aggregate	995.49 kg/m^3
Fine aggregate	849.425kg/m^3

Table 3. 8 Table Mix Ratio for C-25 Concrete Grade

Ingredients	Cement	Fine aggregate	Coarse aggregate
Amount / m^3	377.55/377.55	849.425/377.55	995.49 /377.55
Ratio	1	2.25	2.64

3.6 Batching and mixing

In this study batching by weight was used for this investigation since it is more simple and accurate than batching by volume. The percentage of replacement of CDA used were 5%, 10%,15% and 20% for each of them. This is due to the pozzolanic activity index for organic pozzolanic material above 15% is less than 75% (Dhinakaran & Chandana, 2016). Furthermore, 0 percent CDA was employed as a control mix. The mix plan of concrete with determined ratios of cement, Fine aggregate, water, coarse aggregate, CDA were proportioned for a C-25 concrete grade based on the ACI the 211.1mix design method. Table 3.10 below shows matrix formed by replacing cement with CDA.

Table 3. 9 Sample code and description

No	Sample code	Description
1	C-1	Control mix (without CDA and EF)
2	C-2	5% substitution of cement with CDA and 0.5% addition of EF
3	C-3	10% substitution of cement with CDA and 0.5% addition of EF
4	C-4	15% substitution of cement with CDA and 0.5% addition of EF

5	C-5	20% substitution of cement with CDA and 0.5% addition of EF

In mix design the specific gravity of CDA much less than that of cement and in all the blended mixes in this research by weight measurements were taken. However, the ratio of replacement is not 1:1 rather 1:0.456, i.e. 1kilo gram of cement is replaced by 0.456 kilo gram of cow dung ash. since the replacement is by volume occupy high space for the lower density of cow dung ash and to keep the paste volume constant ACI 2011.1-91 mix design method orders equivalency of weight and water to cement plus pozzolanic material by using the following formulas and detailed calculations.

$$\mathbf{Fw} = \frac{\mathbf{1}}{\mathbf{1}+(\frac{\mathbf{3.15}}{\mathbf{Gp}})(\frac{\mathbf{1}}{\mathbf{Fv}}-\mathbf{1})} \quad \text{………………………………………………………………… Equ (3.1)}$$

Where:-

Fw= pozzolanic materials percentage by weight expressed as a decimal factor

Fv = pozzolanic materials percentage by the absolute volume of the total absolute volume of cement plus pozzolanic materials expressed as a decimal factor.

Gp = specific gravity of pozzolanic materials

Specific gravity of cement = 3.15

For 5% CDA

$$Fw = \frac{1}{1+(\frac{3.15}{2.07})(\frac{1}{0.05}-1)} = 0.021 = 2.1\%$$

To determine the water to cement plus pozzolanic (W/c + p) of material by using the following formula

$$\frac{W}{C+P} = \frac{3.15(\frac{W}{C})}{(3.15(1-Fv)+GpFy)} \quad \text{……………………………………………… Equ (3.2)}$$

Where:

$\frac{W}{C+P}$ = weight of water divided by the weight of cement + pozzolanic materials

Fv = pozzolan percentage by the absolute volume of the total absolute volume of cement plus pozzolana, expressed as a decimal factor.

For 5 % replacement

$$= \frac{W}{C+P} = \frac{3.15(0.586)}{(3.15(1-0.05)+2.07*0.05)} = 0.596$$

The quantity of each ingredient for one cubic meter C-25 grade concrete is summarized in table below. Here 2% value of cement wastage was considered and the water absorption of inset fiber was considered for an adjustment of the quantity of water.

Table 3. 10 water absorbed by enset fiber for 1m^3 concrete

1 m^3 cocr't wght	% enset fiber	enset (kg)	wtr.abt'n	water (kg)
2414.206	0.005	12.07	3.13	37.78

Table 3. 11 Mix proportion for 1 m^3 concrete in kg/m^3

Mix matrix no	Cement	Cow dung ash	Enset fiber	Coarse aggregate	Fine aggregate	W/B	Water
1	385.101	0	0	995.49	849.425	0.495	184.19
2	365.846	8.087	12.07	995.49	849.425	0.586	219.12
3	346.591	16.944	12.07	995.49	849.425	0.596	216.67
4	327.336	26.957	12.07	995.49	849.425	0.607	215.06
5	308.081	38.125	12.07	995.49	849.425	0.618	213.96

3.6.1 Concrete Mixing

Concrete mixing is the process of combining concrete components like cement, fine aggregate, coarse aggregate, water, CDA and enset fiber to get effective and good quality concrete. In this study, a mixer was used to mix concrete ingredients together to obtain homogeneous, good-quality concrete.

Figure 3. 7:Concrete Mixing: Mixer (a), Fresh mixed concrete (b)

3.7 Tests on concrete

3.7.1 Tests on fresh concrete

This test's specific goal is to identify the property of fresh concrete mixtures. Slump test on fresh concrete were performed to investigate the effect of CDA and enset fiber on the workability of concrete. The ASTM C 143/C Standard Test Method for Slump of hydraulic Cement Concrete was used to conduct the test.

Figure 3. 8: Workability test a) conventional concrete b) Modified concrete

3.7.2 Casting of Concrete Specimens and Curing

3.7.2.1 Concrete Casting

The compressive strength, split tensile strength and flexural strength of concrete was investigated after casting a concrete with a 150 x 150 x 150 mm, 300 x 150 mm and 100 x 100 x 500 mm size respectively. The experimenter prepared concrete specimens by incorporating major concrete ingredients such as cement, fine aggregate, coarse aggregate, CDA and enset fiber. The researcher mixed, placed and compacted the concrete in different layers and demoulded the samples after 24 hours.

Figure 3. 9 Concrete Casting

3.7.2.2 Curing of Concrete Specimens

Curing of concrete is a process of providing sufficient moisture, temperature, and time so that the hydration of cement continues till the concrete achieves its desired properties for the intended use based on ASTM C192. After removed the mould of the concrete specimens, the researcher cured the concrete at room temperature for 7, and 28 days in a water curing medium (Figure 3.10). At 7 days of curing, concrete attains 65% of its target mean strength and it attains 99% of its target mean strength at a curing age of 28 days.

Figure 3. 10: Concrete Curing

3.7.3 Hardened concrete tests

3.7.3.1 Compressive strength test

The compressive strength test is the most significant experiment that provides insight into all the properties of concrete. The compressive strength test is performed on either cube or cylinder specimens. A concrete cube or cylinder is advised as the standard specimen for the test by various standard codes. A total of 48 sample specimen were used for 7 and 28 days' compressive strength test. For the cube test, two types of specimens are used, depending on the size of the aggregate and strength concrete: cubes of 150 mm*150 mm*150 mm or 100 mm*100 mm*100 mm used. In this specific study cubes of 150 mm*150 mm*150 mm size were preferred due to the availability of mould in laboratory. After casing, demoulding and curing the specimens were tested with a compression testing machine after 7th and 28th days curing.

Figure 3. 11: Compressive strength test

3.7.3.2 Split tensile strength test

Cylindrical concrete specimens like drilled cores and moulded cylinders are tested for split tensile strength according to the ASTM C496 specification. Splitting tensile strength typically exceeds direct tensile strength while falling short of flexural strength. The ASTM C496 method involves applying a diametric compressive force down a cylindrical concrete specimen's length at a rate that stays within a specified range until failure occurs. This loading causes tensile stresses in the plane holding the applied load, rather than strong compressive stresses in the area immediately surrounding it. A total of 3 cylinders with150mm diameter & 300 mm height was prepared for each test. For each percentage replacement, 3 samples are selected for each testing day (7th and 28th). A total of 48 samples were prepared for splitting tensile strength.

Figure 3. 12: Split tensile strength test

3.7.3.3 Flexural strength test

The flexural test measures the force required to bend a beam under two-point loading conditions. The data is often used to select materials for parts that will support loads without flexing. Flexural modulus is used as an indication of a material's stiffness when flexed. ASTM C78/C78M-21 is a standard that was developed by the American Society for Testing and Materials (Using a basic beam with two-point loading, this test method determines the flexural strength of concrete**.** According to ASTM C78 use 500mm x100mm x 100mm was prepared. For concrete with partial substitution of CDA with EF in the percentage of 0%, 5%, 10%,15% and 20% is conducted which means 8 sample kinds tested at7 and 28 days of curing. A total of 48 samples were prepared flexural Strength.

Figure 3. 13: Flexural strength test

3.8 micro structural test of concrete

Scanning Electron Microscope (SEM) and X-Ray Diffraction (XRD) tests were used to determine the microstructure of the CDA concrete. The shape and size of CDA particles were determined using SEM, while the amorphous and crystalline structures of CDA particles were examined using XRD.

3.8.1 X-ray diffraction (XRD)

In order to determine the mineralogical makeup of the partially restored concrete, X-ray diffraction (XRD) was performed. Similar to this, the sample was made into concrete powder and put through a sieve with a size of 75micron to prepare it for X-ray diffraction.

General procedures for this test include, after testing compressive the concrete sample were broken and changed in to powder form and sieve in 75 microns and it was immersing in some solvent like ethanol or isopropanol in order to stop the hydration reaction.

3.8.2 Scanning Electron Microscopy (SEM)

scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. Scanning Electron Microscopy analysis showed, the morphology (size and shape) including voids and crack of the control as well as concrete replacement made of enset fiber and cow dung ash concrete were determined. The concrete broken samples that was utilized as the basis for the Scanning Electron Microscopy (SEM) test.

3.9 Data analysis

The data for this specific research was obtained from conducting various laboratory tests. The research design being employed was an experimental research design. This section clearly outlines the research procedures employed and the type of test conducted to accomplish research objectives. The laboratory test result and experimental data were analysed through the mathematical quantitative and quantitative statistical methods and presented in the tables and graphs by using excel and Origin pro 2022b software.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents discussions on the results and analysis of chemical and physical properties of CDA and enset fiber. It also presents physical properties of paste at different replacement. Finally, mechanical property of concrete and microstructural characterization of partial replaced concrete by (SEM and XRD test) are presented. The samples were compared with both the control mixes and the standard to drive conclusions.

4.2 Physical and chemical properties of cow dung ash and enset fiber

4.2.1 Physical properties of cow dung ash

As revealed in the table 4. 1 CDA has lower specific gravity (2.07) than that of cement (3.15) after CDA was calcined at 600^{o}c for 2hours in furnace.

Table 4. 1 Physical properties of CDA

Properties	Test results
Specific gravity	2.07
Density	1120kg/m^3
Fineness in 45µm retained	33.5%
Fineness in75 μm passed	90.13%
Colour	Grey

Compared to OPC, CDA has a lesser specific gravity. CDA's specific gravity is 34.29% lower than that of regular Portland cement, and CDA has a lower density (1120 kg/m^3) than regular Portland cement (1400 kg/m^3). The finding is revealed to the other researcher's findings on the specific gravity of CDA, which is less than the specific gravity of cement (Ramachandran, Vishwakarma, et al., 2015),(Deshpande et al., 2018).

4.2.2 Chemical Composition of Cow dung

Table 4. 2: Chemical composition of CDA

Oxide Percentage	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	MnO	TiO_2	LOI	H_2O
CDA	68.60	8.62	3.86	6.64	2.52	2.14	<0.01	3.33	0.08	0.31	1.61	0.79

Referring to table 4.2 the sum of three oxides as Silicon dioxide (SiO_2), aluminium oxide (Al_2O_3), and iron oxide (Fe_2O_3) for CDA is 81.08% which is greater than the 70% set by ASTM C 618 for pozzolanic material to be used as partial cement replacing materials and It has a loss of ignition (LOI) of 1.61 which was less than the maximum limit specified in the standard (6%), from this CDA is classified into class F pozzolanic material which has better pozzolanic properties to be used in the production of concrete.

4.3 Physical Properties of the cow dung ash blended cement

4.3.1 Consistency of cow dung ash Mixed with Cement Paste

The normal consistency of CDA mixed cement paste was carried out according to ASTM C187. The purpose of this property is to understand how much water the pastes require. A specific minimum amount of water must be added to the cement to ensure a complete chemical reaction between the cement and water. Less water than this amount would cause a chemical reaction to be incomplete, which would decrease strength. Additionally, adding more water would raise the cement's water-to-cement ratio, lowering its strength. To achieve optimum strength while employing adhesive in construction, the proper water-to-cement ratio is necessary. A typical consistency test of blended cement pastes was conducted to determine the appropriate amount of water. The cement paste's resistance to being penetrated by a 500-gram plunger or needle discharged at the paste's surface is a measure of the paste's consistency The Ethiopian standard states that when the penetration depth reaches a specific value, the requisite water content results in a consistency that is between 26 and 33 percent by mass of dry cement (Dinku, 2002.).

Table 4. 3: Normal consistency of cement paste containing CDA.

Sample code	**Consistency test**	
	Consistency (%)	Water increment (%)
CDA 0	28	0
CDA 5	29	3.57
CDA 10	32	14.28
CDA 15	36	28.57
CDA 20	40	42.85

As stated in the table above, the normal consistency of the paste without CDA was 28% and all other pastes containing CDA showed the normal consistency higher than the cement paste. As replacement increases, the normal consistency also increases. This trend may be due to the finer particles of CDA which are finer than those of cement and consequently increase the surface area available for contact with water thereby increasing the water demand of the OPC/CDA blended Paste (Omoniyi et al., 2014a)

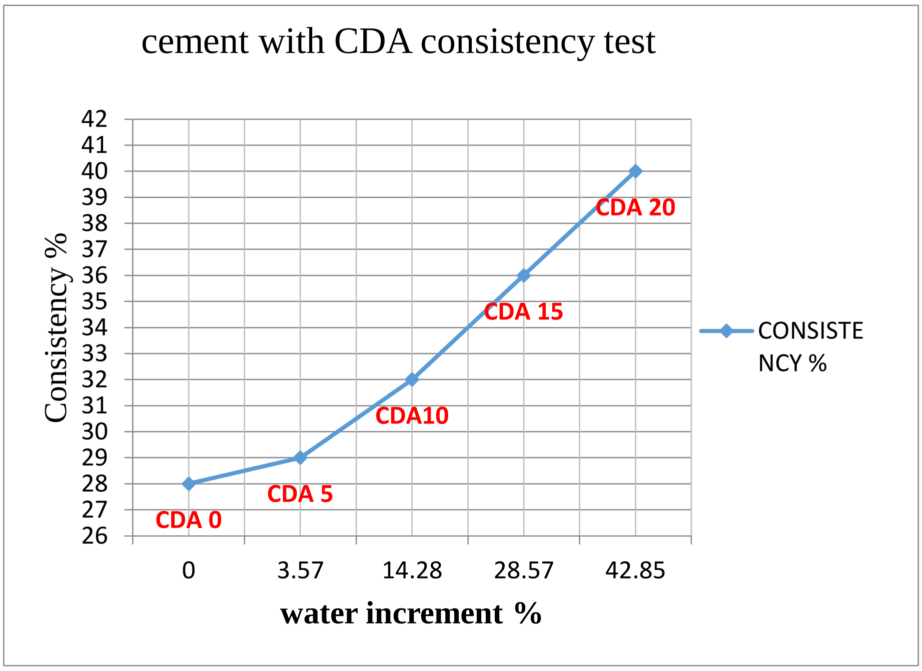

Figure 4. 1 Normal consistency of blended pastes with CDA

4.3.2 Setting time of cow dung ash Mixed Cement Paste

Setting time is the amount of time required for concrete or mortar to go from a liquid state to a plastic state and then from a plastic state to a solid state, resulting in a surface hard enough to withstand a certain amount of pressure. Initial setting time of a cement is the time to the cement can be moulded in to any desired shape without losing its strength. The final setting time of the cement is the time taken to reach the stage when the cement paste becomes hard mass and can take minor load. The amount of water used to make cement paste has an impact on setting time since the hydration of cement is a product of the reaction between cement and water. The water concentration has an impact on the blended cement pastes as well. The setting time of CDA Mixed Cement Paste was carried out in accordance with ASTM C 191. The result is summarized in figure 4.2.

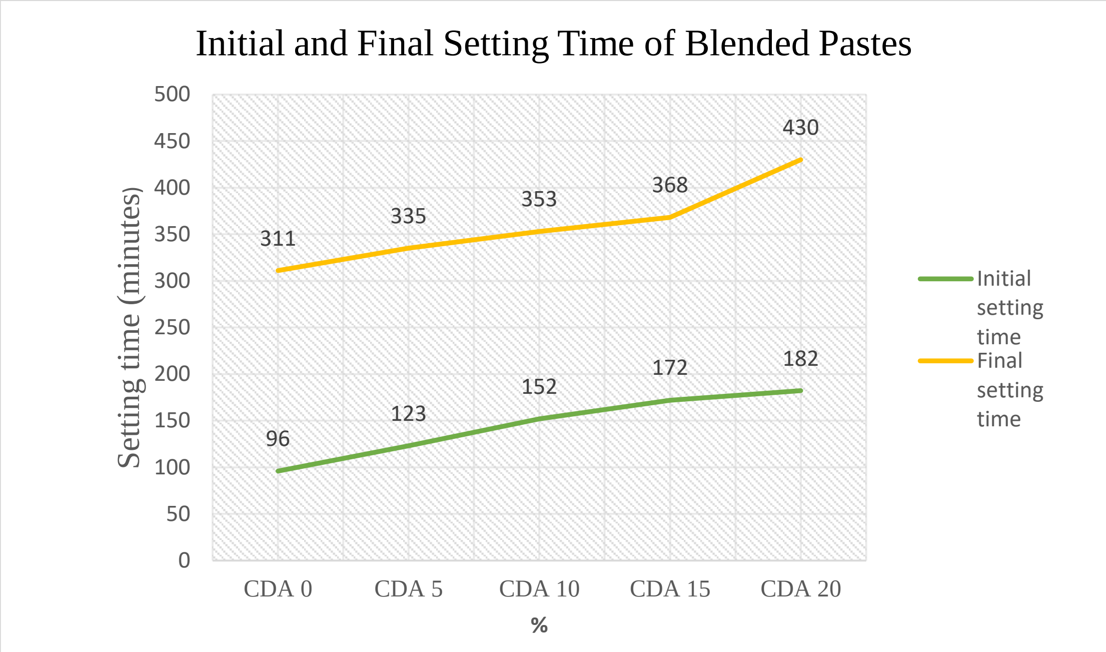

Figure 4. 2 Initial and final setting time of cement blended with CDA

Figure 4.2 indicated that the addition of CDA retarded both the initial and final settings of the paste. The initial setting time of blended paste was retarded from the control paste by 28.12%, 58.33%, and 79.17% and 89.58% at 5%, 10%,15% and 20% replacement respectively. While the final setting was retarded by 7.72%, 13.50%, 18.33% and 38.26% respectively. According to Ethiopian standards, cement paste's early and final setting times should be no less than 45 minutes, and should not be more than 10 hours, respectively (Dinku, 2002).The reason for retardation could be a high demand of water by surface area of CDA and late hydration of pozzolanic materials. In addition, reduction of calcium hydroxides and the development of silica gel film around cement grains may have caused the retardation of setting time (Ajay et al., 2009). As a result, in hot climates where delayed hydration is essential, CDA as a partial replacement for cement is advised.

4.4 Physical properties of ensete fiber

4.4.1 Aspect ratio of Enset fiber

The aspect ratio of the fiber (the ratio of length to diameter) is one of the important characteristics and it plays a key role in effectively improving the mechanical properties of concrete. The typical aspect ratio ranges from 30 to 150 when the aspect ratio is high, the relative strength and toughness will decrease. The lower fiber aspect ratio can produce higher compressive strength.

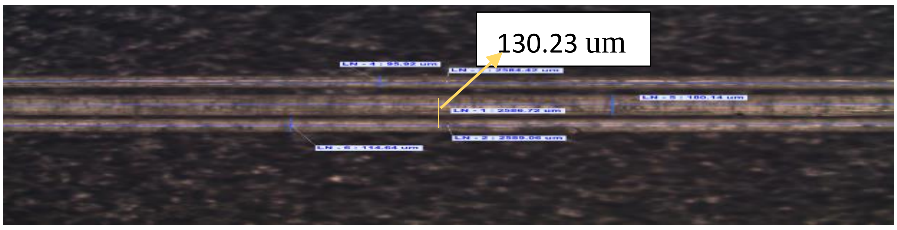

Figure 4. 3 length and diameter of enset fiber

Table 4. 4…Aspect ratio of Enset fiber

Length (um)	Diameter (um)	Aspect ratio (L/D)
15000	130.23	115.18

4.4.2 Water Absorption Test for Ensete Fiber

Water absorption test is used to determine the amount of water uptake by Ensete fiber for concrete product and the test was conducted following ASTM D 2216 standard. The mass of samples was taken in to the oven for 3 hours in order to know the moisture content of the fiber. A 25 g of Ensete fiber weight measurement was taken and immersed the sample in a water bath for 24 hours. (Laddha et al., 2010). water absorption was determined using the formula shown in the table below.

Table 4. 5 Water absorption test result of natural Ensete fiber

Sample no	Weight before immersed (W1) g	Weight after immersed (W2) g	Water absorption (%)
1	25	95	= (95-25)/25 =280
2	25	100	= (100-25)/25 =300
3	25	115	= (115-25)/25 =360
Mean			**313%**

4.5 Effect of addition of Enset fiber on the concrete properties

According to the research objectives and methodology; this research paper has done workability and mechanical properties for both Enset fiber and Enset fiber with cow dang ash (CDA) to examine their effects on the concrete performance. The first discussion made in this part is to determine the optimum percentage value of Enset fiber that is used with different percentage value of CDA. After that, the second discussions are done to examine the combined effects of Enset fiber with partial replacement of cement with CDA on the concrete workability and mechanical properties i.e. compressive strength, flexural strength and split tensile strength.

This test is done only to determine the optimum percentage value of enset fiber that will be used with different percentage value of CDA to study their combined effects on the concrete workability and mechanical properties.

4.5.1 Effect of enset fiber on the concrete workability

Slump test is used to check the workability of fresh concrete. The intention of this test was to check whether the fresh concrete that has 0.5%, 1% and 1.5% EF is working enough for easiness of compaction and placing before the concrete starts to harden. In this test when addition of EF on the fresh concrete increases it decreased the workability of the concrete by increasing the interlocking bond of fresh concrete. Therefore, as the percentage value of EF increases the slumps of the concrete decreases; as shown in the table 4.6 below.

Table 4. 6: Slump of fresh concrete

No.	EF %	Slump height (mm)
1	0%	45
2	0.5%	29
3	1%	14
4	1.5%	0

4.5.2 Effect of enset fiber on the concrete compressive strength

The aim of compressive strength test is to check whether the intended compressive strength capacity of hardened concrete has achieved or not. If the result shows the intended compressive strength after 28 days of curing time is achieved, we will proceed other works: if not we will do another mixing design to achieve the intended value. In this paper the compressive strengths were examined for C-25 grade of concrete reinforced with different percentage value of EF, such as 0%, 0.5%, 1% and 1.5%.

The compressive strength of concrete was determined by dividing the compressive force to the contact area of cube specimen. This test was done for 7 and 28 days of curing time and their result is tabulated in Table 4.7 below.

Table 4. 7:Mean compressive strength of C-25 grade concrete

EF%	Average compressive strength value (MPa)	
	7^{th} day	28^{th} day
0%	27.79	37.16
0.5%	26.01	35.44
1%	23.61	32.18
1.5%	20.37	30.53

As shown in the table above, when the percentage value of EF increased, the compressive strength of EF reinforced concrete is decreased for both 7 and 28 days when it is compared with the controlled value. But, when we compared the compressive strength of 0.5% EF concrete with the target value, 33.5 MPa, it showed that a 5.79 % increment. Moreover, similar findings have been reported in (Yalew, 2019).

4.5.3 Effect of enset fiber on the concrete flexural strength

Flexural strength of concrete is used to check the concrete load resisting capacity, which will be induced on it, without going excess deformation or producing excess cracks. Plain concrete, which has no steel reinforcement, has a very low capacity of flexural stress to resist the applied load without going excess deformation or producing excess cracks. Therefore, in order to resist the induced load on the concrete safely, reinforcement bar will be used inside the concrete and these materials works homogeneously to resist the applied load and they are called reinforced concrete (RC). But in order to increase or upgrade the plain concrete flexural stress capacity different researchers are now trying to study different materials that will be used with concrete: natural enset fiber is one of that.

Hence, by adding EF in the concrete, with different percentage value, this research paper investigates its effect on the concrete flexural stress capacity. The percentage values of EF used in this research were 0%, 0.5%, 1% and 1.5% by total weight of concrete and examined their effects for 7 and 28 days of curing time by testing a beam of 100mmx100mmx500mm.

Table 4. 8 Mean flexural strength of C-25 grade concrete

EF%	Average flexural strength value (MPa)	
	7^{th} day	28^{th} day
0%	3.95	4.16
0.5%	3.98	4.79
1%	4.1	4.4
1.5%	3.76	3.87

The above table shows that, addition of enset fiber in the plain concrete increases the flexural strength for 7 and 28 days up to 1% and decreases for 1.5% EF. But the maximum value of flexural stress increment is observed at 0.5% for both 7 and 28 days when compared with the controlled concrete and the percentage value of increment is 0.76% and 15.14% for 7 and 28 days of test respectively. On top of that these percentage increment values of concrete, shows that when the curing time of EF reinforced concrete increases, the flexural stress of concrete also increases. These results was supported by study conducted by (Yalew, 2019) reported that natural fiber reinforced concrete has a much better flexural strength than unreinforced one. In the other study addition of sisal fiber is found to enhance the flexural strength (Joseph et al., 1999).

4.5.4 Effect of enset fiber on the concrete split tensile strength

Split tensile strength of concrete is indirect method of checking concrete tensile capacity. It is well-known that concrete is weak in tension as compared to its compressive strength capacity. Mostly the tensile capacity of concrete is, between, 8% to 12% of its compressive strength capacity. Hence, in order to enhance this weakness of concrete various materials has been added in the concrete as fiber and studied their effects, this paper used EF.

To study the effects of EF on the concrete tensile strength, different percentage values were added in the concrete, such as 0.5%, 1% and 1.5% by total weight of concrete and their test results were compared with the control concrete that has 0% of EF. Three sample specimens of 150mm diameter by 300mm length cylinder were used for each curing and testing days, such as 7 and 28 days. The mean split tensile strength values of C-25 grade of concrete were quantified in Table 4.9 below.

Table 4. 9 Mean tensile strength of C-25 grade concrete

EF%	Average tensile strength value (MPa)	
	7th day	28th day
0%	1.94	3.02
0.5%	2.04	3.35
1%	2.11	3.5
1.5%	1.81	3.01

As shown in the table above, tensile strength of EF reinforced concrete is increased up to 1% and decreased for 1.5% for 7 and 28 days of curing time compared with the control concrete that has 0% of EF in it. But addition of 1% EF on the concrete mix showed a good result than 0.5% and its increment was by 8.76% and 15.89% compared with the controlled concrete for 7 and 28 days respectively.

4.5.5 Conclusion on the optimum percentage value of EF

The comparison to choose the optimum percentage value of EF that will be used with CDA is done between 0.5% and 1%. Addition of 0.5% EF on the concrete increased the compressive and flexural strength of concrete beyond this value, even if it increased the flexural strength and tensile strength for 1%, it decreased the compressive strength below the target value. Hence, the aim of doing this research is to increases the concrete weaknesses, flexural and tensile strength, without compromising the compressive strength of concrete, which concrete is good at it, this research paper recommended 0.5% EF as an optimum percentage value to use it with different percentage value of CDA for further study.

4.6 Effect of addition of Enset fiber with partial replacement of cement by CDA on the concrete properties

4.6.1 Tests on Fresh Concrete (Workability Test)

Workability is one of the most significant characteristics of fresh concrete. Because of its low cost and rapid findings, the slump experiment is the most straightforward workability test for concrete. Slump experiments were performed on all sorts of mixes to measure the workability of freshly mixed concrete. The slump test is performed under ASTM C143 guidelines. According to ASTM 143, the slump value is measured in inches (millimetres).

Table 4. 10 Slump values of different mixes

Sample code	Cement %age	CDA (%)	EF(%)	W/(C+P)	Observed slump(mm)	Slump Limit(mm)
C-1	100	0	0	0.495	45	25-50
C-2	95	5	0.5	0.586	28	25-50
C-3	90	10	0.5	0.596	25	25-50
C-4	85	15	0.5	0.607	13	25-50
C-5	80	20	0.5	0.618	5	25-50

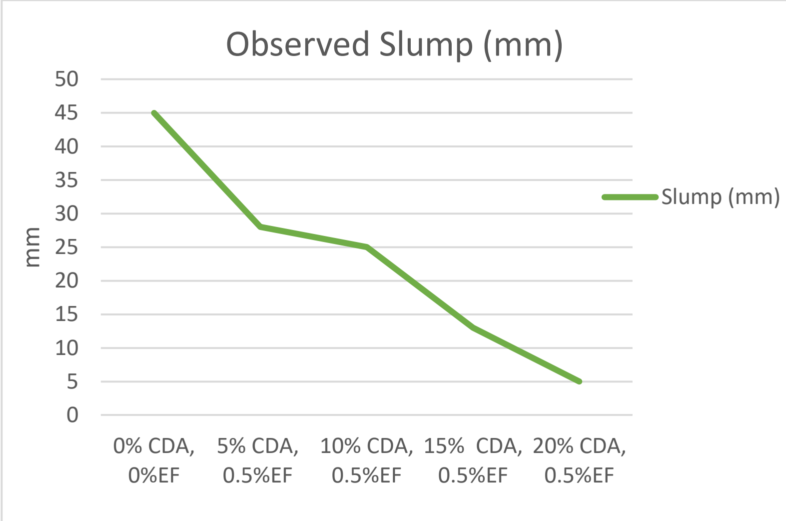

Figure 4. 4: Slump values of different mixes

From table 4.10 and figure 4.5, the observed slump value decreased as replacement increased, even if they had different water-to-cement ratios. This indicates that as replacement increases, workability is decreased. This is due to the absorptive character of cellular CDA and Enset fiber particles (Omoniyi et al., 2014)

4.6.2 Results on Hardened Concrete

In this section, the interpretation of the results on mechanical properties and chemical characterization of hardened concrete are discussed below.

4.6.2.1 Compressive strength

The compressive strength test of concrete is the primary test carried out on the hardened properties of concrete. It is the most crucial test of hardened concrete. The test was conducted for all samples at ages 7 and 28 days. Three samples were used for the tests for each cement replacement with CDA.

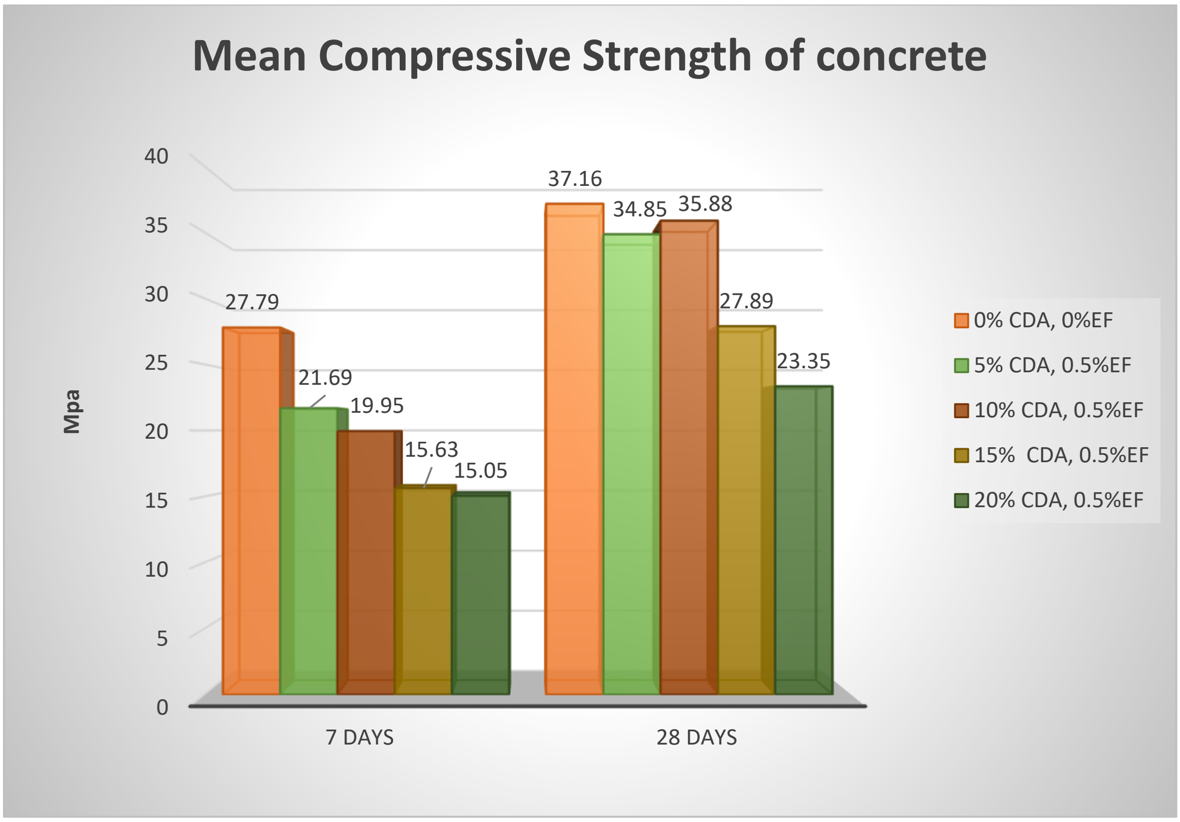

Figure 4. 5: Compressive strength of concrete

From figure 4. 5, it is detected that the compressive strength of the modified concrete shows less compressive strength at seven days' curing time and then increases its strength at the 28th days' of curing. Here, partial replacement of CDA has shown low early strength development. This is caused by the slow rate at which pozzolanic materials hydrate. for 28th days of curing, C-2 (5%CDA with 0.5% enset fiber) and C-3 (10%CDA with 0.5% enset fiber) shows an improvement over target mean strength with 4.03 % and 7.1 % respectively. This shows that increases in strength can be observed at the later curing ages (i.e. 54 and 90 days) than at the early curing periods of 7 and 28 days (P. Magudeaswar et al, 2020). Concrete with more than 10% of CDA with 0.5% enset fiber shows a reduction in compressive strength. The reason for reduction could be the finer particles and porous surface of CDA that leads to incremental in water requirement.

4.6.2.2 Flexural strength

The flexural strength test was conducted on the 7th and 28th days of curing. A mean value of three specimens was taken for each replacement of cement with CDA and EF for five different mixes with different replacement ratios. When compared to the control mix the mix prepared with the incorporation of CDA and EF have depicted increased gain of flexural strength.

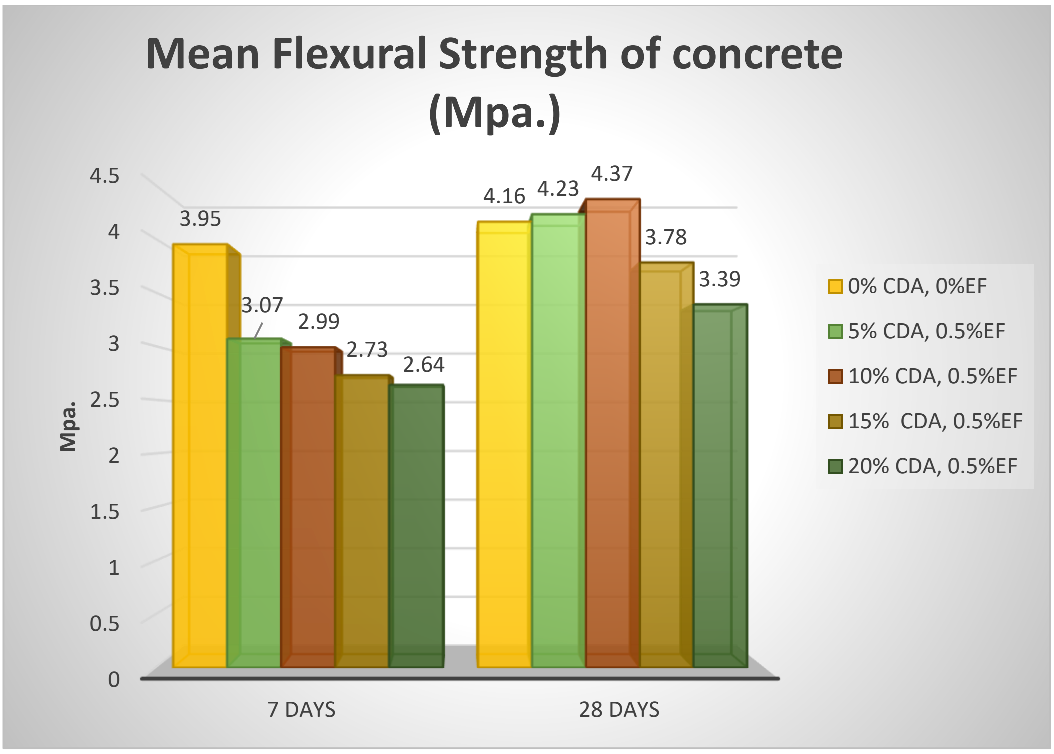

Figure 4. 6: Flexural strength of concrete

Figure 4.6 depicts the flexural strength of fiber-reinforced concrete on the 7th and 28th days after partial cement replacement with cow dung ash and 0.5% addition of enset fibre. When CDA was replaced with 5% and 0.5% enset fibre, and 10% CDA with 0.5% EF, the 28th day flexural strength increased by 1.68% and 5.05%, respectively, when compared to the control mix. This is due to the use of enset fibre and the hydration reaction of CDA, which gives it later strength. As CDA is a pozzolanic material, it reacts gradually and forms hydration products, which enhance bond strength by interlocking with aggregate. While the free quantity of portlandite, the primary ingredient for activating the pozzolanic process, is reduced with increased cement substitution of CDA (more than 10% in this study). Similar behaviour was seen with CDA mixed concrete by earlier researchers (Mathur & Chhipa, 2022) .

4.6.2.3 Split tensile strength

The split tensile strength test result has been presented in figure 4.7. The data shows An increment in the split tensile strength in CDA modified concrete with EF were noticed for a substitution level up to 10 %, when the substitution level raised above this limit the strength tend to decrease.

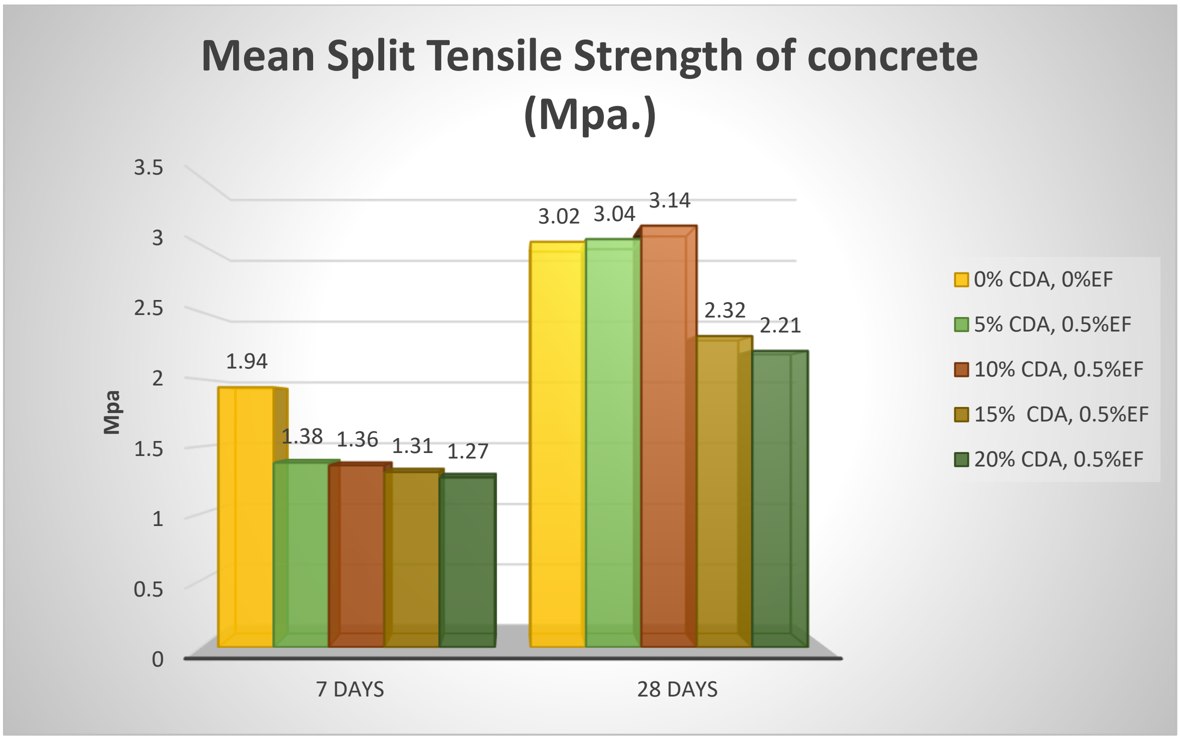

Figure 4. 7: split tensile strength of concrete

The mean split tensile strength of enset fiber reinforced concrete with 5% CDA and 0.5% addition of EF and 10% CDA with 0.5% addition of EF has shown an increment of 0.66% and 3.97% compared to the control mix this improvement is due to application of EF and CDA particles that have a greater filler effect, which decreases linked spaces and increases matrix density leading to an increase in split tensile strength (Mathur & Chhipa, 2022).

4.8 Micro structural analysis of concrete

4.8.1 Characterization of material by X-ray diffraction (XRD)

XRD is a technique that uses the crystal structure of the compounds to identify the chemicals they contain. This approach aids in the identification of chemicals contained in samples. After 28 days of curing, diffraction patterns were detected using XRD data and Origin Pro2022 software to determine the crystallographic phases of the CDA. XRD analysis was done on both control and 10 % replacement of cement by cow dung ash. After 28 days of curing, the control mix (C-1) and modified concrete (C-3) are examined to ascertain their mineralogical content. The samples were scanned over the 2θ range of 10 to 80°using Cu-Kα radiation with a step-size of 0.02. Both control and CDA concrete samples were crushed and pulverized before being mounted on a glass fiber stub to detect the phase change. The powder crystal X-ray examination of the samples with and without CDA (Figure 4.8 and figure 4.9) reveals that CDA concrete samples have several peaks in their XRD spectra. Major peaks such as portlandite (C-H), calcite (CaCO3), Halloysite($Al_2Si_2O_5(OH)_4$)and Ettringite are identified. in the same manner on the control concrete the major peaks such as CSH, portlandite, quartz and calcite are pick outed.

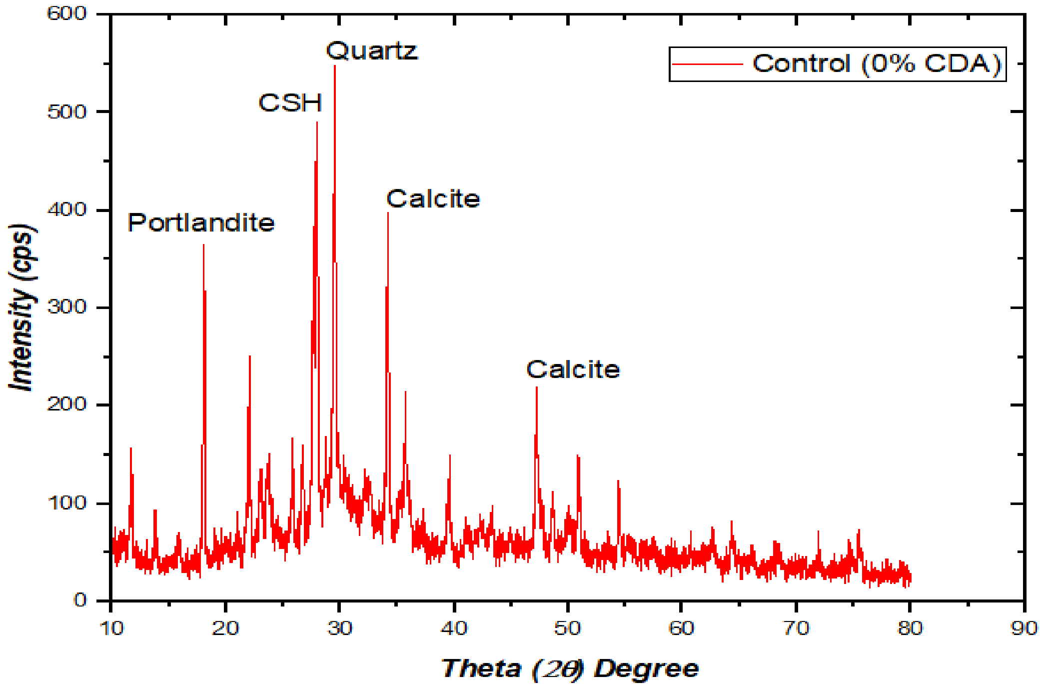

Figure 4. 8 XRD pattern of control concrete

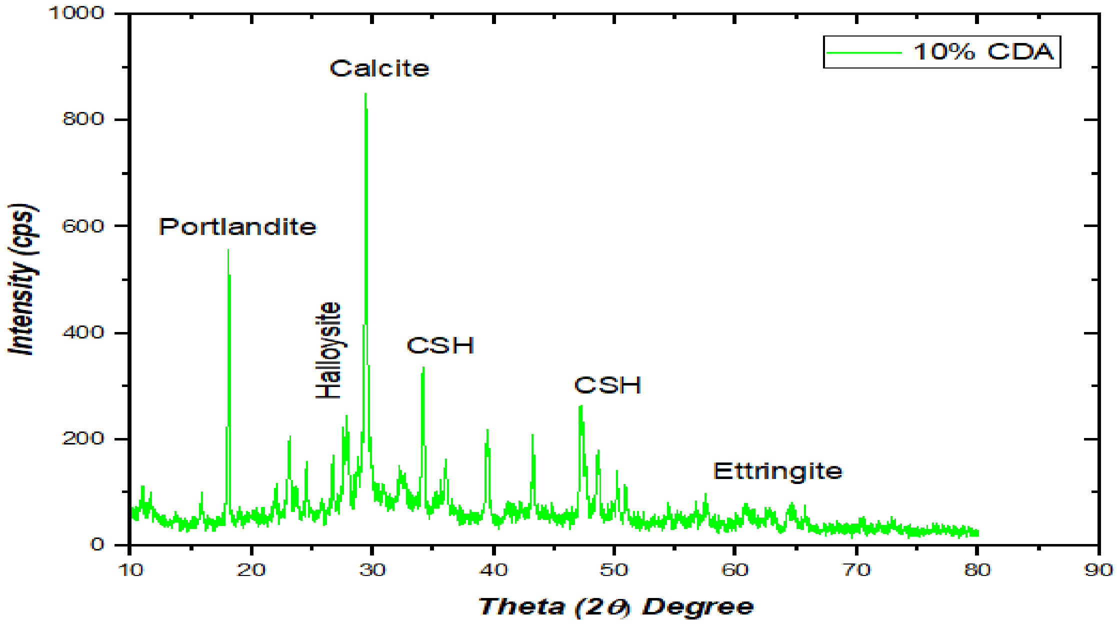

Figure 4. 9 XRD pattern of CDA concrete

As observed on the figure above, X ray diffraction of the control concrete generally shows more intense peaks as compared with CDA concrete. The intensity peak observed at 366,490,548 and 398 shows the presence of portlandite, C-S-H, quartz (SiO_2) and calcite respectively. The peak intensity of C-S-H in CDA concrete is increasing at 338 and 264 at 2 θ degree of 34.12 and 47.16 respectively, this is due to secondary hydration reaction of CDA concrete when silicon dioxide which is present in CDA reacts with calcium hydroxide that was formed from primary hydration reaction of Portland cement (Ramachandran, Vishwakarma, et al., 2015). From Figure 4.9 the peak intensity of portlandite, halloysite ,calcite ,C-S-H and ettringite are at 558, 246, 852, 338 and 98 respectively. From this it can be observed that in CDA concrete there is a peak result of calcite existing at intensity 852 and at 2 θ degree of 29.4 when compared with the results in figure 4.8 for control concrete. This indicates that the formation of CaCO3 helps to increase the early strength, due to the accelerator effect and high rate of hydration which hardens the concrete quicker. At matured age (28days), the concrete with the CaCO3 addition exhibits lower strength as compared with concrete without CaCO3, but still within the target strength (Ali et al., 2015). Also the formation of halloysite has properties similar to SiO2 chemical on its outer surface while the inner cylinder core is related to Al_2O_3 which together may improve the cement matrix. Ettringite, which is produced at intensity of 98 with 2 θ degree of 57.2 generally due to the reaction between C3A and gypsum in the presence of CaCO3 during the early age of setting. The formation of ettringite on the modified concrete by CDA controls the setting of cement, provides strength and stability of the concrete.

4.6.2.4 Scanning Electron Microscopy Analysis (SEM)

The microstructural analysis of the formation and distribution of hydration products in the inner part of concrete for the control mix (C-0) which is 0% replacement, and the optimum modified concrete with enset fiber and cow dung ash replacement were analysed by scanning electron microscopy (SEM). The structural morphology and strength properties of concrete were studied based on the hydration products formed after 28 days. The reason behind the strength of the concrete was analysed and explained based on the growth of hydration products in the concrete microstructure. The result of SEM is given in the figures below that show, for the control mix (C-1) and the optimum amount of CDA and EF modified concrete.

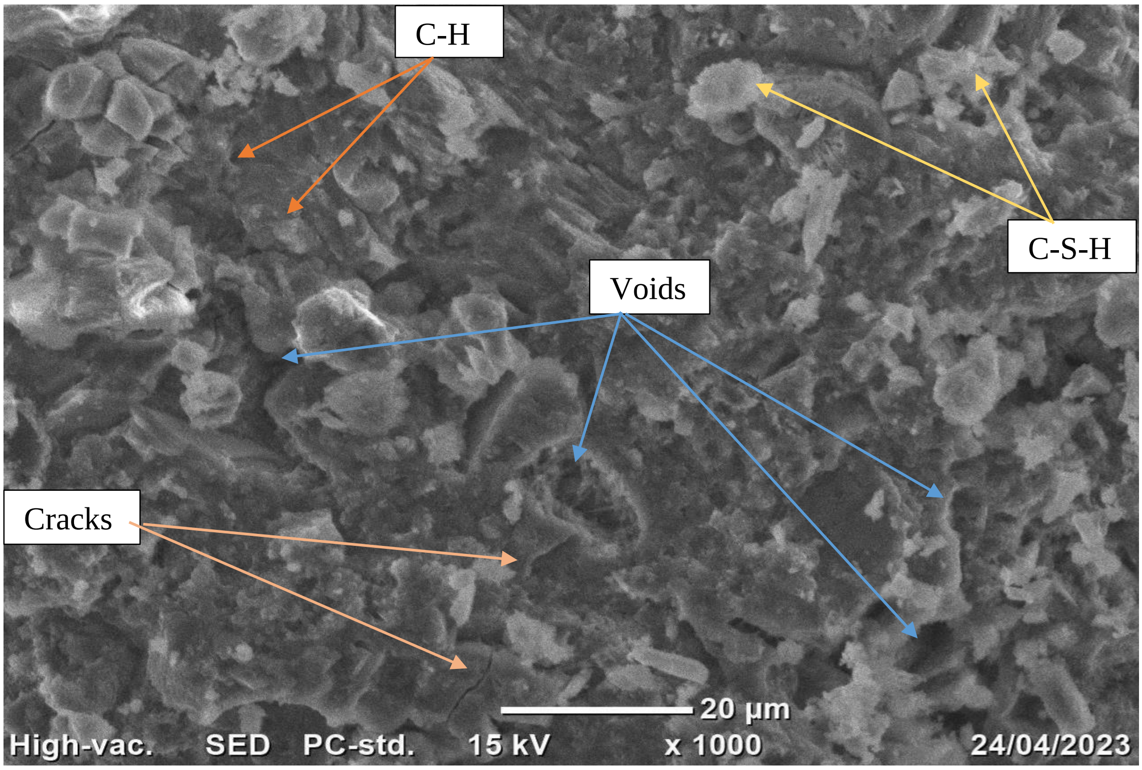

Figure 4. 9: SEM micrograph for control mix (C-0)

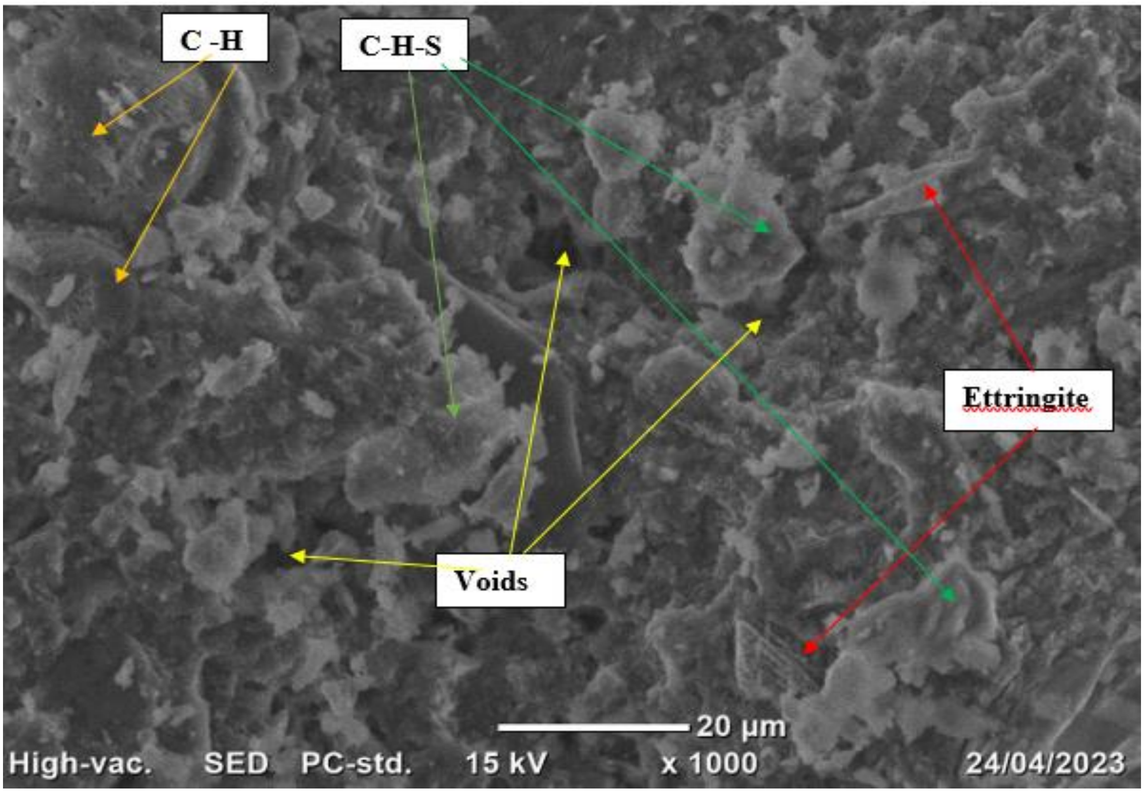

Figure 4. 10: SEM micrograph for 10% CDA mix (C-2)

From Figure 4.9 and Figure 4.10, the results of the SEM analysis pictures for hydrated samples of control mix (C-1) and modified concrete(C-2) at 28 days of curing explains the change in the morphology, size and chemical composition in both C-1 and C-2 particles. The C-1 analysis image shows presence of some voids between the grains and considerable cracks, whereas the modified concrete (C-2) is closely filled and packed by small grains. This shows that incorporation of pozzolonic materials into cement reduce the C-H formation (that promote micro cracking) and enhances formation of C-S-H, which promotes later strength gain (P. Magudeaswaran et al.2020). The figure 4.10 shows the formation of important product when calcium, sulfate, aluminate, and hydroxyl ions interact to form ettringite which have needle-shaped crystals (Sarker et al., 2023). This product is very crucial for stability of the concrete structure, by forming the network (polymer) between the aggregate and the paste of the concrete.

4.9 Environmental and Economic Benefits of Using CDA as a Cementitious Material

One of the reasons why using agricultural waste materials in concrete has financial and environmental benefits is that they are frequently abandoned. The difficulty of today is not only to improve the technology of construction materials, but also to choose the greatest resources while balancing costs. Utilising agricultural waste products considerably reduces the negative environmental effects and better economic benefit.

4.9.1 Energy Saving and carbon dioxide reduction

The cement industry is one of the major contributors for greenhouse gases (GHG) emissions, specifically, CO2 emissions, this is due to the calcinations of raw materials for the production of cement and burning fuels needed to maintain high temperatures in a clinker (Zhang et al., 2014). Even if the researcher used national OPC cement, the required data is taken from the case study of Mugher cement factory that is correspondingly represent the OPC national cement. Based on this the energy used intensity for production of OPC showed 3.67 GJ /ton and 0.84 ton/ton of CO_2 (Lemma & Saradhi, 2021). Portland clinker is produced by an energy intensive process that involves burning raw materials at a temperature of 1450 °C (Wako, 2022). The current study's CDA formation requires 600 °C, a reduction of 850°C (58.62%) from the temperature needed to make clinker. This is very important for tackling both global warming and energy costs.

Table 4.11 shows energy consumption and CO2 emission to produce one ton of cement and one ton of CDA. The total energy taken to produce one ton of cement and one ton of CDA were 3.67GJ/ton and 0.56GJ/ton respectively. From this energy percentage reduction of CDA production is 84.74 %. Therefore, the usage of CDA as a partial replacement of cement in concrete has great benefits in terms of reducing energy consumption.

Table 4. 11: Energy consumption and CO_2 emission to produce one ton of materials

Material	Required temperature ^{0}c	CDA to cement temperature ratio	Required coal (MJ/ton)		Diesel fuel (MJ/ton)	Heavy fuel oil (MJ/ton)	Electricity (MJ/ton)	Total Energy required (GJ/ton)	CO2 emissions (ton/ton) of material
			Imported	Local					
Cement	1450		2287.83	842.33	167.13	26.66	345.51	3.67	0.84
CDA	600	0.414	0	348.72	69.19	0	143.04	0.56	0.35
Reduction	850		2287.83	493.61	97.94	26.66	202.47	3.11	0.49

The majority of CO2 emissions and energy use in the cement industry are related to clinker production; 63% of CO2 emitted during cement production comes from the calcination process, with the remainder (37%) produced during the combustion of fossil fuels to feed the calcination process. The weighted average globally is approximately 0.83 kg of CO2 per kg of cement (Pardo & Moya, 2013). As illustrated in Table 4.11 production of cement emits much more CO2 than CDA production. As a result, reduction of 58.33% carbon dioxide emission from CDA production was estimated.

4.9.2 Economic Implication

In order to assess the potential economic effects of utilising CDA to partially replace cement in the manufacturing of concrete, the expected energy costs for producing both cement and CDA were taken into consideration. Additionally, a one-meter cube of concrete's production costs for components both with and without CDA are analysed. Based on a survey of the materials' current market prices conducted on May 25, 2023. The cost of the energy to produce one ton of cement and one ton of CDA has been computed. The unit price of each energy source is estimated as per ETB in the table below.

Table 4. 12 Estimated total cost of energy for production of one ton of cement

Energy sources	Unit	Cement	Unit Price (ETB/unit)	Price (ETB/ton)
Electricity	KWH	96.052	2.48	238.21
Heavy fuel	Litter	0.845	69.52	58.74
Diesel fuel	Litter	5.3	69.52	368.46
Imported coal	Kg	78.062	12.88	1005.44
Local coal	Kg	28.74	3.752	107.83
Total price of cement (ETB/ton)				1778.68

Table 4. 13: Estimated total cost of energy for production of one ton of CDA

Energy sources	Unit	Cement	CDA to cement ratio	CDA	Unit Price (ETB/unit)	CDA Price (ETB/ton)
Electricity	KWH	96.052	0.414	39.765528	2.48	98.619
Heavy fuel	Litter	0.845		0	69.52	0
Diesel fuel	Litter	5.3		2.1942	69.52	152.54
Imported coal	Kg	78.062		0	12.88	0
Local coal	Kg	28.74		11.89836	3.752	44.643
Total price of CDA (ETB/ton)						295.8

The projected energy cost of cement manufacturing is higher than that of CDA production, as indicated in table 4.12 and table 4.13, and the estimated percentage reduction cost of CDA production is 83.37%. Therefore, from an economic standpoint, utilising CDA as a cement substitute material is preferable.

4.9.3 Cost of CDA during production

The production cost of CDA is determined with both purchased price of cow dung for one quantal and its burning price. To produce CDA initially, the dung is purchased after that it was prepared to burn in the furnace. While burning the dung, one lab assistant is proposed for the process and worked for two consecutive days with four working hour of each day to complete CDA production. The assistant's hourly rate was 40 ETB, and the total cost was 320 ETB. The total cost of producing 14 kg of CDA was 574.20 ETB. Table 4.14 and Table 4.15 illustrates costs incurred during production of CDA and total cost of materials for production of concrete with 0% 5%,10% ,15% and 20% of cement replaced by CDA.

Table 4. 14: Total cost incurred for production of 14 kg of CDA

Item	Quantity	working day	working hour	rate per hour	Amount (ETB)
Cow dung purchased	1 quantal	-	-	-	250
Labour	1	2	4	40	320
Energy	-				4.20
Total	574.20 ETB				

According to current market prices of construction materials, one quantal of OPC National cement cost is approximately 2,100 ETB and its unit price is 21 birr per kg. Fine aggregate cost is 1267 ETB per cubic meter, whereas coarse aggregate cost is 1467ETB. Furthermore, the cost of water per cubic meter is 25 ETB. The estimated total cost of materials for producing one cubic meter of concrete without CDA is 9,655.72 ETB and costs 9583.01, 9,542.95 9,9548.16 and 9,601.81 ETB for 5%, 10%, 15% and 20% replacement of cement by CDA respectively as presented in the Table 4.16.

Table 4. 15: Materials quantity and their costs/ Bill of quantity

Material		Quantity	Unit	Rate	Amount (ETB)
Aggregates	Coarse Aggregate	0.59	m3	1467	865.53
	Fine Aggregate	0.56	m3	1247	698.32
Water		0.19	m3	25	4.75
Cement	100%	385.101	kg	21	8087.12
	95%	365.846	kg	21	7682.76
	90%	346.591	kg	21	7278.41
	85%	327.336	kg	21	6874.05
	80%	308.081	kg	21	6469.7
CDA	5% CDA	8.087	kg	41.01	331.65

percentage	10% CDA	16.97	kg	41.01	695.94
	15% CDA	26.957	kg	41.01	1105.51
	20% CDA	38.125	kg	41.01	1563.51

Table 4. 16:Total Costs for 1 m^3 of concrete (ETB/m^3)

%CDA Replaced	Material Cost (ETB)					ETB/m3 of concrete	Cost Difference ETB/m3
	Cement	CDA	Coarse Aggregate	Fine Aggregate	Water		
0%	8087.12	0	865.53	698.32	4.75	9,655.72	
5%	7682.76	331.65	865.53	698.32	4.75	9,583.01	72.71
10%	7278.41	695.94	865.53	698.32	4.75	9,542.95	112.77
15%	6874.05	1105.51	865.53	698.32	4.75	9,548.16	107.56
20%	6469.7	1563.51	865.53	698.32	4.75	9,601.81	53.91

According to the cost comparison shown in table 4.16, the estimated cost for 1 m3 of concrete for each replacement is lower than the concrete without CDA. The percentage reduction is 0.75 %, 1.17%, 1.1%, and 0.56% for concrete replacement with CDA at 5%, 10%, 15%, and 20%, respectively. These show that when CDA replaces cement, the cost savings is only felt up to a maximum of 10% CDA replacement in which correspondingly reduce the cost by 112.77 ETB for 1 m^3 of concrete.

Finally, using CDA as cement replacement have more advantages on environment by reducing the CO2 emission and reduce the depletion of useful natural resources. Further improve strength and durability of concrete. Moreover, it is beneficial from the economic point of view as the price of cow dung ash is cheaper and its replacement will reduce the cost of concrete when it is produced by mass production (Sarker et al., 2023)

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

Based on the experimental investigation conducted on combined effect of partial replacement of cement by cow dung ash and addition of enset fiber on the workability, mechanical properties and microstructural properties of concrete produced were studied and the following conclusions are drawn.

5.1 Conclusions

The conclusion is forwarded comparing each mix with controlled concrete and concrete produced with addition of 0.5%enset fiber with different percentage of cow dung ash as a cement replacement. After analysing the laboratory results the following conclusions were given:

- The XRF test result shows that the chemical composition of Cow Dung Ash has conducted. The sum of chemical compositions of SiO_2 + Al_2O_3 + Fe_2O_3=81.08>70 which satisfies the standard and it can be classified as class F pozzolana, as per ASTM C 618 classification. It has a loss of ignition (LOI) of 1.61, which was less than the maximum limit specified in the standard (6%), from this cow dung ash has better pozzolanic properties to be used in the production of concrete.
- It is shown that the consistency and setting time of cement blended with CDA increased as the CDA replacement is increasing.
- The slump of the concrete with 0.5% EF is decreased as the percentage value of CDA is increasing, this is due to the fiber interlocking the concrete paste together and the water demand increases as CDA increases even if the water adjustment is made.
- According to the observed result, the mechanical properties such as, compressive strength of the modified concrete was decreasing order for all replacement at early age (7^{th} day) compared with the control mix. But as curing time increased the strength of the modified concrete C-2 (5% CDA with 0.5% EF) and C-3 (10% CDA with 0.5%EF) shows improvement. The compressive strength at 28 days' test result of 10% CDA with 0.5%EF shows 7.1% increment when it is compared with the target mean compressive strength (33.5). The split tensile strength and flexural strength of modified concrete were increasing. As a result, the percentage of split tensile strength increases was recorded 3.97% at 10% CDA with 0.5% addition of enset fiber, when compared with control concrete. Also, for 5% CDA with 0.5% EF

and 10% CDA with 0.5% EF shows 1.68% and 5.05% improvement on the flexural strength of concrete respectively. This is due to the inter locking capacity of enset fiber in the concrete mix. Moreover, enset fiber can resist crack formation and improve weakness of concrete.

- From microstructure analysis (SEM and XRD) it is witnessed that amount of calcium silicate hydrate (C-S-H) gel in C-3 (10%CDA with 0.5% EF) is higher than in C-1 (control mix) and there is cracks and voids in C-1 (control mix) but this crack is filled by the presence of fiber and pozzolanic reaction C-H and silica of CDA in C-3 (10%CDA and 0.5% EF). The formation of important product from Tricalcium aluminate and gypsum (calcium sulfate) which is ettringite have important implication for the stability and durability on the modified concrete.
- Lastly, using CDA as a partial cement replacement in concrete reduces the consumption of non-renewable materials, saves energy, minimizes CO2 emissions, and reduces the cost incurred for cement production.

5.2 Recommendation

According to the findings of this study, CDA is one of the cattle waste products that can be used to replace cement in the production of concrete. Cement industries, government institutions, and research communities should be made aware of the possibility of using CDA for partial cement replacement by encouraging standardized production and use. According to the current investigation, the maximum compressive strength, flexural strength and split tensile strength was obtained at 10 % cement replacement by CDA and reinforced with addition of 0.5% EF, so this is the optimum percentage value for both CDA and EF`. Therefore, the researcher forwarded the following recommendations for future study.

- Based on the analysis and conclusion of the result, this paper recommends addition of 0.5% EF with 10% CDA replacement should a better improvement of the concrete for flexural and split tensile strength as compared with the controlled concrete. The compressive strength is increasing based on the target concrete strength.
- Testing additional engineering properties of concrete such as durability, permeability, water absorption, sulfate attack and modulus of elasticity should be done to optimize the usage of CDA as a cement replacement using optimization model.

- Depending on different paper review the silica content of CDA are vary from place to place for this reason, further study should be needed to determine the relationship between CDA chemical composition property and food intake of cattle.
- This research investigated the partial replacement of cement by CDA has economic advantages in addition to improving microstructural and mechanical properties. Therefore, cement industries should be made aware of the potential of these cement-replacing materials and be encouraged to standardize them in market as an alternative option.
- CDA concrete is recommended to apply in the construction of compound walls, non-load bearing partition walls, lightly loaded precast members-shelf slabs, sill slabs, cut lintels and sunshades, kerb walls and medians of road.

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APPENDICES

Appendix-A Complete silicate analysis Cow Dung Ash

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

Customer Name:- Beza Meskele Kefa
Sample type :-Powder
Sample Preparation: -200 Mesh
Date Submitted:- 24/03/2023
Analytical Result: In percent (%) Element to be determined Major Oxides & Minor Oxides.
Analytical Method: $LiBO_2$ FUSION, HF attack, GRAVIMETERIC, COLORIMETRIC and AAS

Issue Date:-18/04/2023
Request No:- GLD/RQ/1034/23
Report No:- GLD/RN/1677/23
Number of Sample:-One (01)

Collector's code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H2O	LOI	Weight of Sample
BM-01	68.60	8.62	3.86	6.46	2.52	2.14	<0.01	0.30	3.33	0.31	0.79	1.61	500 gm

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

Analysts
Haimanot Bayeh
Gadisa Wakuma
Nigist Fikadu aw

Checked By
Lidet Endeshaw

Approved By
Yohannes Getachew

Quality Control
Negash Worku

Appendix-B Physical properties tests of Cow Dung Ash

B-1 Specific gravity of CDA

description	CDA (gm)
Weight of Le-Chatelier Flask (w_1)	124.5
Weight of Le-Chatelier Flask and sample(W_2)	175.5
Weight of Le-Chatelier Flask + sample + kerosene(W_3)	498.3
Weight of Le-Chatelier Flask +kerosene(w_4)	478.5
Weight of Le-Chatelier Flask +weight of water(W_5)	497.4
Specific gravity	2.07

Calculation

1) Specific gravity of kerosene (GsK) = $\frac{Weight\ of\ kerosene}{Weight\ of\ water} = \frac{W4-W1}{W5-W1} = \frac{364.7-125.2}{411.2-125.2}$ =0.79

2) Specific gravity of Cow dung ash (GsCDA) = $\frac{Weight\ of\ cow\ dung\ ash}{Equivalent\ Weight\ of\ kerosene} * GsK$ = $\frac{W2-W1}{(W4-W1)-(W3-W2)} * GsK = \frac{175.5-124.5}{(478.5-124.5)-(498.3-175.5)*0.79} = \frac{51}{(354-322.8)*0.79}$= 2.07

B-2 Fineness test of Cement and CDA on 75 µm (No. 200)

Sample no	Cement			CDA		
	Before sieve (gm)	After sieve (gm)	%age	Before sieve (gm)	After sieve (gm)	% age
1	50	3.1	93.8	50	3.5	93
2	50	2.8	94.4	50	6.4	87.2
3	50	3.3	93.4	50	4.9	90.2
Average %			93.87	Average %		90.13

Appendix-C tests on fine and coarse aggregate

Appendix-C-1 tests on fine aggregate

A) **Gradation test**

Sieve size (mm)	Weight retained(gm)	Percentage retained (%)	Cumulative retained (%)	Cumulative passing (%)	ASTMC33 standard passing range (%)
9.5	0	0	0	100	100
4.75	50	5	5	95	95-100
2.36	110	11	16	84	80-100
1.18	190	19	35	65	50-85
0.6	270	27	62	38	25-60
0.3	250	25	87	13	5-30
0.15	90	9	96	4	0-10
pan	40	4	100	0	0
Total			298		
FM			2.98		

$$Fineness\ modules = \frac{\sum Cumulative\ coarser\ retained\ \%}{100}$$

$$= \frac{298.01}{100} = 2.98$$

B) Moisture content test

Mass taken = A = 1000 grm

Oven dried mass = B = 980 grm

$$Moisture\ content\ \% = \ \mu = \frac{(A-B)}{B} * 100 = \frac{(1000-980)}{980} * 100 = 2.04\%$$

C) Silt content of sand

Silt content (%) = $\frac{amount\ of\ silt}{clean\ sand}$ 100% = $\frac{4ml}{98ml}$ 100% = 4.08%

D) Unit weight of fine aggregate

Passed mass of sieve size of 4.75mm was taken for the analysis purpose

- ✓ Data taken for loose unit weight of sand

Mass of sample + Mold = A = 19430 grm

Mass of Mold =B=5605

Mass of sample = C = (A – B) = 19430-5605=13825 grm

Volume of cylinder = Vcy = 10 litter

$$Unit\ weight = \ \gamma_s = \frac{Mass\ of\ sample\ (grm)}{Volume\ of\ cylinder\ (lit.)} = \frac{C}{Vcy} = \frac{13825grm}{10\ lit.} = 1382.5\frac{Kg}{m^3}$$

- ✓ Data taken for dry rodded unit weight of sand

Mass of sample + Mold = A = 20760 grm

Mass of Mold =B=5605

Mass of sample = C = (A – B) = 20760-5605=15155 grm

Volume of cylinder = Vcy = 10 litter

$$Unit\ weight = \ \gamma_s = \frac{Mass\ of\ sample\ (grm)}{Volume\ of\ cylinder\ (lit.)} = \frac{C}{Vcy} = \frac{15155grm}{10\ lit.} = 1515.5\frac{Kg}{m^3}$$

E) Specific gravity and water absorption capacity of fine aggregate.

Mass of sand taken	Y	500	grm
oven dried mass	A	490	grm
Pycnometer + water	B	1462	grm
Pycnometer + water+ sand	C	1769	grm

- ✓ Apparent Specific. Gravity

$$Appt.sp.gr. = \frac{A}{(B+A-C)} = \frac{490}{(1462+490-1769)} = 2.68$$

- ✓ Bulk Specific Gravity (Saturated surface dry)

$$Bulk\ sp.gr.SSD\ =\ \frac{Y}{(B+Y-C)}=\frac{500}{(1462+500-1769)}=2.60$$

- ✓ Absorption capacity

$$Abson.capacity\ \%\ =\ \frac{(Y-A)}{A}*100=\frac{(500-490)}{490}*100=2.04\%$$

Appendix-C-2 Tests on coarse aggregate

A) Gradation test

Mass taken for sieve analysis test was 10000 grm.

Sieve size (mm)	Weight retained (gm.)	Percentage retained (%)	Cumulative retained (%)	Cumulative passing (%)	ASTM C33 standard passing range (%)
37.5	269.99	2.7	2.7	97.3	95-100
19	4249.66	42.5	45.2	54.8	35-70
9.5	3202.74	32.03	77.23	22.77	10-30
4.75	1833.85	18.34	95.57	4.43	0-5
pan	442.96	4.43	100	0	0

B) Fineness modulus

The fineness modulus of coarse aggregate for sieve diameters of 37.5mm, 19mm, 9.5mm, 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm, and 0.15mm is shown in the following table. The values of intermediate sieves are not taken into account when calculating the fineness modulus of coarse aggregate.

Size of sieve(mm)	Cumulative retained (%)
37.5	2.7
19	45.2
9.5	77.23
4.75	95.57
2.36	100
1.18	100
0.6	100
0.3	100

0.15	100
Total	718

$$Fineness\ modules = \frac{\sum Cumulative\ coarser\ retained\ \%}{100}$$

$$= \frac{720.7}{100} = 7.2$$

C) Specific gravity and absorption capacity

Mass of aggregate in water	C	3300	grm
Saturated surface dried mass	B	5080	grm
Oven dried mass	A	5000	grm

- ✓ Apparent Specific. Gravity

$$Appt. sp. gr. = \frac{A}{(A-C)} = \frac{5000}{(5000-3300)} = 2.94$$

- ✓ Bulk Specific Gravity (oven dried)

$$Bulk\ sp. gr. OD = \frac{A}{(B-C)} = \frac{5000}{(5080-3300)} = 2.81$$

- ✓ Bulk Specific Gravity (Saturated surface dry)

$$Bulk\ sp. gr. SSD = \frac{B}{(B-C)} = \frac{5080}{(5080-3300)} = 2.85$$

- ✓ Absorption capacity

$$Abson. capacity\ \% = \frac{(B-A)}{A} * 100 = \frac{(5080-5000)}{5000} * 100 = 1.6\%$$

D) Unit weight of coarse aggregate

- ✓ Data taken for loose unit weight of coarse aggregate

Mass of sample + Mold = A = 20590 grm

Mass of Mold =B=5605

Mass of sample = C = (A – B) = 20590-5605=14985 grm

Volume of cylinder = Vcy = 10 litter

$$Unit\ weight = \gamma_s = \frac{Mass\ of\ sample\ (grm)}{Volume\ of\ cylinder\ (lit.)} = \frac{C}{Vcy} = \frac{14985grm}{10\ lit.} = 1498.5\frac{Kg}{m^3}$$

- ✓ Data taken for dry rodded unit weight of sand

Mass of sample + Mold = A = 22410 grm

Mass of Mold =B=5605

Mass of sample = C = (A – B) = 22410-5605=16805 grm

Volume of cylinder = Vcy = 10 litter

$$Unit\ weight = \gamma_s = \frac{Mass\ of\ sample\ (grm)}{Volume\ of\ cylinder\ (lit.)} = \frac{C}{Vcy} = \frac{16805grm}{10\ lit.} = 1680.5\frac{Kg}{m^3}$$

Moisture content of enset fiber

Sample no	Weight before oven dry (W1) g	Weight after oven dry (W2) g	Moisture content (%)
1	30	28.65	= (30-28.65)/28.65 = 4.7
2	30	28.94	= (30-28.94)/28.94 =3.6
3	30	28.75	= (30-28.75)/28.75=4.3
Average			4.2%

Appendix-E Mix Design for C-25 Grade Concrete

STEP-1 Material Properties

No	Description of test	cement	Coarse aggregate	Fine aggregate
1	Fineness modulus(FM)	--------	7.2	2.98
2	Unit weight	--------	1680.5Kg/m^3	1515.5Kg/m^3
3	Moisture content	--------	0.6%	2.04%
4	Water absorption	--------	1.6%	2.04%
5	Specific gravity	3.15gm/cm^3	2.85	2.6

STEP-2 Slump selection

According to ACI 211 Table: 6.3.1 (Recommended slumps for various types of construction), the recommended slump to address more frequent constructions of concrete we considered Beams, Columns, and reinforced walls whose slump ranges between 25mm to 50mm where maximum slump = 50mm, and minimum slump = 25mm.

STEP-3 Choice of maximum aggregate size

For higher compressive strength, a reduced maximum size aggregate was selected. In this case, the maximum size aggregate was 20, and the nominal size aggregate was 19mm.

STEP-4 Estimation of mixing water and air content

From Table 6.3.3 of ACI standards (Approximate mixing water and air content requirements for different slumps and nominal maximum size of aggregates), considering non-air-entrained concrete and for non-air-entrained and slump of 25 mm-50 mm, the water in $1m^3$ of concrete is $185kg/m^3$**.**

STEP 5 Selection of water to cement ratio (w/c)

According to Table 6.3.4 (a) (Relationship between water – cement or water – cementitious materials ratio and compressive strength of concrete), for the slump of 25mm to 50mm, water to cement ratio is calculated based on 28-day compressive strength of concrete.

Target mean strength

Ft=fck + 8.5 for fck < 34.5

Ft = 25Mpa + 8.5 Mpa =33.5 Mpa.

Water to cement ratio is determined for target mean strength concrete of 33.5 Mpa. It is determined by interpolation = 0.490

Step 6 Calculation of cement content

W/c = 0.494, w = $185kg/m^3$ and cement content = w/0.494 = 166/0.494 = $377.55Kg/m^3$

Step 7 Estimation of coarse aggregate

According to Table 6.3.6 (Volume of coarse aggregate per unit volume of concrete), for Fineness modulus of fine aggregate (F.M) = 2.98 and Maximum aggregate size = 20mm, the volume of oven dry – rodded coarse aggregate per cubic meter of concrete is determined by interpolation and is equal to 0.602. The mass of coarse aggregate can be estimated as:

Coarse aggregate = 0.602*1680.5Kg/m^3 = 1011.661 Kg/m^3

Step 8: Determining the solid volume of coarse aggregate.

$$\text{solid volume of coarse aggregate} = \frac{\text{Weight of coarse aggregate}}{\text{specific gravity}}$$

$$= \frac{1011.661}{2.85}$$

$$= 354.969 \text{ Kg/m}^3$$

Step 9: Calculating the solid volume of cement, water, and air

$$\text{volume of cement (VC)} = \frac{\text{Weight of cement}}{\text{specific gravity of cement}}$$

$$= 377.55/3.15$$

$$= 119.86 \text{ kg/m}^3$$

Volume of water (VW) = 185 kg/m^3

Volume of air (VA) = 2% or 20 kg/m^3

Step 10: Calculating solid volume of sand

Solid volume of sand = 1000 - (VCA + VC + VW + VA)

= 1000 - (354.969+ 119.86 + 185 + 20)

1000 – 679.829

= 320.171 kg/m^3

Solid weight of sand = dry volume of sand x specific gravity

= 278.046 kg/m^3 x 2.6

= 832.445 kg/m^3

Step 11 Adjustments for aggregate moisture and absorption

Fine aggregate adsorption = 2.04 % and coarse aggregate absorption = 1.60%

Water absorbed by coarse aggregate = 1011.661 kg/m^3 x 0.016

= 16.17 kg/m^3

Water supplied by fine aggregate = 832.445 kg/m^3 x 0.0204

= 16.98 kg/m^3

Amount of water needed = 185 kg/m^3 + 16.17kg/m^3 – 16.98 kg/m^3

= 184.19 kg/m^3

Cement = 377.55 kg/m^3

Fine aggregate = 832.445 kg/m^3 + 16.98 kg/m^3

= 849.425 kg/m^3

Coarse aggregate = 1,011.661 kg/m^3 – 16.17 kg/m^3

= 995.49 kg/m^3

Appendix-E Compressive Test Result for C-25 Fiber Reinforced Concrete

Compressive Strength Test Result for 7th day

Spl. No	% EF &CDA	Test Age (day)	Diam. (cm)			Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight ($gm./cm^3$)	Comp. Strength (MPa.)
			L	W	H					
1	0.00%	7 days	15	15	15	8175	3375	617	2.42	27.42
2			15	15	15	8135	3375	631	2.41	28.04
3			15	15	15	8164	3375	628	2.416	27.91
Mean								**625.33**	**2.42**	**27.79**
1	0.50%	7 days	15	15	15	8089	3375	587	2.396	26.09
2			15	15	15	8015	3375	593	2.37	26.356
3			15	15	15	8043	3375	576	2.38	25.6
Mean								**585.33**	**2.38**	**26.01**
1	1%	7 days	15	15	15	8011	3375	546	2.373	24.267
2			15	15	15	7997	3375	531	2.369	23.6
3			15	15	15	8003	3375	517	2.371	22.978
Mean								**531.33**	**2.37**	**23.61**
1	1.50%	7 days	15	15	15	7957	3375	478	2.357	21.244
2			15	15	15	7716	3375	445	2.286	19.78
3			15	15	15	7863	3375	452	2.329	20.089
Mean								**458.33**	**2.32**	**20.37**

Compressive Strength Test Result for 28th day

Spl. No	% EF	Test Age (day)	Diam. (cm)			Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight ($gm./cm^3$)	Comp. Strength (MPa.)
			L	W	H					
1	0.00%	28 days	15	15	15	8050	3375	843	2.389	37.46
2			15	15	15	8125	3375	830	2.407	36.88
3			15	15	15	8076	3375	836	2.393	37.15
Mean								**836.33**	**2.4**	**37.16**
1	0.50%	28 days	15	15	15	7987	3375	816	2.366	36.267
2			15	15	15	8013	3375	781	2.374	34.711
3			15	15	15	8027	3375	795	2.378	35.33
Mean								**797.33**	**2.37**	**35.44**
1	1%	28 days	15	15	15	7954	3375	746	2.356	33.156
2			15	15	15	7919	3375	691	2.346	30.711
3			15	15	15	8014	3375	735	2.374	32.667
Mean								**724**	**2.36**	**32.18**
1	1.50%	28	15	15	15	7895	3375	656	2.34	29.156

2		days	15	15	15	7918	3375	693	2.346	30.8
3			15	15	15	7959	3375	712	2.358	31.64
Mean								**687**	**2.35**	**30.53**

Appendix-E Flexural Strength For C-25 Fiber Reinforced Concrete

Flexural Strength test result for 7th day

Spl. No	% EF	Test Age (day)	Diam. (cm)			Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight ($gm./cm^3$)	Flexural Strength (MPa.)
			L	W	H					
1	0.00%	7 days	50	10	10	12100	5000	13.71	2.42	4.112
2			50	10	10	12130	5000	12.66	2.426	3.799
3			50	10	10	12115	5000	13.1	2.423	3.932
Mean								**13.16**	**2.42**	**3.95**
1	0.50%	7 days	50	10	10	11950	5000	13.39	2.39	4.017
2			50	10	10	11560	5000	13.13	2.312	3.939
3			50	10	10	11695	5000	13.27	2.339	3.981
Mean								**13.26**	**2.35**	**3.98**
1	1%	7 days	50	10	10	11590	5000	14.05	2.318	4.215
2			50	10	10	11670	5000	13.58	2.334	4.074
3			50	10	10	11880	5000	13.39	2.376	4.017
Mean								**13.67**	**2.34**	**4.1**
1	1.50%	7 days	50	10	10	11240	5000	12.78	2.248	3.834
2			50	10	10	11375	5000	12.53	2.275	3.759
3			50	10	10	11420	5000	12.33	2.284	3.699
Mean								**12.55**	**2.27**	**3.76**

Flexural Strength test result for 28th day

Spl. No	% EF	Test Age (day)	Diam. (cm)			Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight ($gm./cm^3$)	Flexural Strength (MPa.)
			L	W	H					
1	0.00%	28 days	50	10	10	11700	5000	12.94	2.34	3.883
2			50	10	10	11830	5000	14.43	2.366	4.33
3			50	10	10	11775	5000	14.23	2.355	4.27
Mean								**13.87**	**2.35**	**4.16**
1	0.50%	28 days	50	10	10	11650	5000	16.07	2.33	4.821
2			50	10	10	11535	5000	15.9	2.307	4.77
3			50	10	10	11480	5000	15.88	2.296	4.764
Mean								**15.95**	**2.31**	**4.79**
1	1%	28 days	50	10	10	11700	5000	14.31	2.34	4.293
2			50	10	10	11525	5000	14.75	2.305	4.425
3			50	10	10	11345	5000	14.89	2.269	4.467
Mean								**14.65**	**2.3**	**4.4**
1	1.50%	28 days	50	10	10	11250	5000	12.85	2.25	3.855
2			50	10	10	11345	5000	13.11	2.269	3.933
3			50	10	10	11190	5000	12.78	2.238	3.834
Mean								**12.91**	**2.25**	**3.87**

Appendix-F Split Tensile Strength For C-25 Fiber Reinforced Concrete

Split Tensile Strength test result for 7th day

Spl. No	% EF	Test Age (day)	Diam. (cm)		Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight ($gm./cm^3$)	Split Tensile Strength (MPa.)
			D	H					
1	0.00%	7 days	15	30	12940	5298.75	148	2.442	2.08
2			15	30	12480	5298.75	126	2.355	1.78
3			15	30	12730	5298.75	139	2.402	1.96
Mean							**137.67**	**2.4**	**1.94**
1	0.50%	7 days	15	30	12560	5298.75	133	2.370	1.882
2			15	30	12355	5298.75	142	2.331	2.009
3			15	30	12800	5298.75	157	2.416	2.222
Mean							**144**	**2.37**	**2.04**
1	1%	7 days	15	30	11990	5298.75	145	2.263	2.052
2			15	30	12100	5298.75	158	2.283	2.236
3			15	30	12055	5298.75	145	2.275	2.052
Mean							**149.33**	**2.27**	**2.11**
1	1.50%	7 days	15	30	11880	5298.75	123	2.242	1.741
2			15	30	11560	5298.75	129	2.182	1.826

3			15	30	11635	5298.75	131	2.196	1.854
Mean							**127.67**	**2.21**	**1.81**

Split Tensile Strength test result for 28th day

Spl. No	% EF	Test Age (day)	Diam. (cm)		Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight (gm./cm^3)	Split Tensile Strength (MPa.)
			D	H					
1	0.00%	28 days	15	30	12610	5298.75	195	2.379	2.76
2			15	30	12630	5298.75	210	2.383	2.97
3			15	30	12640	5298.75	235	2.385	3.33
Mean							**213.33**	**2.38**	**3.02**
1	0.50%	28 days	15	30	11870	5298.75	221	2.240	3.128
2			15	30	12150	5298.75	237	2.293	3.355
3			15	30	11995	5298.75	253	2.264	3.581
Mean							**237**	**2.27**	**3.35**
1	1%	28 days	15	30	11845	5298.75	246	2.235	3.482
2			15	30	11835	5298.75	239	2.233	3.383
3			15	30	12050	5298.75	256	2.274	3.623
Mean							**247**	**2.25**	**3.5**
1	1.50%	28 days	15	30	11770	5298.75	213	2.221	3.015
2			15	30	11690	5298.75	209	2.206	2.958
3			15	30	11315	5298.75	217	2.135	3.071
Mean							**213**	**2.19**	**3.01**

Appendix-G Compressive Strength Test Results of CDA And EF With Control Mix

G-1 Seventh and 28th days compressive strength test results

Spl. No	% CDA	% EF	Test Age (day)	Diam. (cm)			Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight (gm./cm^3)	Comp. Strength (MPa.)
				L	W	H					
1	0%	0.00 %	7 days	15	15	15	8175	3375	617	2.422	27.42
2				15	15	15	8135	3375	631	2.410	28.04
3				15	15	15	8164	3375	628	2.418	27.91
Mean									**625.33**	**2.42**	**27.79**
1	5%	0.50 %	7 days	15	15	15	7940	3375	474	2.352	21.067
2				1	1	1	7730	3375	428.844	2.290	19.05

				5	5	5					9
3				15	15	15	7480	3375	487	2.216	21.644
Mean									**488**	**2.29**	**20.5897**
1	10%	0.50%	7 days	15	15	15	7900	3375	448	2.340	19.911
2				15	15	15	7980	3375	447	2.364	19.867
3				15	15	15	7940	3375	451.5	2.352	20.067
Mean									**448.83**	**2.35**	**19.95**
1	15%	0.50%	7 days	15	15	15	7760	3375	362	2.299	16.088
2				15	15	15	7390	3375	348.08	2.189	15.470
3				15	15	15	7580	3375	344.88	2.245	15.328
Mean									**351.65**	**22.24**	**15.63**
1	20%	0.50%	7 days	15	15	15	7810	3375	344	2.314	15.289
2				15	15	15	7450	3375	322	2.207	14.311
3				15	15	15	7640	3375	350.13	2.263	15.561
Mean									**338.71**	**2.26**	**15.05**
Spl. No	% CDA	% EF	Test Age (day)	Diam. (cm)			Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight ($gm./cm^3$)	Comp. Strength (MPa.)
				L	W	H					
1	0%	0.00%	28 days	15	15	15	8050	3375	843	2.385	37.46
2				15	15	15	8125	3375	830	2.407	36.88
3				15	15	15	8076	3375	836	2.393	37.15
Mean									**836.33**	**2.4**	**37.16**
1	5%	0.50%	28 days	15	15	15	7935	3375	795.50	2.351	35.356
2				15	15	15	8020	3375	792.1	2.376	35.204
3				15	15	15	8065	3375	802.3	2.389	35.658
Mean									**796.63**	**2.37**	**35.41**
1	10%	0.50%	28 days	15	15	15	7780	3375	805.5	2.305	35.8

2				15	15	15	7695	3375	805.8	2.28	35.81
3				15	15	15	7750	3375	810.5	2.296	36.02
Mean									**792.9**	**2.29**	**35.88**
1	15%	0.50 %	28 days	15	15	15	7655	3375	642.6	2.268	28.56
2				15	15	15	7525	3375	588.83	2.229	26.170
3				15	15	15	7450	3375	651.16	2.207	28.940
Mean									**627.53**	**2.24**	**27.89**
1	20%	0.50 %	28 days	15	15	15	7525	3375	484.2	2.229	21.52
2				15	15	15	7545	3375	532.58	2.235	23.670
3				15	15	15	7520	3375	559.35	2.228	24.86
Mean									**525.38**	**2.23**	**23.35**

G- 2 Seventh and 28th days split tensile strength test results

Spl. No	% CDA	% EF	Test Age (day)	Diam. (cm)		Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight (gm./cm^3)	Split Strength (MPa.)
				D	H					
1	0%	0.00%	7 days	15	30	12940	5298.75	148	2.442	2.08
2				15	30	12480	5298.75	126	2.355	1.78
3				15	30	12730	5298.75	139	2.402	1.96
Mean								**137.67**	**2.4**	**1.94**
1	5%	0.50%	7 days	15	30	11870	5298.75	95	2.240	1.345
2				15	30	11980	5298.75	98	2.261	1.387
3				15	30	11935	5298.75	100	2.252	1.415
Mean								**97.67**	**2.25**	**1.38**
1	10%	0.50%	7 days	15	30	12290	5298.75	96	2.319	1.359
2				15	30	12240	5298.75	94	2.309	1.330
3				15	30	12265	5298.75	98	2.315	1.387
Mean								**96**	**2.31**	**1.36**
	15%	0.50%	7 days	15	30	12000	5298.75	85	2.268	1.203
				15	30	11950	5298.75	95	2.255	1.345
				15	30	11980	5298.75	90	2.261	1.274
								90	2.26	1.27

Spl. No	% CDA	% EF	Test Age (day)	Diam. (cm) D	H	Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight ($gm./cm^3$)	Split Strength (MPa.)
1	20%	0.50%	7 days	15	30	11655	5298.75	90	2.199	1.274
2				15	30	11900	5298.75	92	2.246	1.302
3				15	30	11778	5298.75	95	2.223	1.345
Mean								**92.33**	**2.22**	**1.31**

Spl. No	% CDA	% EF	Test Age (day)	Diam. (cm)		Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight ($gm./cm^3$)	Split Strength (MPa.)
				D	H					
1	0%	0.00%	28 days	15	30	12610	5298.75	210	2.379	2.972
2				15	30	12630	5298.75	209.83	2.383	2.969
3				15	30	12640	5298.75	220.27	2.385	3.118
Mean								**213.37**	**2.38**	**3.02**
1	5%	0.50%	28 days	15	30	12165	5298.75	217.1	2.296	3.073
2				15	30	12275	5298.75	205.5	2.317	2.909
3				15	30	13200	5298.75	220.8	2.491	3.125
Mean								**214.47**	**2.37**	**3.04**
1	10%	0.50%	28 days	15	30	12235	5298.75	223.04	2.309	3.157
2				15	30	12115	5298.75	208.5	2.286	2.951
3				15	30	12055	5298.75	234.2	2.275	3.315
Mean								**221.91**	**2.29**	**3.14**
1	15%	0.50%	28 days	15	30	12085	5298.75	157.55	2.280	2.230
2				15	30	12070	5298.75	163.2	2.278	2.309
3				15	30	11985	5298.75	170.97	2.262	2.419
Mean								**163.91**	**2.27**	**2.32**
1	20%	0.50%	28 days	15	30	12010	5298.75	162.7	2.267	2.303
2				15	30	11575	5298.75	149.78	2.184	2.120
3				15	30	11650	5298.75	156.14	2.198	2.210
Mean								**156.21**	**2.22**	**2.21**

G- 3 Seventh and 28^{th} days flexural strength test results

Spl. No	% CDA	% EF	Test Age (day)	Diam. (cm)			Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight ($gm./cm^3$)	Flexural Strength (MPa.)
				L	W	H					
1	0%	0.00%	7 days	50	10	10	12100	5000	13.71	2.42	4.112
2				50	10	10	12130	5000	12.66	2.426	3.799
3				50	10	10	12115	5000	13.1	2.423	3.932

Mean									**13.16**	**2.42**	**3.95**
1	5%	0.50%	7 days	50	10	10	11715	5000	10.72	2.343	3.216
2				50	10	10	11580	5000	9.56	2.316	2.868
3				50	10	10	11648	5000	10.377	2.3296	3.1131
Mean									**10.22**	**2.33**	**3.07**
1	10%	0.50%	7 days	50	10	10	11630	5000	9.42	2.326	2.826
2				50	10	10	11590	5000	10.32	2.318	3.096
3				50	10	10	11620	5000	10.17	2.324	3.051
Mean									**9.97**	**2.32**	**2.99**
1	15%	0.50%	7 days	50	10	10	11620	5000	9.2	2.324	2.76
2				50	10	10	11815	5000	8.86	2.363	2.658
3				50	10	10	11718	5000	9.286	2.3436	2.7858
Mean									**9.12**	**2.34**	**2.73**
1	20%	0.50%	7 days	50	10	10	11120	5000	8.54	2.224	2.562
2				50	10	10	11220	5000	9.08	2.244	2.724
3				50	10	10	11180	5000	8.75	2.236	2.625
Mean									**8.79**	**2.23**	**2.64**
Spl. No	% CDA	% EF	Test Age (day)	Diam. (cm)			Weight (gm.)	Volume (cm^3)	Failure Load (kN)	Unit weight (gm./cm^3)	Flexural Strength (MPa.)
				L	W	H					
1	0%	0.00%	28 days	50	10	10	11700	5000	12.94	2.34	3.883
2				50	10	10	11830	5000	14.43	2.366	4.33
3				50	10	10	11775	5000	14.23	2.355	4.27
Mean									**13.87**	**2.35**	**4.16**
1	5%	0.50%	28 days	50	10	10	12030	5000	14.1	2.406	4.23
2				50	10	10	11380	5000	14.2	2.276	4.26
3				50	10	10	11895	5000	13.95	2.379	4.185

Mean									**14.08**	**2.35**	**4.23**
1	10%	0.50%	28 days	50	10	10	11775	5000	14.5	2.355	4.35
2				50	10	10	11145	5000	14.8	2.229	4.44
3				50	10	10	11120	5000	14.35	2.224	4.305
Mean									**14.55**	**2.27**	**4.37**
	15%	0.50%	28 days	50	10	10	11195	5000	13.1	2.239	3.93
				50	10	10	11205	5000	12.2	2.241	3.66
				50	10	10	11155	5000	12.5	2.231	3.75
Mean									**12.6**	**2.24**	**3.78**
1	20%	0.50%	28 days	50	10	10	11165	5000	10.95	2.233	3.285
2				50	10	10	11240	5000	11.69	2.248	3.507
3				50	10	10	11050	5000	11.3	2.21	3.39
Mean									**11.31**	**2.23**	**3.39**

APPENDIX-H Sample photos taken from Laboratory

Cow dung and CDA production

Figure H-1 sun dried cowdung, furnace and cow dung ash

Figure H -2 Specific gravity test of CDA

Figure H -3 coarse aggregate and fine aggregate physical properties test.

Figure H4 normal consistency and setting time test.

Figure H 5 workability testing

Figure H 6 Measuring and preparation of material for mixing

Figure H 7 : tensile ,compressive and flexural strength test conducting

Figure H 8 Enset fiber and chopped enset fiber