Evaluation of Concrete Properties with Eggshell and Chicken Manure as Accelerating Additives

TSEGAYE ADMASSU

A Thesis Submitted to the Department of Civil Engineering
School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement of Masters of Science in Civil Engineering (Specialization in Construction Engineering and Management)

Office of Graduate Studies
Adama Science and Technology University

October, 2024
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Advisor: Fikireyesus Demeke (Ph.D)

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DECLARATION

I declare that this thesis entitled **"Evaluation of Concrete Properties with Eggshell and Chicken Manure as Accelerating Additives"** is my own work and has not been submitted to any university for similar purpose. The references used in this thesis research are duly recognized by proper citations.

Tsegaye Admassu	______________________	_______________
Name of student	Signature	Date

APPROVAL PAGE

I, the major advisor of this research, hereby certify that I have closely advised the student while developing this thesis research and read the draft thesis research entitled **"Evaluation of Concrete Properties with Eggshell and Chicken Manure as Accelerating Additives"** prepared under my guidance by Tsegaye Admassu. Therefore, I recommend the submission of the thesis to the department for further review and evaluation.

Fikireyesus Demeke (Ph.D)	______________________	_______________
Major Advisor	Signature	Date

APPROVAL OF BOARD OF REVIEWERS

I, the advisor of the thesis entitled **"Evaluation of Concrete Properties with Eggshell and Chicken Manure as Accelerating Additives"** prepared under my guidance by Tsegaye Admassu, here by certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Fikireyesus Demeke (Ph.D)	________________________	________________
Major Advisor	Signature	Date

We, the undersigned, members of the Board of examiners of the thesis open defense by Tsegaye Admasu have read and evaluated the thesis entitled **"Evaluation of Concrete Properties with Eggshell and Chicken Manure as Accelerating Additives"** and examined the candidate about the thesis research. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Civil Engineering.

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Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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ABSTRACT

Concrete, a composite material made from cement, aggregates, and water, is enhanced by the addition of chemical admixtures in small amounts just before or during mixing to improve its properties. From those Calcium nitrates is a commonly used chemical accelerator in the construction industry, which enhances the hydration process of cement and the early-age strength development of concrete. However, the extraction method of this admixture utilizing natural sources, such as limestone and fossil fuel, has led to concerns about resource depletion and its long-term environmental impact. To overcome these difficulties, exploring alternatives to nonrenewable calcium and nitrate sources becomes more important. The current study aims to produce calcium nitrate-based accelerator additive derived from eggshell and chicken manure and investigate its effects on various properties of C-30 concrete. Chicken manure from a poultry farm was treated by anaerobic digestion method with wheat straw to achieve the balance of carbon-to-nitrogen (C/N) ratio in the compost pile. Filtration and distillation were used in the experiment, and the Engineering Corporation of Oromia conducted a photometric test on the results, showing that nitrate (NO_3) was 11.6 mg/L and nitrite (NO_2) was 4.3 mg/L. Eggshells were also utilized for calcium ions (Ca^{2+}) ions through solid-state reaction, resulting in 48.02% (CaO). The extracted solution was then used to obtain $Ca(NO_3)_2$ and $Ca(NO_2)_2$. The fresh and hardened concrete tests were conducted to evaluate the impact of this accelerating additive on workability, compressive strength, flexural strength, water absorption, and resistance to acid attack. Different dosages of the admixture (1%, 2%, 3%, and 4%) were tested. The experimental results showed that, with a 2% addition of the extracted additive, the compressive strength improved by 17.09%, 11.264%, 7.09%, and 7.48% at 7, 14, 21, and 28 days from the conventional concrete, respectively. The flexural strength also improved by 11.86%, 9.90%, and 12.31% at 7, 14, and 28 days from the conventional concrete with a 2% addition of extracted admixture. The water absorption was at its lowest at 3.03% with the 2% dosage. The FTIR results show that adding eggshell and chicken manure to the concrete mixture significantly alters its chemical composition. This may affect the performance and physical properties of the concrete. In terms of acid attack resistance, the conventional concrete experienced a 3.87% strength reduction, whereas the concrete with a 2% dosage showed a 4.7% reduction, indicating lower acid resistance compared to the control mix. While the extracted additive showed improved physical properties, further research may be needed to optimize the dosage levels for enhanced acid resistance without compromising other concrete properties.

Keywords: Calcium Nitrate, Accelerator Admixture, Eggshell, Chicken Manure, Concrete

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LIST OF ACRONYMS

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
ASTU	Adama Science and Technology University
CDA	Cow dung ash
DOE	British Department of Environment
EBCS	Ethiopian Building Code Standard
EDS	Energy Dispersive Spectroscopy
ESP	Eggshell powder
FM	Fineness Modulus Methods
IS	Indian standard
kN	kilo newton
KPa/min	kilo Pascal per minute
MPa/sec.	Mega Pascal per second
OPC	Ordinary Portland cement
pH	power of hydrogen
POFA	Palm oil fuel ash
RHA	Rice husk ash
SCBA	Sugar cane bagasse ash
SEM	Scanning Electron Microscope
wt	weight
XRD	X-ray diffraction.

LIST OF CHEMICAL FORMULAS

Formula	Name of chemical compound
Ca^{2+}	Calcium ion
HNO_3	Nitric acid
H_2SO_4	Sulfuric acid
$Ca(OH)_2$	Calcium hydroxide
CH_3COOH	Acetic acid
CO_2	Carbon dioxide
Ca_3SiO_5	Tricalcium silicate
Ca_2SiO_4	Dicalcium silicate
CaH_2O_4Si	Calcium silicate hydrate
HCl	Hydrochloric acid
$Ca_3Al_2O_3$	Tricalcium aluminate
$CaCO_3$	Calcium carbonate
$2CaO \cdot Al_2O_3 \cdot Fe_2O_3$	Dicalcium aluminate ferrite
$Ca(NO_3)_2$	Calcium nitrate
CaO	Calcium oxide
N_2	Nitrogen
NaSCN	Sodium thiocyanate
NH_3	Ammonia
NO_3^-	Nitrate ion
OH^-	Hydroxide ion
SiO_4^{2-}	Silicate ion
TEA	Triethanolamine

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Concrete is frequently used material in the world, next to water, comprises cement, aggregates, and water as its fundamental components (Gagg, 2014). Additionally, chemical admixtures and mineral additives may include to enhance its performance (ACI Committee E-701, 2013). From those, cement is an ingredient used to bind the components together by setting, hardening, and bonding to other materials (Kovler & Roussel, 2011). The most typical raw ingredients used in the production of cement are lime, silica, alumina, and iron oxide. These components are heated to a temperature of around 1400°C-1500^{o}C after mixing to give the cement its final chemical characteristics (Dunuweera & Rajapakse, 2018 ; Oliveira et al., 2019) .

Chemical admixtures were initially used in the middle of the 1930s. They are typically used in small quantities added to the concrete immediately before or during mixing, and they can modify the properties of fresh or hardened concrete, or occasionally both (Gök & Kılınç, 2015). Chemical admixtures may classify into several categories based on their function and effect on concrete. The most common admixtures include accelerators, retarders, air-entrainers, water reducers, and specialty admixtures. Retarders and accelerators modify cement hydration, with implications for concrete placement, while water reducers and air-entrainers enhance durability (Cheung et al., 2018).

Calcium nitrate ($Ca(NO_3)_2$) is a commonly used chemical accelerator admixture in the construction industry, known for its ability to accelerate the hydration process of cement and enhance the early-age strength development of concrete (Karagöl et al., 2013). In addition to this, it reduced the alkali-silica reaction. The alkali-silica reaction is a chemical reaction between the alkalis present in cement and certain types of reactive silica in aggregates. This reaction can cause the formation of gel-like substances, leading to expansive cracking and the deterioration of concrete (Weise et al., 2022). According to a previous study, dissolved calcium nitrate has been demonstrated to reduce alkali-silica reaction-induced expansion (Oey et al., 2020). However, in the industrial production of calcium and nitrate sources, using natural and nonrenewable resources is a significant concern. The Haber-Bosch process is a method from the early 20th century that extracts ammonia from nitrogen in the air. It remains expensive and energyintensive, sticking to its original form despite technological progress (Yüzbaşıoğlu et al., 2022). Additionally, the Ostwald process plays a crucial role in converting ammonia to nitric acid by utilizing oxygen and water (Yüzbaşıoğlu et al., 2022). These production method led to exploration of alternatives, such as deriving calcium and nitrate source from other agricultural waste, an industrial by-product, plant residual, animal dung, and renewable sources, has gained attention as a sustainable and eco-friendly solution (Hakeem et al., 2023). Utilizing waste materials as admixtures/additives in concrete production can contribute to the circular economy in the construction industry. The circular economy aims to minimize waste and maximize resource efficiency through innovative reuse and recycling methods. This approach reduces the demand for virgin resources, conserves natural resources, and minimizes the environmental impact of extracting and processing new materials (Arora et al., 2020; Sparrevik et al., 2021).

When calcium nitrate is added to water, it dissociates into calcium ions (Ca2+) and nitrate ions (NO3-) (Renaudin et al., 2000). The calcium ions react with various compounds in cement, such as tricalcium silicate (C3S) and dicalcium silicate (C2S), to form calcium silicate hydrate (C-S-H) gel (Kičaite et al., 2017), which is responsible for the strength and binding properties of concrete (Wang et al., 2018). These calcium ions can also form insoluble compounds with reactive silica, preventing them from reacting with alkalis and reducing the risk of an alkali-silica reaction. Additionally, nitrate ions can react with aluminate compounds in cement, such as tricalcium aluminate (C3A), to form ettringite. However, ettringite (AFt) is a calcium-aluminum sulfate hydrate compound that does not contribute to the strength of concrete (A. Ahmed, 2019). The reduction of delayed ettringite formation is crucial for improving concrete durability. Delayed ettringite formation in concrete can lead to excessive heat during curing, resulting in cracking and a reduction in the concrete's long-term durability (Nguyen et al., 2013).

This research aims to produce calcium nitrate-based accelerator additives derived from eggshell and chicken manure and investigate its effects on fresh and hardened properties of concrete. Eggshells primarily consist of calcium carbonate, which can be converted to calcium oxide (quicklime) by heating to a temperature of around 600–700^{o}C (Azarian & Sutapun, 2022). On the other hand, chicken manure contains nitrogen compounds. Therefore, by combining eggshells and chicken manure, it is possible to obtain calcium nitrate through the differences process.

1.2 Statements of the problem

Calcium nitrate is typically made by reacting calcium carbonate or calcium hydroxide with nitric acid. However, the extraction process from natural sources, such as limestone and fossil fuel, has led to concerns about resource depletion and its long-term environmental impact. Mining operations for calcium extraction involve the removal of large quantities of rock, leading to habitat destruction and the loss of biodiversity (Venkata Sudhakar et al., 2022). The nitrate extraction also requires nitric acid, which is predominantly synthesized from ammonia by the Haber-Bosch process, which has a large carbon footprint since it produces ammonia primarily using non-renewable fossil fuels like coal or natural gas (Yüzbaşıoğlu et al., 2022). As the need for calcium nitrate increases, so does the extraction process, further depleting resources and jeopardizing the ecosystem. Research from recent years has shown that an additive made from waste materials can help protect natural resources by lowering the requirement to extract fresh raw materials (Islam et al., 2017; Madurwar et al., 2013; Minunno et al., 2020). In comparison to chemical admixtures, natural products or waste materials are inexpensive, environmentally friendly, and natural (Woldemariam et al., 2014).

However, it is possible to overcome the difficulties finding alternative to nonrenewable calcium and nitrate sources become more important. One such waste resource that effectively substitutes a calcium supply for the chemical admixture/additive and aids in its proper functioning is eggshells (Fouladi et al., 2023; Kulanthaivel et al., 2022). Chicken manure also has a high amount of nitrogen, which is essential to extracting nitrate in the form of undigested protein, uric acid, and ammonia (Fuchs et al., 2018).

Eggshell and other waste materials have been the subject of numerous studies by earlier researchers as alternatives to chemical additives; however, the extraction of both eggshell and chicken manure has not been studied. Because of this, the thesis research uses waste items like eggshells and chicken manure as sources of calcium nitrate, reducing the need for synthetic admixture and resulting in a more environmentally friendly and sustainable method of producing concrete additive. The purpose of this study is to determine whether it is feasible to include calcium nitrate that has been taken from waste sources, specifically eggshells and chicken manure.

1.3 Research Questions

The research questions that the study went to explain were as follows:

1. What are the properties of calcium nitrate-based additives derived from eggshells and chicken manure?
2. How do varying dosages of calcium nitrate-based additives from eggshells and chicken manure affect the workability of fresh concrete?
3. What is the impact of different dosages of calcium nitrate-based additives from eggshells and chicken manure on the workability, physical properties of concrete, and what are the optimal dosages for accelerating concrete strength?
4. How does the micro-structure of control mix concrete compare to that of concrete with calcium nitrate-based additives from eggshells and chicken manure?

1.4 Objectives

1.4.1 General objective

The main objective of the study is to evaluate calcium nitrate-based accelerator additive of cement concrete from eggshell and chicken manure.

1.4.2 Specific objective

- ❖ To characterize the properties of calcium nitrate-based additives from eggshells and chicken manures,
- ❖ To investigate the workability of concrete with additives from eggshell and chicken manure,
- ❖ To investigate the impact of different dosages of additives derived from eggshell and chicken manure on physical properties, and determining their optimal dosages to accelerate concrete strength,
- ❖ To investigate micro-structure of control mix concrete and the concrete with additive from eggshells and chicken manure.

1.5 The Scope of the Study

This study aims to produce and characterize the properties of a calcium nitrate-based additive derived from eggshells and chicken manure. The research involved analyzing the calcium nitrate content in the additive using analytical techniques. By characterizing these properties, the research provided valuable insights into the quality and suitability of calcium nitrate-based additives.

Additionally, this study aims to investigate the fresh and hardened properties of C-30 conventional concrete with varying dosages of calcium nitrate-based additive by evaluating workability, compressive strength, tensile strength, and water adsorption characteristics. Furthermore, the research involves calculating the production cost of concrete with the extracted calcium nitrate-based admixture from eggshells and chicken manure.

1.6 Significance of the Study

The construction industry is increasingly embracing sustainable practices to reduce its environmental impact and carbon footprint. As concrete stands as the primary building material, this study aims to bridge the existing knowledge gap by exploring eco-friendly alternatives for concrete production. By examining the utilization of calcium nitrate accelerator additives sourced from waste materials, this research seeks to offer a sustainable solution. These additives have the potential to decrease the reliance on chemical accelerators derived from fossil fuels, thereby paving the way for a more environmentally friendly and sustainable concrete industry.

1.7 Organization of research report

This thesis research paper consists of five chapters.

CHAPTER ONE: This chapter serves as an introduction and focuses on the background of the study, the statement of the problem, the objectives of the study, the scope of the study, the significance of the study, and the organization of the study.

CHAPTER TWO: This chapter is a literature review, concentrating on the effects of eggshell powder and chicken manure, the reaction mechanisms, chemical compositions, and their effects, along with characterization.

CHAPTER THREE: This chapter outlines the research methods, materials, mixing methods, and testing procedures and techniques to be demonstrated during casting.

CHAPTER FOUR: This chapter presents the results and discussions.

CHAPTER FIVE: This chapter summarizes the findings, presents conclusions, and offers recommendations.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Introduction

This chapter provides an indication of several approaches that scholars have used to address accelerator admixture and additives from natural and waste material sources in concrete. The primary target of this study is focused on accelerator admixture. The main objective of this chapter is to give a comprehensive overview of the recent studies concerning on the impacts of using nonrenewable resources for manufacturing process of calcium nitrate admixture and their alternative mechanisms. The different types of agricultural and poultry wastes are discussed in terms of their accessibility as sources of calcium and nitrate.

2.2 Overview of concrete and its main ingredients

Concrete is an artificial stone composed of cement, aggregates, water, and admixtures, plays a crucial role in civil engineering by providing the strength essential for diverse structural applications (Bamigboye et al., 2015). The strength of concrete is influenced by several key factors, including the type and amount of cement used the size and type of aggregates, the water-to-cement ratio, and the conditions under which it is cured, and the techniques employed for compaction (Elsharief et al., 2003). Achieving optimal concrete performance requires a careful balance of these ingredients, ensuring that the resulting mixture is not only structurally sound but also cost-effective, thus making concrete a practical choice for a variety of construction projects (Demissew, 2022).

2.2.1 Cement

The cement component in the construction industry has been extensively studied and analyzed. Its composition and properties play a crucial role in determining the performance and durability of concrete structures. Cement production begins with processing a combination of raw materials, including limestone for calcium, clay minerals and sand for silicon and aluminum, and iron-containing materials (J. P. John, 2020). Then, the row mix subjected to a temperature of around 1500 °C becomes a fine powder known as clinker (Oliveira et al., 2019). This process leads to the formation of various mineral phases, including alite (C3S), belite (C2S), aluminate (C3A), and ferrite (C2AF), which contribute to the overall strength and setting properties of cement (Darmanto & Amalia, 2020).

Table 2. 1 Major compounds of normal Portland cement

Cement compounds	Normal Portland cement by weight % **(Nuhu et al., 2020)**
Alite (C3S)	50-70%
Belite (C2S)	15-30%
Aluminate (C3A)	5-10%
Ferrite (C4AF)	5-15%

Cement Hydration

When water is incorporated into the cementitious materials, such as cement, and aggregates it initiates the chemical reaction known as hydration. The hydration of cement is a complex chemical process that transforms the powdered cement into a solid and durable material (Bahraq et al., 2022). The first step in cement hydration is the dissolution of cement particles in water. This process involves the release of various ions, including calcium (Ca^{2+}), hydroxyl (OH^{-}), and silicate (SiO_4^{2-}) (Qi et al., 2021) . The dissolved calcium and silicate ions undergo nucleation and precipitation reactions to form the primary hydration product, calcium silicate hydrate (C-S-H). C-S-H is responsible for the development of strength and stiffness in concrete (E. John et al., 2018). The formation of C-S-H involves the polymerization of silicate units and the incorporation of calcium ions, resulting in the formation of a gel-like structure (Zhang et al., 2012). During cement hydration, a significant amount of calcium hydroxide (CH) is also formed. This reaction occurs as a result of the excess calcium ions released from the dissolution of cement compounds (Bullard et al., 2011). CH is a crystalline compound that contributes to the long-term strength development of concrete. However, it is less chemically stable compared to C-S-H and can lead to potential durability issues, such as alkali-silica reaction (Shin et al., 2015). Another important reaction during cement hydration is the formation of ettringite (AFt). According to Jakob et al.(2019), this process takes place when C3A reacts with water in the presence of sulfate sources, primarily anhydrite, bassanite, and gypsum, as represented by the following equation:

$$\text{C3A + calcium sulfate + water} \rightarrow \text{ettringite.}$$

However, ettringite does not contribute to the strength of the concrete (A. Ahmed, 2019).

2.2.2 Aggregate

Aggregates used in concrete, classified as Fine aggregate (Sand) and Coarse aggregate (Gravel). Fine aggregate, also known as sand, plays a crucial role in the production of concrete by filling the voids between coarse aggregate particles, significantly influencing workability, strength, and durability (Fung & Kwan, 2014). The grading, shape, surface texture, and mineralogy of fine aggregate have been identified as key factors affecting the workability and strength of concrete (Fournari & Ioannou, 2019). The range of grain sizes for different types of sand are as follows: Coarse sand is between 0.6 and 2.0 mm, coarse-medium sand is between 0.2 and 0.6 mm, and fine-medium sand is between 0.06 and 0.2 mm (Atkinson, 2020). Moreover, the use of manufactured sand as a replacement for natural sand has gained attention, with studies indicating that it can produce concrete with comparable or even improved properties. Additionally, the incorporation of supplementary cementitious materials, such as sand with marble waist, in concrete mixtures has shown promising results in terms of enhancing the strength and durability of concrete (Yifru & Mitikie, 2020).

Coarse aggregate plays a critical role in concrete by affecting strength, durability, and workability. Several researchers have investigated the effect of coarse aggregates on the performance of concrete. According to Yılmaz (2022), different types of coarse aggregates including limestone, granite, and basalt were examined and the results showed that basalt aggregate exhibited the highest compressive strength and durability compared to the other types. In another study, researchers found that the shape of coarse aggregates in concrete mixture design significantly influences workability and mechanical properties, with angular aggregates increasing compressive strength and rounded aggregates enhancing workability (Oluwasola et al., 2020). It shows that importance of considering the shape of coarse aggregates when designing concrete mixtures. The range of grain sizes for coarse aggregate types is as follows: Coarse-gravel has a range of 20-60 mm, Coarse-medium Gravel has a range of 6.0-20 mm, and Fine-medium Gravel also has a range of 2.0-6.0 mm (Atkinson, 2020).

2.3 Admixture of concrete

Admixtures are used to enhancing the properties and performance of concrete structures. The historical background of admixtures dates back to ancient times, with the Romans using natural pozzolanic materials as admixtures (Moropoulou et al., 2005). In modern times, synthetic chemical admixtures have been developed and extensively researched, leading to the discovery of new types of admixtures and improved effectiveness in enhancing concrete properties. The benefits of using admixtures in cement concrete include improved workability, strength, durability, and the ability to meet specific project requirements (S Shah et al., 2014).

According to American Society for Testing and Materials (ASTM C494, 2013) chemical admixtures are categorizes into various types based on their intended use and the effects they have on concrete. The classification system helps in identifying and understanding the characteristics and benefits of different admixtures. The main types of chemical admixtures classified by ASTM include: Water-reducing admixtures (Type-A), Retarding admixtures (Type-B), Accelerating admixtures (Type-C), Water-reducing and retarding admixtures (Type-D), Water-reducing and accelerating admixtures (Type-E), Water-reducing, high range admixtures (Type-F), Water-reducing, high range, and retarding admixtures (Type-G), and Type S- Specific performance admixtures (ASTM C494, 2013).

2.3.1 Accelerating admixtures

Accelerator admixtures (Type C) are used to speed up the setting and hardening time of concrete. These admixtures function by increasing the rate of hydration, which is the chemical reaction between C3S and C3A with water that leads to the formation of the hardened concrete (Yuan et al., 2020). Type C admixtures typically contain one or more of the following chemicals: Calcium chloride ($CaCl_2$), Sodium nitrite ($NaNO_2$), Calcium nitrate ($Ca(NO_3)_2$), Triethanolamine (TEA), Sodium thiocyanate (NaSCN), and Alkali-free accelerators (ASTM C494, 2013). These compounds release ions that react with the cement particles, promoting the formation of hydration products and thus accelerating the strength development of concrete (Tao et al., 2021).

Calcium Chloride (CaCl2): It is a white, crystalline powder that is soluble in water. When added to concrete, it helps to speed up the hydration process, which is the chemical reaction between cement and water that forms the hardened concrete (Tao et al., 2021). However, it's important to note that while Calcium Chloride is an effective accelerator, it can have some drawbacks. It has the potential to cause corrosion of embedded steel reinforcement if used in excessive amounts or in concrete with a high water-cement ratio (Ahmad, 2003; Saeed, 2023).

Sodium nitrite (NaNO2): Sodium Nitrate is significantly effective in cold weather conditions when concrete takes longer to set and harden (Karagol et al., 2015). It provides a rapid initial set, preventing freezing and ensuring the concrete can be protected from the detrimental effects of low temperatures (Kothari et al., 2022). According to Liu's study conducted in 2020, sodium nitrite exhibited acceleration of concrete hydration but not as much as calcium chloride (Liu et al., 2020). It's important to note that Sodium Nitrate may have some limitations. It is occasionally employed as an accelerator in certain applications, but its usage is generally limited due to its poor efficiency in the reaction process and potential toxicity concerns.

Triethanolamine (TEA): Several studies have reported that the addition of TEA as an accelerator admixture can significantly improve the early-age strength of concrete. This is particularly beneficial in situations where early removal of formwork or rapid construction is required (Cuesta et al., 2023). Studies have shown that TEA does not adversely affect the compressive strength, chloride ion penetration resistance, or carbonation resistance of concrete when tested in appropriate conditions (Hirsch et al., 2021). It can be used in combination with other admixtures, such as water reducers and air-entraining agents, without any significant compatibility issues. TEA is considered a safe and environmentally friendly accelerator admixture for concrete (Cheung et al., 2011)

Potassium carbonate (K2CO3): The previous study examines the effects of potassium carbonate on the setting time and early strength development of concrete in cold weather conditions (Cheah et al., 2020). The authors provide experimental data from previous studies to support their findings. They discuss how the addition of potassium carbonate can significantly reduce the setting time of concrete, allowing for faster construction in cold weather conditions (Cheah et al., 2020).

Calcium formate ($Ca(HCOO)_2$): Calcium formate is a calcium salt of formic acid; several studies have investigated its effectiveness in speeding up the setting and hardening processes of concrete (Saedi et al., 2021). Researchers have found that the addition of calcium formate as an admixture significantly reduces the curing time, leading to improved early-age strength development of concrete structures (Rashad, 2023). Furthermore, Calcium formate has the advantage of being less corrosive to infrastructure and environmentally friendly (Sathiparan, 2021).

Sodium Thiocyanate (NaSCN): The demand for faster construction processes and reduced project timelines has led to an increasing interest in the development of accelerator admixtures (Ahmadi, 2023). The previous studies analyze the impact of NaSCN on workability, setting time, early age strength development, and long-term durability of concrete (Kothari et al., 2020). According to a study by Khan & Santha Kumar, the admixture of 8% calcium nitrate and 1.5%

sodium thiocyanate has a significant impact on enhancing the strength of concrete in cold weather conditions. This could be a useful solution to promote the use of concrete in such environments. The strength of concrete with the admixture increased by 414.14%, 469.11%, and 426.66% for 7 days, 28 days, and 56 days at -10 ◦C compared to the control mix concrete(Khan & Santha Kumar, 2021).

2.3.2 Calcium nitrate admixture ($Ca(NO_3)_2$)

Calcium nitrate ($Ca(NO_3)_2$) is a versatile compound commonly used in the construction industry as a chemical accelerator admixture to accelerate the hydration process of cement and enhance early-age strength development of concrete, as well as in agriculture as a fertilizer to provide essential nutrients, particularly calcium and nitrogen, to plants (Al-Dosary et al., 2022; Karagöl et al., 2013). Depending on the amount used, calcium nitrate can also function as a versatile concrete admixture with difference properties that can set accelerator, long term strength enhancer, inhibit corrosion and modify rheology (Justnes, 2010).

When neutral salts produced from the reaction of a strong base and a strong acid, such as calcium nitrate, are dissolved in water, they dissociate into their anions and cations, such as calcium ions (Ca^{2+}) and nitrate ions (NO_3^-) (Kičaite et al., 2017; Orwat et al., 2017; Renaudin et al., 2000). These NO_3^{2-} and Ca^{2+} ions are react with cement compounds to enhance the hydration of cement. According to Dorn et al., (2023), the NO_3^- ions influence the replacement of the sulfate ion (SO_4^{2-}) from mono-sulfoaluminate (SO_4^-AFm) to form nitrate-including AFm phases (NO_3^-AFm). The availability of SO_4^{2-} ion in the hydration of cement is contributes to the early development of ettringite (Balonis et al., 2011).

Scholars have found that the presence of Ca^{2+} cations in admixtures like calcium nitrite and calcium nitrate speeds up the hydration process by accelerating the onset of alite hydration and enhancing the hydration rate for belite (Kičaitė_2017_IOP_Conf._Ser. Mater.Sci.Eng.251 012017.Pdf, n.d.; Oey et al., 2015). The rapid saturation of the pore solution with portlandite occurs when $Ca(NO_3)_2$ dissolves, leading to the quick precipitation of portlandite, which in turn causes the early start and faster rate of alite hydration (Nicoleau, 2011).

Table 2. 2 Effect of calcium nitrate admixture on the setting time and compressive strength of concrete

Author	Title	Description	Findings
(Karagöl et al., 2013)	The influence of calcium nitrate as antifreeze admixture on the compressive strength of concrete exposed to low temperatures	The concrete samples, both with and without calcium nitrate admixture, were placed in molds and then immediately moved to deep freezes controlled at temperatures of -5°C, -10 °C, -15 °C, and -20 °C for periods of 7, 14, and 28 days. The uses of calcium nitrate in the study remained constant at 6wt % of the cement.	Compressive strength of concrete with $Ca(NO_3)_2$ increased by approximately 353%, 133%, 130%, and 137% after 7 days deep freeze curing at temperatures of -5°C, -10°C, -15°C, and -20°C, respectively. After a total of 35 days (7 days deep freeze curing plus 28 days water curing), the compressive strength increased by 47.78%, 97.93%, 114.85%, and 120.26% at the same temperatures compared to control samples. In low temperature, calcium nitrate admixture containing concrete can achieve the required strength by minimizing the effects of internal freezing and speeding up the hardening process.
(Rusu et al., 2023)	Analyzing the Effects of Calcium Nitrate over White Portland Cement: A Multi-Scale Approach	CEM I 52.5 R White Portland cement was used to produce concrete with and without $Ca(NO_3)_2$ admixture to measure its initial and final setting time in accordance with ASTM C 191-04 standards.	The initial setting time was reduced to 58% with respect to the control sample at 2% and 3% of admixture, while the final setting time was reduced to 57.9% with respect to the control sample for at 3% of admixture. The outcomes of tests results also for compression and flexural show that the inclusion of CN helps enhance the cement paste's strength at optimum value (2%).
(Yoneyama et al., 2021)	Effect of a Nitrite/Nitrate-Based Accelerator on the Strength	The researchers utilized Ordinary Portland cement, calcium nitrite ($Ca(NO_2)_2$), and calcium nitrate ($Ca(NO_3)_2$) that	Adding 11% of calcium nitrate/nitrite decreased the initial setting time by 46.72% and the final setting time by 45.57%, which can help improve issues like delayed setting and frost

	Development and Hydrate Formation in Cold-Weather Cementitious Materials	were readily available at a concentration of 45%. The early compressive strength test was conducted after 24 hours.	damage in cold-weather concrete projects. The strength of the concrete increased in proportion to the amount of admixture added, with increases of 148%, 184%, 211%, and 279% on CN13 with the addition of admixture at 7%, 9%, 11%, and 13%, respectively, compared to the control.
(Gök & Kılınç, 2015)	Effect of Calcium Nitrate, Triethanolamine and Triisopropanolamine on Compressive Strength of Mortars	The study evaluated impact of calcium nitrate, Triethanolamine (TEA), and Triisopropanolamine (TIPA) on the 7 and 28-day compressive strength of Portland cement concrete, using TS EN 12390 guidelines. Dosages were 1% calcium nitrate, 0.05% TEA, and 0.05% TIPA per weight of cement.	TEA admixture was discovered to decrease compressive strength by 7%, but when used in combination with calcium nitrate, a 22% increase in 7-day compressive strength was observed. However, using TIPA alone or with calcium nitrate produced no difference in 7-day compressive strength.
(Kičaite et al., 2017).	The influence of calcium nitrate on setting and hardening rate of Portland cement concrete at different temperatures	Portland cement CEM I-42,5R (CEM I R), limestone Portland cement CEM II A-LL 42,5 R (CEM II R) Setting time of normal consistency cement pastes was tested at different temperatures: +20 °C and +5 °C. The content of admixture was used 0 %,0.5 %, 1 %, 2 %, and 3 %	The addition of calcium nitrate admixture can significantly reduce setting time for cement pastes at higher temperatures, but the effect is reduced at lower temperatures. Proper dosage of admixture is crucial in achieving desired setting time reductions for different types of cements. The research found that calcium nitrate reduced the setting time of concrete about 20% at 20°C temperature. Additionally, the research showed that the initial and final setting time of cement pastes increased with a reduction in curing temperature to +5°C.

Source: Karagö (2013), Rusu (2023), Yoneyama (2021), Gök & Kılınç (2015), Kičaite(2017).

2.4 Concrete mix design

The process of determining both the type and amount of ingredients required for producing concrete that satisfies requirements like durability, strength, and workability is known as concrete mix design (Demissew, 2022). Workability, water-to-cement and binder ratio, material characteristics, and an extensive knowledge of matrix composition are all necessary for mix design. Each of these elements is extremely important in deciding how well the finished product performs (Khalaf et al., 2019).

ACI (American Concrete Institute) is a widely recognized standard for concrete mix design. According to a study conducted by Alizadeh, (2019) ACI provides a comprehensive approach to mix design, taking into account factors such as desired strength, durability, and workability (Alizadeh, 2019). The ACI method utilizes a combination of laboratory testing and statistical analysis to determine the optimal proportions of cement, aggregates, and water. The study found that the ACI mix design method resulted in concrete with consistent and predictable performance, meeting the specified requirements for strength and durability(Alizadeh, 2019). The Ethiopian Building Code of Standards (EBCS) is a national standard used in Ethiopia for concrete mix design. A comparative study by Demissew, (2022) evaluated the performance of EBCS in comparison to other international standards, including ACI, British Department of Environment (DOE), and Indian standard (IS) methods. In comparison to the other methods for producing C-25 grade concrete, the study concluded that the EBCS method is not cost-effective since it requires a large amount of cement per cubic meter, ranging from 12.2 kg/m3 to 52.2 kg/m3 (Demissew, 2022). The researchers recommended that the EBCS be revised to incorporate a more holistic approach to mix design, considering various performance parameters to ensure the long-term durability of concrete structures.

The DOE method for concrete mix design has been widely used in the construction industry for several decades. This method relies on empirical relationships derived from extensive testing to determine the optimal proportions of cement, aggregates, and water in a concrete mixture. Similar to ACI methods, the process of determining the water/cement ratio establishes the goal strength of the DOE approach (Zanwar & Jamkar, 2016). Research on sustainable concrete has demonstrated the effectiveness of DoE methodologies in terms of concrete qualities, the impact of substituting materials, and the advancement of the concrete mix design (Chong et al., 2021).

Furthermore, the previous study found that the DOE method is the most expensive approach and generates a dense mix from the ACI and Fineness Modulus Methods (FM) of designing concrete mixes (M. Ahmed et al., 2016).

The IS for concrete design is provides guidelines for the design and construction of reinforced concrete structures in India. It covers a wide range of aspects, including material properties, mix design, structural design, and construction practices. One notable difference is that the IS approach yields more strength compared to the ACI method for concrete with less strength, or M25 concrete. The ACI technique combination yields more strength compared to the IS method for greater amounts of M35 and M45 (Kumar et al., 2017).

2.5 The use of agro-waste in chemical admixture of concrete

The utilization of agricultural waste as chemical admixtures in concrete has gained significant attention in recent years due to its potential to enhance the properties of concrete while addressing environmental concerns (Luhar et al., 2019). Several studies have explored the utilization of various agricultural waste materials, such as rice husk ash, sugar cane bagasse ash, palm oil fuel ash, and animal manure can used as supplementary of cementitious material on the properties of concrete. These waste materials not only improve the properties of concrete, but also a major contributor to carbon emissions (Mark et al., 2019). A study by (Endale et al., 2023) investigated the effect of incorporating rice husk ash (RHA) as a partial replacement for cement in concrete. The researchers found that RHA significantly improved the compressive strength of the concrete. They attributed this enhancement to the pozzolanic reaction between RHA and calcium hydroxide, which resulted in the formation of additional calcium silicate hydrate (C-S-H) gel, the main binding phase in concrete. Moreover, the presence of RHA enhances the durability of concrete and resistance to aggressive environments. Similarly, another study by (Andrade Neto et al., 2021) explored the use of sugar cane bagasse ash (SCBA) as a partial replacement for cement in concrete. The researchers observed that SCBA incorporation led to an increase in the compressive strength and improve the formation of additional C-S-H gel. Additionally, the use of SCBA reduced the heat of hydration and improved the resistance to chloride ion penetration, making the concrete more durable in aggressive environments. Palm oil fuel ash (POFA) has also been investigated as a potential agricultural waste material for concrete production. A study by (Sanawung et al., 2017) examined the effect of POFA as a partial replacement for cement on the durability properties of concrete. The researchers found that the incorporation of POFA improved the water permeability resistance and reduced the chloride ion penetration of concrete.

Animal manure, a common agricultural waste material, has gained attention as a potential source of chemical admixture in concrete production. In a review study conducted by (Vishwakarma & Ramachandran, 2018), The effect of using CDA as a partial replacement for cement in concrete was observed by the researchers when they used energy-dispersive X-ray spectroscopy (EDS) to compare the weight percentages of OPC and cow dung ash (CDA) for various elements. CDA's basic nature revealed a higher silica content than OPC. The findings indicated that CDA might be added to enhance workability and durability or serve as an extra binder.

The utilization of eggshell powder (ESP) as a chemical additive in concrete has been studied by different scholars. Like cement, eggshell powder also has a significant calcium percentage in its chemical composition. The calcination temperature, treatment method, and grinding process all have a major effect on the chemical content of the ESP. Most of the $CaCO_3$ present in an eggshell changes into calcium oxide (CaO) at temperatures between 700 and 800 °C as a result of calcination (Sathiparan, 2021). The results of the study indicate that the high level of calcium and positive filling result of eggshell powder have several benefits, such as enhanced hardening qualities, shortened setting times, accelerated hydration, and greater resistance to carbonation and water penetration (Chong et al., 2020).

2.6 Chicken manure as nitrogen source material

Animal manure contains organic nitrogen (N), which is a mixture of proteinaceous molecules, purines, nucleic acids, uric acid, and other N-containing compounds that are converted to NH4+ by enzymatic hydrolysis and made available to crops (Whalen et al., 2019). Several studies have also demonstrated that chicken manure contains a substantial amount of nitrogen (Y. Li et al., 2022) carried out a thorough investigation of the nutritional makeup of chicken manure. They discovered that a significant amount of nitrogen is present in chicken manure. They also observed that the manure that was collected from a company had the following characteristics: 22.82% ±0.03 total solids (% fresh matter), 19.94%±0.1 volatile solids (% fresh matter), 39.42% ±0.9 carbon (% total solids), 5.53% ±0.01 hydrogen (% total solids), 7.32%±0.6 nitrogen (% total solids), and 5.4±0.5 carbon/nitrogen ratio. The other researchers similarly found that urea and protein forms of nitrogen are prevalent in chicken manure, making for 30% and 70% of the total nitrogen contents, respectively. Chicken manure is a great source of nitrogen, which is necessary for plant growth because of its high amount (Shapovalov et al., 2020).

The material characterization results confirm the findings, Greenhouse gas emissions might be decreased, and value-added production could occur from the nitrogen extracted from chicken manure digestate to produce concentrated nitrogen fertilizer. Chicken dung is currently used as a co-substrate by several agricultural wet digestion biogas facilities. Nevertheless, the feedstock's high sand and nitrogen contents can cause biological and technical process issues when used on a large scale, which is why mono-digesting chicken manure in farm biogas facilities has proven to be quite difficult (Wedwitschka et al., 2020).

2.7 Chemical Extraction method of Calcium from waste material

There is several chemical extraction methods commonly used to obtain calcium oxide (CaO) from eggshells. These methods involve the use of chemical reactions to convert calcium carbonate ($CaCO_3$) present in the eggshells into calcium oxide.

2.7.1 Thermal decomposition

This is one of the simplest methods used to extract calcium oxide from eggshells. In this method, eggshells are heated at high temperatures (around 800-1000°C) in a controlled environment, such as a furnace or kiln (Ontiveros-Ortega et al., 2018). The heat causes the calcium carbonate in the eggshells to undergo thermal decomposition, resulting in the formation of calcium oxide and the release of carbon dioxide gas. Thermal decomposition is a simple and straightforward method of chemical extraction (Karunadasa et al., 2019). It requires minimal equipment and chemicals, making it a cost-effective option (Kaur & Singh, 2023). Additionally, it can be performed at relatively low temperatures, reducing energy consumption. However, there are some disadvantages to consider. If the temperature is not controlled properly, it may result in impure calcium oxide. Furthermore, thermal hazards must be taken into account, and careful handling is required. Lastly, there is a possibility of losing some calcium carbonate due to incomplete decomposition (Car et al., 2022).

2.7.2 Acid-base reaction

Another common method is to use an acid-base reaction to extract calcium oxide from eggshells. In this method, the eggshells are first crushed into a fine powder. The powder is then mixed with an acid, such as hydrochloric acid (HCl) or acetic acid (CH_3COOH). The acid reacts with the calcium carbonate, producing calcium chloride or calcium acetate and carbon dioxide gas. The resulting solution is then heated or evaporated to remove the excess liquid, leaving behind calcium chloride or calcium acetate (Jony et al., 2021). These compounds can be further heated to obtain calcium oxide. The acid-base reaction method of chemical extraction is accessible and can be performed using readily available household materials, such as vinegar or lemon juice (Choi et al., 2016). This makes it a convenient option for those without access to specialized equipment. It does not require high temperatures, minimizing the risk of thermal hazards. However, there are some drawbacks to consider. The presence of other substances in the acid used may result in impure calcium oxide. The reaction may also be slow, requiring extended periods of time for complete reaction. Additionally, acids must be handled with care to avoid skin irritation or other hazards (Ooi et al., 2021).

2.7.3 Solvent extraction

This method involves using a solvent to dissolve calcium carbonate from the eggshells, followed by evaporation or precipitation to obtain calcium oxide. Organic solvents, such as ethanol or acetone, can be used to dissolve the calcium carbonate (Yilmaz et al., 2019). The eggshells are first clean and crushed into a fine powder and then mixed with the solvent. The mixture is stirred or shaken to ensure proper dissolution of the calcium carbonate. Afterward, the solution is filtered to remove any solid impurities. The solvent is then evaporated or precipitated to obtain calcium oxide. Solvent extraction is a method that can yield relatively pure calcium oxide. It allows for the removal of impurities present in the eggshells, resulting in a higher quality product (Habte et al., 2019). The use of organic solvents, which are readily available, makes it a practical option. However, there are some disadvantages to be aware of additional steps, such as filtering and evaporating the solvent, are required in the solvent extraction method, which can increase the complexity and time required for the process. Organic solvents can be flammable and may require careful handling and storage. There is also the possibility of solvent contamination in the final product, which may require additional purification steps (Teagarden & Baker, 2002). Lastly, solvent extraction can be more expensive compared to thermal decomposition or acid-base reactions due to the cost of solvents and additional equipment needed.

2.8 Biological Extraction method of Calcium from waste material

Biological extraction method can be used to obtain calcium oxide from eggshells. Two commonly used methods are enzymatic extraction and microbial extraction.

Enzymatic extraction: In this method, enzymes such as proteases are used to break down the proteins in the eggshell. The eggshells are crushed and then treated with an enzyme solution (Pinandita Faiz, 1998). The enzymes degrade the proteins, allowing for the release of calcium carbonate. The calcium carbonate can then be further processed to obtain calcium oxide.
Microbial extraction: Microorganisms like bacteria or fungi can be used to degrade the organic matrix of the eggshell. These microorganisms produce enzymes that break down proteins. The eggshells are treated with a culture of these microorganisms, which gradually degrade the organic matter and release calcium carbonate. The calcium carbonate can be processed to obtain calcium oxide (Smith & Hayward, 2010).

Both enzymatic and microbial extraction methods are more sustainable and environmentally friendly compared to chemical extraction methods. However, they may require longer extraction times and additional steps for purification and drying of the resulting calcium oxide (Yadav et al., 2021).

2.9 Extraction method of Nitric acid from waste material

Extracting nitric acid directly from chicken manure in a laboratory setting is not a common practice. While chicken manure contains nitrogen compounds, primarily in the form of organic matter, the process of converting these compounds into nitric acid involves several steps, including the conversion of organic nitrogen into inorganic nitrogen compounds, such as ammonia (NH3), and then further processing to obtain nitric acid (Ghaly Ae & Ramakrishnan Vv, 2015).

2.9.1 Acid digestion technique

Acid digestion is a laboratory technique used to break down organic and inorganic samples into their elemental or molecular components using strong acids. The choice of acid or acid mixture for digestion depends on the nature of the sample and the analyses of interest. For example, hydrochloric acid (HCl) is commonly used for the digestion of inorganic samples, while nitric acid (HNO3) is effective for both organic and inorganic samples (ZHu & LQi, 2013). In some cases, a mixture of acids may be used to enhance the digestion process.

Chicken manure contains significant amounts of nitrogen, mainly in the form of organic nitrogen compounds such as proteins and urea. When the strong acid, such as sulfuric acid (H2SO4), is added to the chicken manure, it reacts with the organic nitrogen compounds present in the manure. The acidification step helps to break down the proteins and urea into their constituent amino acids and ammonia. Once the organic nitrogen compounds are broken down, the next step involves oxidizing the resulting ammonia and amino acids to form nitric acid (HNO3) (Matsumura et al., 2021). This oxidation reaction is facilitated by the presence of excess acid and heat during the digestion process. Once the digestion mixture is neutralized, the nitric acid can be separated from the solution using various separation techniques, such as distillation and solvent extraction. The extracted nitric acid can then be further purified after neutralizing the digestion mixture; the separation of nitric acid can be carried out using different techniques distillation and solvent extraction method (Journal & Meshram, 2019).

2.9.2 Steam distillation

Steam distillation is a technique used to separate volatile compounds from non-volatile substances, primarily in the field of chemistry. It involves the use of steam to carry and vaporize the volatile components, which are then collected and condensed to obtain a purified product (Batool et al., 2018). The distillation method is commonly used after the acid digestion process; the resulting solution contains various nitrogen compounds, including nitric acid. It is a separation technique that utilizes the different boiling points of substances to separate them. In this case, the solution is heated in a distillation apparatus, and as the temperature rises, the nitric acid vaporizes. The vapor is then condensed and collected separately, leaving behind the other compounds in the solution (de Mello et al., 2020). This process allows for the isolation and purification of nitric acid from the chicken manure solution.

The distillation method offers several advantages in extracting nitric acid from chicken manure. Firstly, it allows for the concentration of nitric acid, as the process separates it from other compounds present in the solution. This concentrated nitric acid can then be used in various industrial applications, such as in the production of accelerator additive or explosives. Additionally, distillation is a widely utilized and well-established technique, making it a reliable method for extracting nitric acid (Matheswaran et al., 2007). However, it is important to note that the distillation process should be carried out with caution, as nitric acid is highly corrosive and can be hazardous if mishandled. Proper safety measures, such as wearing protective clothing and working in a well-ventilated area, should be followed to ensure the safety of the operators. In conclusion, the distillation method is an effective way to extract nitric acid from acid-digested chicken manure. It allows for the concentration and purification of nitric acid, making it suitable for various industrial applications (Gopalaswami & Han, 2020). However, it is crucial to prioritize safety and follow proper protocols when performing the distillation process to avoid any potential hazards.

2.9.3 Solvent extraction

Acid digestion techniques and distillation may break down or separate the sample into its constituent components, but they do not always provide selectivity in isolating specific compounds. Solvent extraction allows for the selective extraction of desired components from the digested or distilled sample (Kokosa, 2019). By using appropriate organic solvents, specific compounds can be dissolved and separated from the mixture, enhancing the purity and concentration of the target compound. Solvent extraction of chicken manure is a process that aims to recover valuable components from the manure, such as nutrients and organic matter. The mechanism of this extraction involves the use of solvents that selectively dissolve and separate the desired components from the solid waste (X. Li et al., 2020). In this case, the solvent is typically an organic solvent, such as ethanol or methanol, which has a high affinity for the organic compounds present in the manure.

When selecting solvent chemicals for separation processes, factors such as cost and environmental impact should be taken into consideration (Clark et al., 2009). In the case of separating nitric acid from water and impurities, hexane, diethyl ether, and toluene are all viable options that can be evaluated based on these factors (Dabrowski, 2016).

To extract the valuable components, the chicken manure is first mixed with the solvent, allowing the organic compounds to dissolve into the liquid phase. This step is usually facilitated by mechanical agitation or stirring. The mixture is then separated into two phases: the solid phase, which contains the remaining un-dissolved waste, and the liquid phase, which contains the dissolved components. The liquid phase, also known as the extract, is then further processed to separate and recover the desired components. This can involve techniques such as evaporation or distillation to remove the solvent and concentrate the extracted compounds (Ballesteros-Gómez et al., 2010). Overall, the solvent extraction of chicken manure offers a promising method for recovering valuable resources from waste, contributing to the sustainable management of agricultural byproducts.

2.10 Research Gap

Previous research has focused on utilizing both industrial and agricultural wastes such as rise husk ash, eggshells, slag, and fly ash for concrete admixtures and additives. However, there is a research gap in exploring the extraction of calcium nitrate-based additives from chicken manure and eggshells. Despite the significant nitrogen content in chicken manure and the presence of calcium oxide or calcium carbonate in eggshells, no studies have been conducted on extracting calcium nitrate-based additive from these sources.

Extracting calcium nitrate from waste and recycled materials offers sustainable and cost-effective solutions by recycling valuable resources and reducing waste and pollution. This approach offers several benefits (Rujitanapanich et al., 2014). Firstly, it reduces the extraction of natural resources, helping to conserve them for future generations. Secondly, it minimizes waste generation by utilizing materials that would otherwise be discarded. Lastly, extracting calcium nitrate from waste and recycled materials can potentially lower production costs, making it a more economically sustainable option (Sandanayake et al., 2020). Overall, extracting calcium nitrate from waste and recycled materials aligns with the principles of a circular economy. It supports environmental conservation, resource efficiency, and economic sustainability.

Investigating the use of calcium nitrate-based additive derived from chicken manure and eggshells could provide insights into its impact on the properties of concrete, such as fresh, hardened, mechanical, and durability characteristics. Investigating how this unique additive influences concrete properties can contribute to the development of innovative and environmentally friendly construction materials. By addressing this research gap, that possible to advance the knowledge in sustainable construction materials and contribute to the development of innovative solutions for the concrete industry.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Introduction

This chapter includes a brief description of the experimental guidelines, sample preparations, material types and qualities, and test settings as per standard that were carried out on the performance and durability of calcium nitrate-based accelerator additive derived from eggshells and chicken manure in C-30 grade of concrete. The construction engineering laboratory at Adama Science and Technology University (ASTU) was the location of the material preparations, tests, and detailed experimental programs. The material qualities and testing were verified using the criteria outlined as per standards and specifications.

3.2 Materials, and chemicals

Waste eggshells, chicken manure, cement, fine and coarse aggregates, distilled water, Sulfuric acid (H_2SO_4), calcium hydroxide ($Ca(OH)_2$) or lime, beakers, filter paper, funnel, hot plate, mortar and pestle, stirring rod, Pycnometer, oven drying, pH meter, thermometer, distillation apparatus, ice bath are the materials, and chemicals employed in this study.

3.2.1 Cement

This experimental study was used commercially available National Ordinary Portland Cement (OPC) with CEM I 42.5N, which has a great contribution to the strength of concrete after completing the desired hydration process by reacting with water.

3.2.2 Fine aggregate

For this study, the source of fine aggregate was natural sand from lakes and rivers. The fine aggregate that passed through a 4.7-mm sieve but remained on a 0.07-mm sieve was selected. It was washed to eliminate any silt content. The fineness modulus of the sand used was 2.97, which was within the acceptable range according to ASTM-C136.

Figure 3. 1 Fine aggregate

3.2.3 Coarse aggregate

Aggregates larger than 4.75mm, on average, have a diameter of 9.5–37.5 mm, making them coarse aggregates. Stones such as boulders, cobbles, or large-size gravel can be crushed to create coarse aggregate (Tam et al., 2021). For this experiment, a coarse aggregate measuring 20mm made from crushed basaltic rock was obtained from a nearby material provider. The unit weight of the coarse aggregate was measured at 1680.95, which met the ASTM C 29 standard requirements.

Figure 3. 2 Coarse aggregate

3.2.4 Water

Clean tap water is essential for mixing concrete specimens because it activates the hydration process in cement. The water from the Civil Engineering Construction Laboratory at Adama Science and Technology University was used in all mixes and curing for this study.

3.2.5 Chicken manure

Historically, chicken manure has been utilized as an organic fertilizer in agriculture (Bai et al., 2021). It is cheap and readily available, making it a preferred additive for extracting nitrates from nitrogen. For this study, chicken manure was collected from the poultry farm in Arsi Eteya, Ethiopia and treated using the anaerobic digestion method. The photo-metric test results analyzed by the Oromia Engineering Corporation laboratory showed that the chicken manure had a good concentration of nitrate and nitrite, making it a viable option as a source.

Figure 3. 3 Chicken manure

3.2.6 Hen's egg shell

The study looked into the possibility of using eggshells as a calcium oxide source. 95% of the eggshell was made up of calcium carbonate ($CaCO_3$), along with other important elements like boron and strontium (Arnold et al., 2021). The eggshells were collected from a nearby hotel and restaurant in Adama city. In order to extract the calcium content in the form of calcium carbonate, it went through a number of treatment procedures. The purity, concentration of the resultant calcium oxide for use as a concrete accelerator additive was then examined. The results of this investigation offered significant perspectives on the application of eggshells as an affordable and sustainable calcium oxide source, hence aiding in the creation of environmentally and financially sound substitutes within the calcium nitrate demands.

Figure 3. 4 waste eggshell

3.3 Research Methods

The research method was crucial to successfully accomplishing the objectives of the study. The research output was interpreted and discussed in this study using both qualitative and quantitative design methodologies. This included the mix design, laboratory test procedure, extraction technique for calcium nitrate base additive, and study design. A design for experimental research was used, which made apparent the steps and types of tests carried out in order to achieve the research objectives.

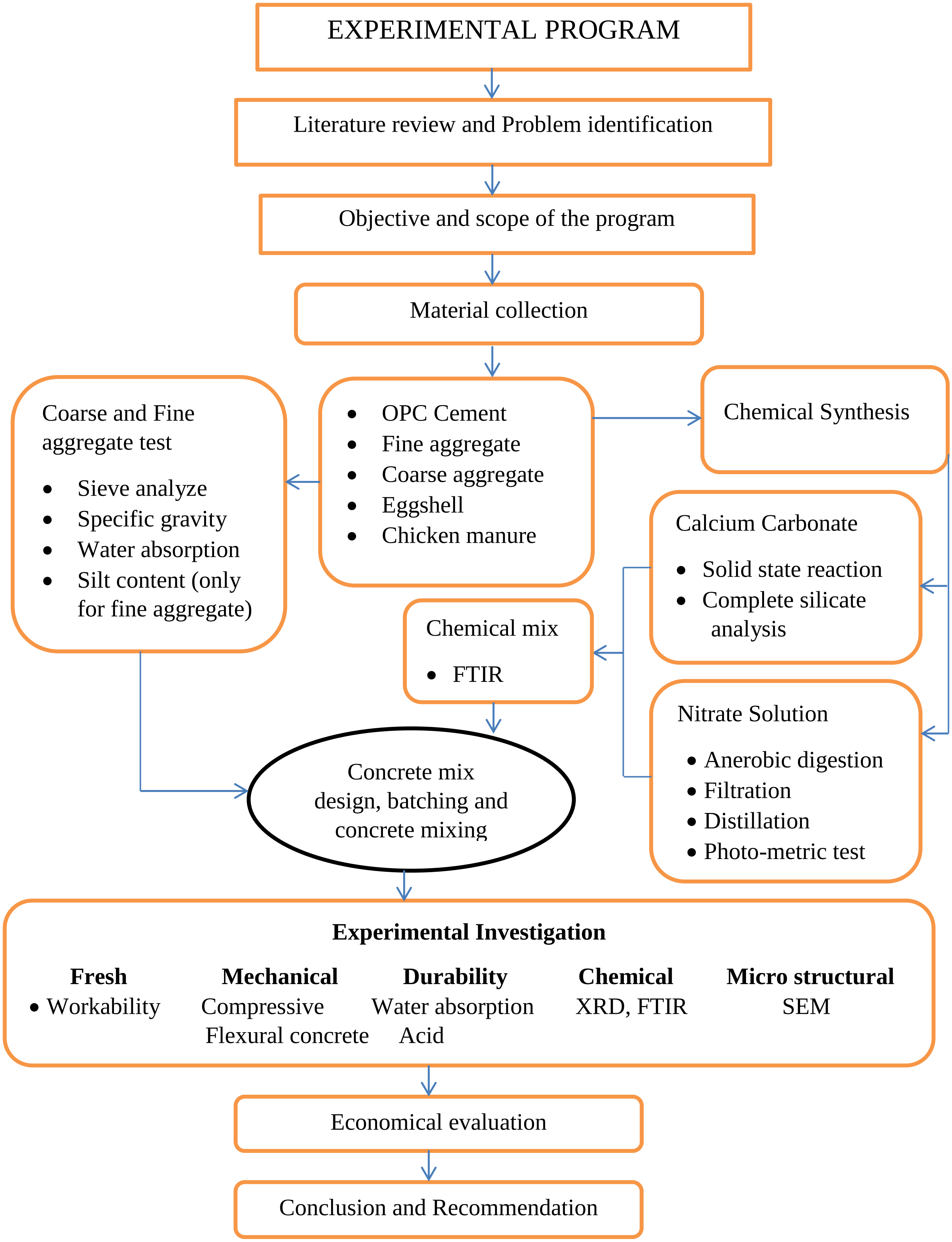


Figure 3. 5 Research design structure

3.4 Physical property test of fine aggregate

Testing the physical properties of fine aggregate is crucial to ensure the quality and performance of concrete in construction projects. It helps in selecting the right materials and proportions for concrete mixes that meet the desired specifications and standards. In this section, tests for fine aggregate on silt content, sieve analysis, unit weight, specific gravity, and water absorption properties are investigated.

3.4.1 Silt content of fine aggregate

Sand, which was one ingredient for concrete, contained various things like silt, clay, and dust. The excess of these particles had a negative impact on the strength of the concrete. Therefore, it was important to ensure that the silt content of the sand used was only as much as allowed. This study was performed for silt content measurement according to ASTM C117. The procedures of silt content are listed in Appendix 1c.

Figure 3. 6 Silt content of fine aggregate

3.4.2 Sieve Analysis of Fine Aggregate

A crucial method for ensuring uniformity and particle size distribution is sieve analysis, which involves passing the fine aggregate through a succession of sieves with progressively finer mesh sizes to separate the various fractions. The ASTM standard states that the strength of concrete is dependent on the quantity and quality of fine aggregate in the mix. Inconsistent sizes and distribution of sand particles can result in variations in the concrete mix, potentially hindering the ability to reach the desired strength level. The present study tests for sieve analysis, carried out according to ASTM C136, used a range of IS sieves, ranging from 4.75 mm, 2.36 mm, 1.18 mm, 0.6 mm, 0.3 mm, 0.15 mm, to the pan size, in order to ascertain the fineness modulus of the fine aggregate. The procedures of grading fine aggregate are listed in Appendix 1d.

Figure 3. 7 Sieve for sand

3.4.3 Unit Weight, Specific Gravity, and Water Absorption of Fine Aggregate

The key characteristics that define the nature and behavior of fine aggregate in construction materials are unit weight, specific gravity, and water absorption. Unit weight, also known as bulk density, represents the weight of aggregate per unit volume, including any voids present. Specific gravity is a dimensionless ratio obtained by comparing the density of the aggregate with that of water. The water absorption capacity of the aggregate can influence the workability and durability of concrete mixes. These properties are crucial for evaluating the performance and suitability of fine aggregate in various construction applications, aiding in concrete mix design and quality control. In this study, the ASTM C128 standard was utilized to determine the specific gravity and water absorption capacity of the fine aggregate.

Unit Weight of Fine Aggregate (UWFA) Test Procedure

1) Pour the measuring cup with a third of its capacity, and then smoothen the top using your fingertips. Compress the aggregate layer with 25 firm strokes, ensuring the tamping rod covers the surface evenly. Next, fill the container up to two-thirds, level it, and compact it as directed earlier. Finally, continue filling the measuring cup until it spills over, then compact it as previously advised.
2) Smooth out the aggregate surface with your fingertips, ensuring that any little ridges in the aggregate match the large spaces below the top surface of the measure.
3) During the initial layer's consolidation, avoid forcefully striking the measure's bottom with the rod. For subsequent layers, apply gentle pressure to allow the tamping rod to penetrate the underlying aggregates.
4) Upon measuring the fine aggregate, unit weight of fine aggregate is equal to the sum of the fine aggregate weight and cylinder weight, minus the weight of the empty cylinder, all divided by the cylinder volume.

Specific Gravity and Water Absorption of Fine Aggregate

During the experiment following ASTM C128 standard for specific gravity and water absorption of fine aggregate, it was noted that the specific gravity of the fine aggregates tested fell within the acceptable range of 2.5 to 2.7. Additionally, the water absorption for concrete aggregate also met the criteria as it did not exceed the specified limit of 3%. This adherence to the ASTM standard ensures that the fine aggregates used in concrete production have the proper characteristics necessary for optimal performance and durability in construction applications.

Preparation of the Test Specimen:

1) About 1 kilogram of the fine aggregate was readied.
2) The sample was dehydrated at 110^{o} C until reaching a consistent weight in an appropriate container. Let it cool for a full day and then saturate it.
3) The surplus liquid was poured off cautiously to prevent fine particles from being lost, spreading the specimen on a level, non-absorbent area under the influence of a softly flowing stream of warm air.
4) The specimen underwent regular mixing to ensure uniform evaporation, reaching the point of saturated surface dryness through the cone method to assess surface moisture.

5) Secure the mold tightly on a flat, impermeable area with a wide circumference. Add a segment of semi-dried fine aggregate gently into the mold by filling it to the edge and piling extra materials beyond the mold's top.
6) Carefully press down on the sand within the mold using the tamper, ensuring 25 gentle taps from a height of 5 mm above the sand's surface.
7) Adjusted the top layer by removing excess sand and lifted the mold vertically. If there was any remaining moisture, the sand held its form. When the sand settled a bit, it signaled that it had achieved the saturated-surface-dry state.

Specific Gravity of Fine Aggregate Procedure:

To conduct the specific gravity test, the initial step involved weighing the sample in the saturated surface condition at 500 grams. Subsequently, the Pycnometer was partially filled with water, and 500g of aggregates in the saturated surface dry state were added to the container. The Pycnometer was then filled with additional water until it reached 90% of its total volume, followed by a gentle shaking to eliminate any trapped air pockets. The next step was to immerse the Pycnometer in a temperature-controlled water bath set at 23°C for 60 minutes. Upon completion, the liquid volume inside the Pycnometer was adjusted to its designated limit, and the combined mass of the pycnometer, sample, and liquid was determined. Subsequently, the fine aggregate was dried in an oven at 105°C until a stable weight was achieved, then cooled in ambient air for an hour before measurements were taken. The final measurements were recorded after weighing the Pycnometer at 23°C with its full water capacity.

Figure 3. 8 Pycnometer

The Bulk Specific Gravity of fine aggregate can be calculated by dividing the weight of the saturated surface-dry specimen by the sum of the weight of the water-filled pycnometer and the weight of the saturated surface-dry specimen minus the pycnometer weight with the specimen and water to the calibration mark.

The Apparent Specific Gravity of fine aggregates is calculated by dividing the weight of the oven-dry specimen in air by the weight of the water-filled pycnometer added to the weight of the oven-dry specimen in air minus the pycnometer weight with specimen and water to the calibration mark.

The equation for water absorption is calculated by subtracting the weight of the oven-dry specimen in air from the weight of the saturated surface-dry specimen, then dividing that by the weight of the oven-dry specimen in air and multiplying by 100%.

3.5 Physical property of Coarse Aggregate

3.5.1 Sieve Analysis of Coarse Aggregate

In order to obtain optimal performance, the fineness modulus is an important factor in the design of concrete mixes. It ensures that the particle sizes are distributed appropriately. The coarse aggregate obtained from the local quarry should be tested against gradation to determine its particle size distribution. To determine the fineness modulus of the coarse aggregate, the testing procedure followed the rules outlined in ASTM C136. The following equipment was used: a set of IS sieves with sizes ranging from 20 mm, 19 mm, 12.5 mm, 9.5 mm, 4.75 mm, and pan; 2 kg of coarse aggregate; a balance for weighing; a sieve shaker for the sieving process; a shovel for handling the aggregate; and a sieve brush for cleaning the sieves. The procedures of Sieve Analysis of Coarse Aggregate are listed in Appendix 1e.

3.5.2 Unit Weight, Specific Gravity, and Water Absorption of Coarse Aggregate

The unit weight of coarse aggregate, expressed in kilograms per cubic meter (kg/m^3), signifies the weight of a unit volume of aggregate material and is crucial for determining the volume occupied by the aggregate within a given space. Specific gravity, a dimensionless quantity representing the ratio of the weight of a certain volume of aggregate to the weight of an equal volume of water, offers insights into the density and compactness of the aggregate. Water absorption, indicating the percentage of water absorbed by the aggregate when immersed for a set period, reflects the porosity and permeability of the material, affecting concrete workability and durability. Following ASTM standards, specific gravity and water absorption were calculated, with aggregate unit weights typically ranging between 1200 and 1750 kg/m³ (ASTM C29).

Figure 3. 9 Unit weight measurement (10 litter cap)

Unit Weight of Coarse Aggregate (UWCA)

1) Fill the measuring cup one-third full and level the surface pack with 25 strokes. Add more material to the two-thirds capacity level pack. Top off until overflowing pack again.
2) Smooth the surface of the aggregate in the measuring cup to ensure large pieces balance voids below the top of the measure.
3) While compacting the first layer, avoid striking the bottom of the measure forcefully. For the second and third layers, use just enough force to penetrate the previous layers.
4) A measurement of the coarse aggregate was made, and the data was documented appropriately.

$$\text{Unit Weight of Coarse Aggregate} = \frac{X - Y}{V}$$

Where: X = aggregate plus cylinder weight

Y = Weight of the empty cylinder

V = Volume of the cylinder (m^3)

Test Procedures

1. Sample Collection: The researcher takes the sample of coarse aggregate using a sample splitter.
2. Sieve Analysis: The sample is sieved with a 4.75 mm sieve. Any material passing through the 4.75 mm sieve is disregarded.
3. Washing of Sample: The sample is washed thoroughly to remove any dust particles.

4. Oven Drying: Place the washed sample in an oven set at 105°C for 24 hours.
5. Weighing after Drying: After 24 hours, remove the sample from the oven and allow it to cool. Measure and record the weight of the dried sample.
6. Submersion in Water: Submerge the sample in water for 24 hours.
7. Drying after Submersion: Remove the sample from water and roll it in a large absorbent cloth to remove excess water.
8. Saturated Surface Dry (S.S.D) Condition: Weigh the sample in its S.S.D condition.
9. Determination of Weight in Water: Immediately place the S.S.D sample in a sample container. Determine the weight in water at 23°C and record the data.

Bulk Specific Gravity of Coarse aggregate = $\frac{G}{G-F}$

Apparent Specific Gravity of Coarse aggregates = $\frac{H}{H-F}$

Water absorption =$\frac{G-H}{H} * 100\%$

H-F = (G - H)/H * 100 %

Where: H: Weight of air-dried oven-dried specimen

G: Weight of the saturated surface-dry specimen

F: Pycnometer weight with specimen and water to calibration mark

3.6 Water Test

Maintaining proper pH levels in the water used for mixing and curing concrete is crucial to avoid negative effects on the final product. Employing a pH meter enables accurate monitoring and regulation of the water's pH throughout the concrete production process. Following the specified procedure of preparing the water sample, calibrating the electrode, immersing it in the sample, and recording the pH reading allows concrete to proactively manage any potential issues related to water pH. The researcher used a pH meter to evaluate the pH levels of both the mixing and curing water in the concrete. This process included preparing the water sample, immersing the electrode in a buffer solution, inserting it into the sample, and documenting the pH levels as part of the testing protocol.

3.7 Synthesis of Calcium Carbonate from Waste Eggshells

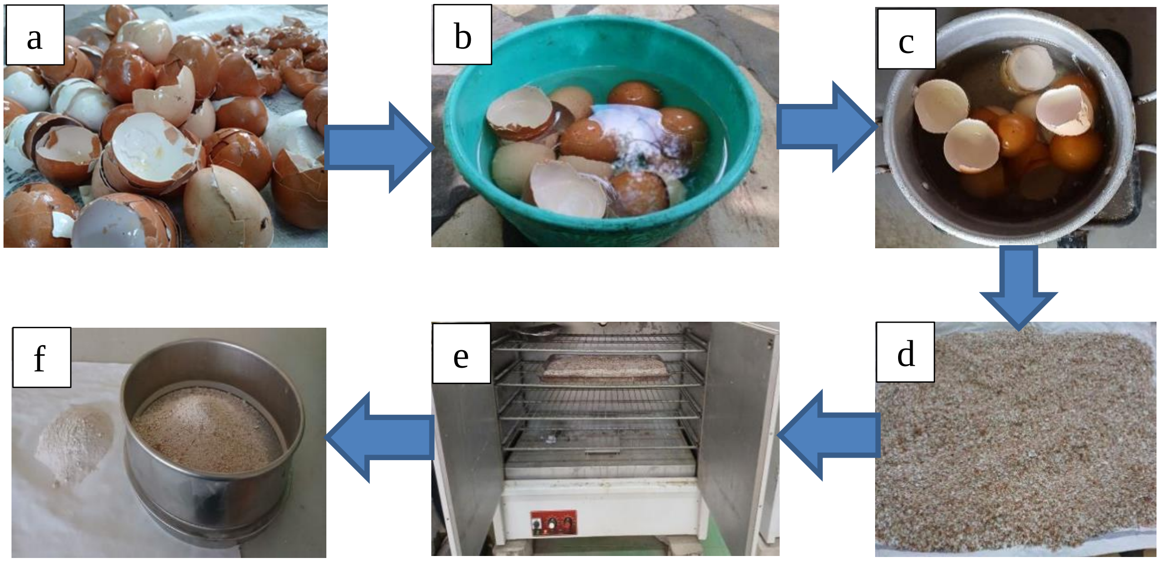
The researcher utilized eggshells through the solid-state reaction technique to extract calcium carbonate, which serves as a source of calcium ions (Ca^{2+}). These calcium ions combine with nitrate ions to form calcium nitrate. When calcium carbonate is added to a nitrate solution, it reacts with the nitrate ions to produce calcium nitrate, along with carbon dioxide and oxygen as byproducts. The chemical equation for this reaction is:

$$CaCO_3 + 2NO_3^- \rightarrow Ca(NO_3)_2 + CO_2 + O_2$$

In most cases, during a chemical reaction, gases like CO_2 and O_2 are simply released into the atmosphere as they are not retained or collected. This is because gases have the ability to escape freely from the reaction mixture due to their nature.

Procedure:

1) Sample Collection: An eggshell was gathered from the hotels and restaurants in Adama town.
2) Cleaning and Drying Eggshells: The eggshell underwent a thorough washing to eliminate any dirt, followed by air-drying at room temperature. This step was crucial, especially for eggshells with visible contaminants that required prior cleaning before drying.
3) Boiling of Eggshells: The eggshells were boiled at 205°C for 1 hour with 40:1 water to eggshell ratio. This step was done to remove waste, protect nutrients, and eliminate harmful bacteria from the eggshells.
4) Drying of Eggshells: The eggshells were in an oven at 100 °C for two hours to remove moisture and prepare them for the subsequent crushing stage.
5) Grinding: The eggshells were finely ground using a grinder for the following sieving process during the synthesis of calcium carbonate from waste eggshells.
6) Sieving: Passing the ground eggshells through a 100µm sieve helps to separate any larger particles, ensuring that only particles 100µm or smaller are collected for calcium carbonate synthesis. This process results in a more uniform and consistent particle size, promoting effective chemical reactions without the need to consider frequency.



a. Waste eggshell b. eggshell cleaning c. Boiling of Eggshells d. Drying of Eggshells

e. Oven drying of Eggshells f. Sieving

Figure 3. 10 Solid state extraction process of calcium carbonate from waste eggshells

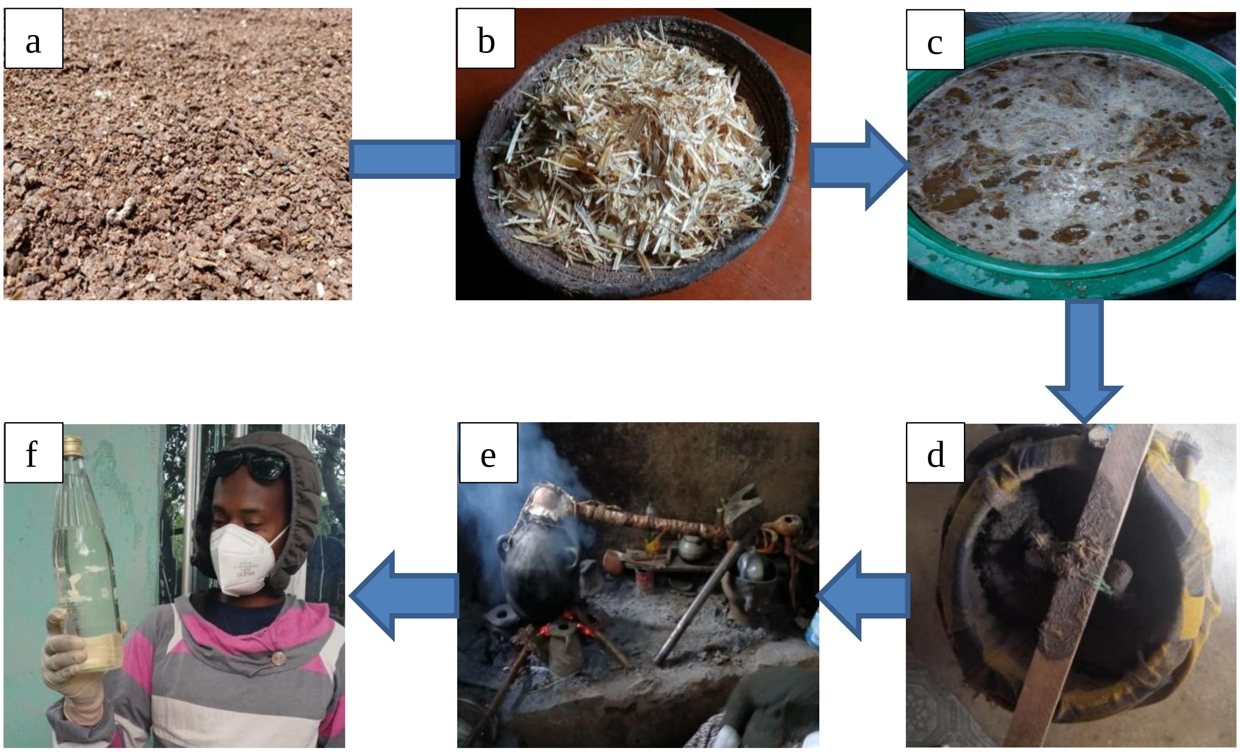
3.8 Synthesis of Nitrate from Chicken manure

Anerobic digestion is used worldwide as a treatment method for industrial, agricultural and municipal wastes. Chicken manure and wheat straw taken from poultry farm and local agricultural were used in each experiment. Wheat straw is a high-carbon material, which is essential for achieving the right carbon-to-nitrogen ratio in the compost pile as well as it acts as insulation, helping regulate the temperature within the compost pile. Straw was cut using a saw in order to keep pieces with dimensions ranging from 2 to 3.5 cm. The composting reactors were made of plastic were conducted for 30 days and had volumes of about 60 L. Manure and straw were manually mixed, in plastic boxes for 20 min, by hands, in order to achieve better homogenization of material. Synthesis of nitrates from chicken manure involves the extraction of nitrogen compounds, particularly ammonium (NH_4^+), and their conversion into nitrates (NO_3^-). This process is typically achieved through microbial nitrification or chemical oxidation. Below is a detailed procedure for synthesizing nitrate from chicken manure.

Procedure:

- Preparation of Composting Mixture: Mix 20% wheat straw to 80% fresh chicken manure for composting mixed chicken manure, wheat straw, and water in a compost bin in the appropriate ratio. The wheat straw provided the necessary carbon source for the composting process.

- Composting: Allow the compost mixture to decompose over four weeks. Turn the pile regularly to aerate it and promote decomposition. The decomposition process broke down the organic materials, releasing nutrients like nitrates and nitrites.
- Filtration: Once the composting process is complete, filter the compost mixture to separate the liquid portion containing the extracted nitrates and nitrites from the solid compost.
- Distillation: Set up a distillation apparatus to further concentrate and purify the extracted nitrates and nitrites.



a. Chicken manure b. wheat straw c. Compost mixture d. Filtration e. Distillation
f. Extracted nitrate based solution

Figure 3. 11 Follow diagram for extracting Nitrate and Nitrite from Chicken Manure

The concentration of the final solution was analyzed by the Oromia Engineering Corporation laboratory. The photo-metric test results in Appendix 1b showed that the solution had 11.6 and 4.3 nitrate (NO_3) and nitrite (NO_2) concentrations, respectively.

3.9 Combined of Calcium Carbonate from Waste Eggshells and Nitrates from Chicken Manure

In order to determine the correct ratio of calcium oxide powder needed for creating a calcium nitrate-based solution, the stoichiometry of the reaction between nitrate ions and calcium oxide must be taken into account.

The balanced chemical equation for the reaction between nitrate ions and calcium oxide is:

$$CaO + 2NO_3^- \text{ -> } Ca(NO_3)_2$$

The equation shows that a single calcium oxide molecule is combining with two nitrate ions to produce a calcium nitrate molecule. The amount of extracted nitrate-based solution is 6 L with 11.9% concentration. First, it needs to calculate the amount of nitrate ions in the solution:

$$0.119 * 6 \text{ L} = 0.714 \text{ mol}$$

Since one molecule of calcium oxide reacts with two nitrate ions, it needs half the amount of calcium oxide to react with all the nitrate ions:

$$0.714 \text{ mol} / 2 = 0.357 \text{ mol}$$

Now, to convert the amount of calcium oxide needed from moles to grams using its concentration: the molar mass of calcium oxide (CaO) is "40.08 g/mol"

$$0.357 \text{ mol x } (40.08 \text{ g/mol}) = 14.3 \text{ g}$$

Therefore, it needs to add 14.3 g of calcium oxide powder to the 6 L of nitrate ion liquid solution in order to create a calcium nitrate-based solution. The procedures for combining the synthesis of calcium carbonate from waste eggshells and nitrates from chicken manure are detailed in Appendix 2.

3.10 Concrete Mix design

The concrete mix design process, following ACI 211.1 guidelines, aims to create a blend that ensures both the desired workability and sufficient compressive strength. The average compressive strength of the concrete must meet or exceed the specified requirements to ensure optimal performance and durability according to ACI standards. A well-proportioned concrete mixture should be strong, long-lasting, visually uniform, and cost-effective. Achieving the desired qualities of durability, strength, consistent appearance, and affordability in concrete requires a balanced mix. This study used the ACI 211.1 method to design the mix proportion for a concrete grade of C-30, targeting a compressive strength of 30 MPa (equivalent to 38.5 MPa). The specific steps for designing a concrete mix are found in Appendix 3. The results for batches of 1 m3 of concrete and the mix ratio for C-30 concrete grade are presented in the following table.

Table 3. 1 Calculated Batches for 1m 3 of Concrete

Water	178.03 kg / m^3
Cement	425.29 kg / m^3
Fine aggregate	714.08 kg / m^3
Coarse aggregate	1062.78 kg / m^3

Table 3. 2 Mix Ratio for C-30 Concrete Grade

Ingredients	Cement	Fine aggregate	Coarse aggregate
Amount/ m^3	425.29/425.29	714.08/425.29	1062.78/425.29
Ratio	1	1.68	2.50

The amount of cement utilized in the concrete mix was constant both with and without the extracted additive at each dosage. Scholars recommend a dosage range of accelerator admixture for normal weather conditions of 0.5% to 3% by weight of the cement used. However, the extracted accelerator additive used in the experiment was 1%, 2%, 3%, and 4%. Table 3.3 shows that a total of 150 concrete samples were prepared for tests on compressive strength, flexural strength, acid attack resistance, and water absorption.

Table 3. 3 Number of Samples for experiment

Dosage (%)	Compressive strength test				Flexural strength test			Acid attack resistance test		Water absorption test
	7 day	14 day	21 day	28 day	7 day	14 day	28 day	56 day	56 day	28 day
0	3	3	3	3	3	3	3	3	3	3
1	3	3	3	3	3	3	3	3	3	3
2	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	3	3	3	3	3	3	3
Total	15	15	15	15	15	15	15	15	15	15

3.11 Batching, Casting and Curing of Concrete

The components for the concrete, such as cement, sand, coarse aggregate, water, and calcium nitrate additive, were carefully weighed using a weight balance. Studies suggest varying levels of calcium nitrate admixture (0%, 1%, 2%, 3%, and 4% of cement) are recommended for optimal results. These materials were systematically added to the mixing equipment, beginning with the measured coarse aggregate, then proceeding with cement, fine aggregate, water, and additive. The initial dry mixing lasted for a minute, followed by the addition of water and additive, which were then mixed for a few more minutes. Concrete cubes were formed using 15cm×15cm×15cm molds for conducting tests on Compressive Strength, water absorption, and resistance to acid attacks. Additionally, a beam mold sized 10cm×10cm×50cm was used for testing Flexural Strength. Concrete curing involves ensuring proper moisture, temperature, and duration for cement hydration following demolding, as per ASTM C192 standards, with subsequent room temperature curing for 7, 14, 21, and 28 days using a water container.

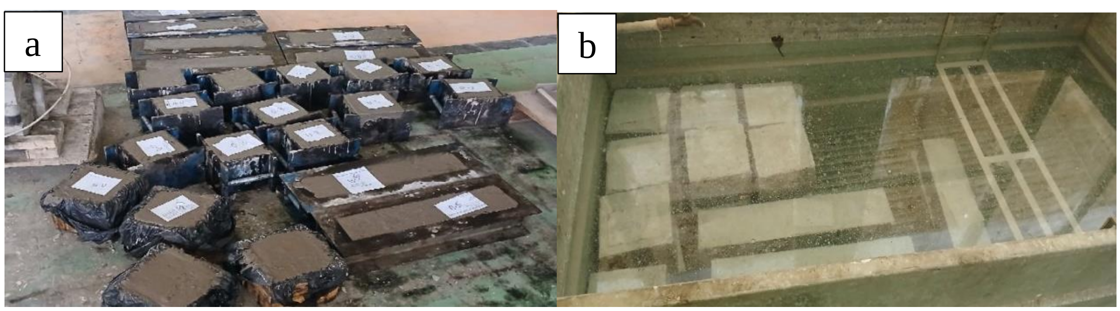


Figure 3. 12 a. Moldinging and b. curing of concrete

3.12 Fresh concrete test

3.12.1 Workability test

Assessment of concrete workability is a crucial step in determining the ease with which fresh concrete can be mixed, placed, and finished to achieve the desired results. In this study, the workability of the concrete was evaluated through a slump test following the guidelines set by ASTM C 143 standards for Portland cement concrete. The test involved the use of varying dosages (0%, 1%, 2%, 3%, and 4% by weight of cement) of a calcium nitrate-based additive to observe its impact on the workability of the concrete mix.

During the test, fresh concrete was carefully placed into a slump cone in three layers, with each layer compacted by lifting and tapping the tamping rod 25 times. Excess concrete was then removed from the top of the cone, and the difference in height between the initial and final positions of the concrete surface after compaction was measured. This difference in height, known as the slump, provided valuable insights into the consistency and flow ability of the concrete mix. The results obtained from the slump test were recorded and analyzed to assess the influence of the calcium nitrate-based additives on the workability of the concrete.

Figure 3. 13 slump test of concrete a. without additive and b. with additive

3.13 Hardened concrete Test

Hard concrete tests, such as the compression test, flexural test, acid attack resistance test, and water absorption test, are essential procedures used to assess the strength, durability, and performance of hardened concrete. These standardized tests provide valuable insights into the structural integrity, load-bearing capacity, and resistance to external factors of concrete elements, aiding in the design and maintenance of durable structures.

3.13.1 Compressive Strength Test

A study was conducted to determine the most effective dosage of calcium nitrate-based additive designed to improve the early strength properties of concrete. The study involved casting standardized concrete cubes sized at 150 x 150 x 150 mm, prepared to enable a comparison of compressive strength between concrete samples with and without the extracted additive. The researcher closely monitored and assessed the compressive strength of the concrete specimens at specific time points of 7, 14, 21, and 28 days after curing, utilizing an advanced automated testing machine following the strict protocols outlined in the ASTM C39 guidelines. During the testing process, a controlled level of compressive stress was consistently applied to the specimens at a rate of 0.23 Mpa/sec until failure, with detailed documentation of the maximum load sustained by each specimen. The compressive strength values were accurately calculated by dividing the maximum load by the specimen's cross-sectional area, ensuring reliability and alignment with ASTM C39 guidelines for valuable insights into the concrete mixes' performance attributes.

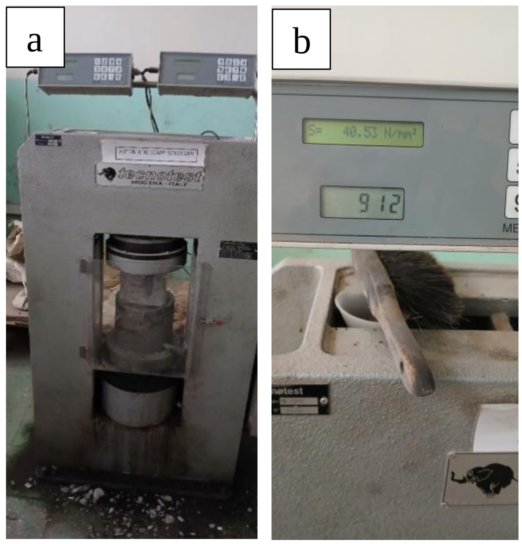


Figure 3. 14 a. Automatic compressing test machine b. 2% additive added concrete carried 40.61MPa stress

3.13.2 Flexural test

The examination of flexural strength was carried out following the guidelines outlined in the ASTM C293 standard. Initially, a concrete sample of specified dimensions (100mm x 100mm x 500mm) was prepared in accordance with the standard system. Subsequently, the sample was positioned atop two supporting rollers to ensure stability during the test. An incremental load was then applied at the center of the specimen, consistently increasing until the point of fracture or bending beyond a predetermined limit. Throughout the testing process, the applied load was carefully monitored and recorded until the sample reached its breaking point. Upon reaching this critical point, the testing apparatus was deactivated, and the peak load sustained by the specimen was documented for further analysis. The flexural strength of the sample was subsequently computed utilizing the prescribed calculation method delineated in the ASTM C293 standard.

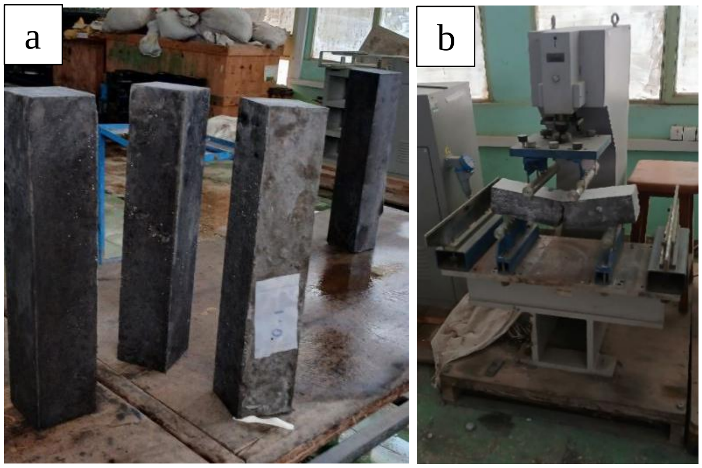


Figure 3. 15 a. concrete sample beam b. Flexural test

3.14 Durability test

3.14.1 Acid attack resistance test

The study conducted a thorough analysis to explore the impact of incorporating a calcium nitrate-based additive on concrete's ability to resist sulfates after a 28-day curing period. It focused on how this additive affected the concrete's resistance to sulfates, particularly regarding compressive strength reduction. Both the control mix concrete and the mix with the calcium nitrate-based additive were exposed to a 5% sodium sulfate solution for 28 days to compare the changes in compressive strength. The study then assesses the effectiveness of the calcium nitrate-based additive in improving the concrete's durability against sulfate attack. By evaluating the reduction in compressive strength after sulfate exposure, the study aimed to determine the additive's ability to mitigate the negative effects of sulfate penetration on the concrete's structural integrity. Through a systematic examination of concrete performance under sulfate exposure conditions, the study sought to gain understanding into enhancing concrete durability against sulfate-induced deterioration.

Figure 3. 16 a. Sulfuric acid   b. acid attack resistance test of concrete

3.14.2 Water absorption Test

The water absorption properties of concrete significantly affect its durability by impacting its resistance to freeze-thaw cycles, chemical attacks, and overall structural integrity. Conducting water absorption tests is crucial to evaluate and enhance the material's long-term performance. The ASTM C1585 standard outlines a specific procedure for the water absorption test of concrete. Initially, samples are taken from the curing water after 28 days and then dried at 105°C for 24 hours to remove moisture, establishing a baseline weight. These samples are then immersed in curing water for 72 hours. After this immersion period, the samples are weighed again to determine any weight gain, ensuring that water absorption remains below the specified 10% limit.

Figure 3. 17 Water absorption test

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 Introduction

This chapter provides a detailed presentation of all the experimental investigation's findings. Initially, the focus was on the materials used in the experiment and the characterization of the calcium-nitrate-based additive specifically extracted for this study. Then, using serious laboratory testing, researchers investigated the effects of extracted additive on the hardened and fresh properties of C-30 concrete using National OPC cement. In the first part of our investigation, researchers evaluated the concrete's workability for the C-30 mix design at various dose ranges. Following, extensive analyses of compressive and flexural strength evaluations to determine the optimal amount of the extracted calcium nitrate-based additive, the evaluation of the cost effects of concrete blends with different concentrations of the extracted additive relative to a standard mix configuration.

4.2 Fine aggregate test result analysis

4.2.1 Silt content of sand

Fine aggregates with particles smaller than 75µm are commonly classified as silt. When the sand in the concrete mixture contains high levels of silt or clay, it can greatly diminish the concrete's strength and durability. The silt content in the sand used for this study was performed in compliance with ASTM C-117 to enhance the concrete quality. The findings were detailed in the following table. The final average silt content value was 2.5%, which is recommended by ASTM C-33.

Table 4. 1 Silt content result for fine aggregate

No	V1-Amount of total sand (gm)	V2-Silt deposited above the sand (gm)	(V1/V2)*100= (%)
1	300	8	2.67
2	300	6	2
3	300	8.5	2.83
		Average	2.5

4.2.2 Gradation of fine aggregates

A well-graded fine aggregate can result in a more workable mixture with reduced voids, improved adhesion to cement paste, and enhanced overall concrete performance. The researchers conducted the sieve analysis to meet the particle size distribution requirements outlined in ASTM C33 before incorporating fine aggregates into the concrete mix.

Table 4. 2 Sieve analysis results of fine aggregate

Sieve No	Weight of retain (gm)	Percent of retained (%)	Cumulative percent of retained	Percent of passing	ASTM Requirement
4.75mm	0	0	0	100	95-100
2.36mm	71	14.2	14.2	85.6	80-100
1.18mm	96	19.2	33.4	66.6	50-85
600µm	154	30.8	64.2	35.8	25-60
300µm	107	21.4	85.6	14.4	10-30
150µm	72	14.4	100	0	0-10
Pan	0	0	0	0	
Total			297.4		

Fineness modulus = $\sum_{n=1}^{7}(Cummulative\ retained\ by\ mass/100)$

Fineness modulus = 297.4 /100 = 2.97

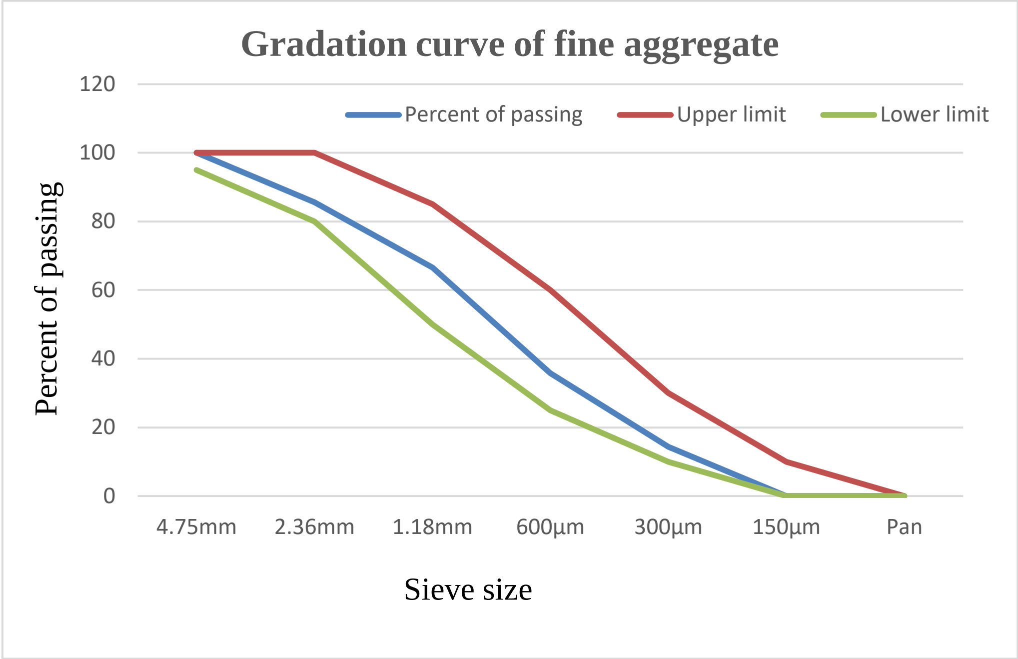


Figure 4. 1 Gradation curve of fine Aggregate.

4.2.3 Unit weight of fine aggregate

The unit weight of fine aggregate (UWFA), as outlined in ASTM C29, refers to the ratio of its weight to its volume. This metric is typically denoted in kilograms per cubic meter (kg/m^3) or pounds per cubic foot (lb/ft^3) and is essential for evaluating the density and compaction of fine aggregate in construction materials. Consequently, the findings from the analysis of the fine aggregate in this experimental study have been detailed in Table 4.3 for comparison with the ASTM standard.

Table 4. 3 Unit weight of fine aggregate

Sample	A-weight of F.A with container (kg)	B-weight of container (kg)	C-volume of container (m^3)	UWFA= A-B/C
1	6.58	4.5	0.0014	1,485.71
2	6.64	4.5	0.0014	1,528.57
3	6.55	4.5	0.0014	1,464.29
Average				1,492.86

At 1492.86 kg/m3, the measured unit weight of the fine aggregate sample came within the permissible range of ASTM C29. This indicated that the fine aggregate was suitable for use in construction applications based on its acceptable unit-weight characteristics.

4.2.4 Specific gravity and Water absorption properties of Fine Aggregate

The water absorption of an aggregate is a crucial parameter that indicates the material's ability to retain moisture. It is typically determined by comparing the weight of the aggregate in a surface-dried saturated state with its weight when completely oven-dried. This method allows researchers to accurately measure the extent of water absorption, providing valuable insights into the performance characteristics of the aggregate in various construction applications. For fine aggregates, the moisture content was assessed by subjecting a 500-gram sample to an oven at 105°C for 24 hours, and the results were calculated as provided below.

Important main results obtained from the test

A = Weight of the sample in Saturated Surface Dry condition = 500g

B = Weight of oven dried sample in air = 486gm

C = Weight of pycnometer occupied by water = 1457gm

D = Weight of pycnometer filled with water and sand up to calibration mark = 1763gm

So, Bulk specific Gravity (BSG) calculated as:

$$BSG = \frac{A}{C+A-D} = \frac{500}{1457+500-1763} = 2.58$$

Apparent specific Gravity (ASG) calculated as:

$$ASG = \frac{B}{C+B-D} = \frac{486}{1457+486-1763} = 2.70$$

Water absorption (%) calculated as:

$$\text{Water absorption} = \frac{A-B}{B} * 100 = \frac{500-486}{486} * 100 = 2.88\%$$

The above result for bulk specific gravity, apparent specific gravity and water absorption are 2.58, 2.70, and 2.88% are satisfying the ASTM C33 standards.

4.3 Coarse aggregate test result analysis

4.3.1 Sieve analysis of coarse aggregate

The coarse aggregate used in this study was sourced from local crushed rocks. In order to achieve a more uniform distribution of particle sizes, laboratory tests were conducted to analyze the gradation of the coarse aggregate. This analysis was carried out using sieve analysis based on the ASTM C-33 standard. The final results from the sieve analysis were described in the table below.

Table 4. 4 Sieve analysis of coarse aggregate

Sieve No	Weight of retain (gm)	Weight of retained (%)	Cumulative retained (%)	Percent finer (%)	ASTM Requirement
20	0	0	0	100	100
19	95	4.75	4.75	95.25	95-100
12.5	700.4	35.02	39.77	60.23	40-80
9.5	802.6	40.13	79.9	20.10	20-55
4.75	402	20.10	100	0	0-10
2.36	0	0	100	0	
1.18	0	0	100	0	
0.6	0	0	100	0	
0.3	0	0	100	0	
0.15	0	0	100	0	
Pan	0	0	0	0	
Total			724.42		

Fineness modulus is equivalent to: 724.4/100= 7.244

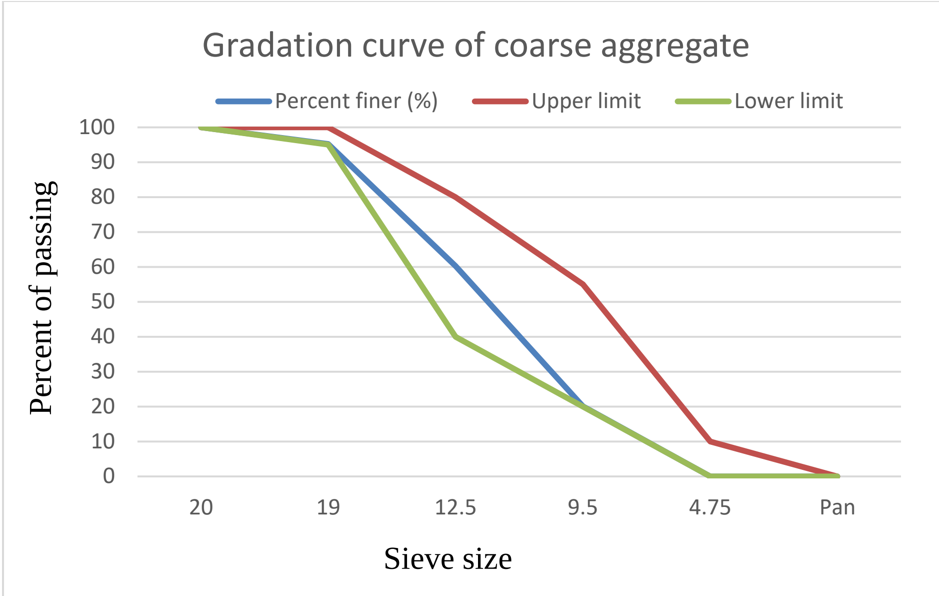


Figure 4. 2 Gradation curve of Coarse Aggregate

4.4.2 Unit Weight of Coarse aggregate

In a similar manner like the fine aggregate, the unit weight of coarse aggregate (UWCA), as outlined in ASTM C29 refers to the ratio of its weight to its volume. The finding results for UWCA were described in the table below.

Table 4. 5 Unit weight of coarse aggregate

Sample	A-weight of C.A with container (kg)	B-weight of container (kg)	C-volume of container (m^3)	UWCA= A-B/C
1	6.79	4.5	0.0014	1,635.71
2	6.90	4.5	0.0014	1,714.29
3	6.87	4.5	0.0014	1,692.86
Average				1,680.95

The unit weight of coarse aggregate, measured at 1680.95, meets the ASTM C 29 standard requirements. Compliance with this standard ensures the quality and performance of the coarse aggregate in construction applications.

4.4.3 Specific Gravity and Water Absorption of Coarse aggregate

Understanding the bulk specific gravity (Bsg), apparent specific gravity (Asg), and water absorption capacity of coarse aggregate is crucial for enhancing material quality and overall project performance. The findings are described below.

A = Weight of the sample in Saturated Surface Dry condition = 3000g

B = Weight of oven dried sample in air = 2964gm

C = Weight of pycnometer filled with water and sand up to calibration mark = 1852gm

So, Bulk specific Gravity (BSG) calculated as:

BSG= (A)/(A-C) = 3000/(3000-1852) = 2.61

Apparent specific Gravity (ASG) calculated as:

ASG= B/(B-C) = 2964/(2964-1852) = 2.67

Water absorption (%) calculated as:

Water absorption= (A-B)/B*100 = (3000-2964)/2964*100 = 1.21%

4.5 Synthesis result of Calcium Carbonate from Waste Eggshell

Calcium carbonate, a compound commonly found in eggshells, was successfully synthesized using a specific procedure aimed at recycling waste eggshells. The method used for extracting calcium carbonate from waste eggshells involved a solid-waste reaction mechanism, thereby reducing environmental impact and promoting circular economy principles. The validation of calcium carbonate production in the ongoing research project was substantiated by the thorough chemical composition analysis conducted by the Ethiopian Geological Survey. The laboratory result for oxidation of eggshell is described in Appendix 1a.

Table 4. 6 Oxidation of eggshell powder after solid state reaction

SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	MnO	P2O3	TiO2	H2O	LOI
1.00	<0.01	0.04	48.02	0.58	<0.01	<0.10	<0.01	0.20	0.06	1.04	48.5

4.6 Synthesis result of Nitrate solution from Chicken manure

Nitrogen is not directly obtained from chicken manure, but rather in the form of uric acid, ammonia, ungraded protein, and other nitrogen-based compounds. Therefore, the anaerobic digestion technique is employed to extract nitrate solution from chicken manure by breaking down large nitrogen compounds into smaller ones. Subsequently, filtration and distillation successfully produced a liquid solution containing 11.6% nitrate and 4.3% nitrite. The Oromia Engineering Corporation conducted photometric analysis to confirm the composition of the final solution, demonstrating the efficiency of the extraction process. The result of the photometric test is presented in Appendix 1b. This study showcases the potential for utilizing chicken manure as a sustainable source of nitrate solution for concrete additive purposes.

4.7 Fresh concrete test result analysis

4.7.1 Workability

Workability is crucial for the ease of handling, flow, and placement of fresh concrete. In this study, concrete workability was assessed according to ASTM C 143. The workability of concrete mixes with a calcium nitrate-based accelerator additive was compared to a control mix to evaluate the accelerator's impact on handling and placement. The examination of concrete mix characteristics reveals a notable trend in the slump values as the extracted additive content is adjusted across a range of 0% to 1.15%. This significant observation is detailed in Table 4.7, indicating a clear correlation between additive concentration and slump behavior.

Table 4. 7 Slump value result

Mix code	Dosage (wt% cement)	Slump (mm)	Present of increase
NBC0	0	20	0
NBC1	1	20.5	1.025
NBC2	2	21	1.05
NBC3	3	22.5	1.125
NBC4	4	23	1.15

Initially, with the introduction of calcium nitrate-based additive at 1% and 2% levels within the concrete composition, an increase of 0.5 mm and 1 mm in slump is noted, respectively. Further increase in the extracted additive content to 3% and 4% leads to enhancement in slump values, registering increments of 2.5 mm and 3 mm, respectively. The progression in this study highlights the increase in extracted additive enhancing workability characteristics of the concrete mix, similar to previous studies that demonstrated reasonably good flow ability. Specifically, the slump of the calcium nitrate sample was higher than that of the control (Karagöl et al., 2013).

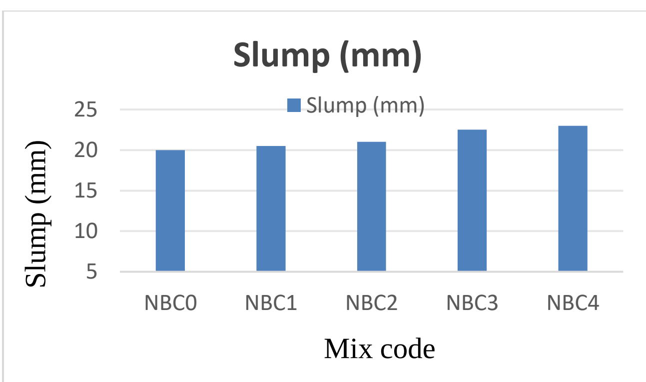


Figure 4. 3 Slump value of concrete in different percentage of extracted additive

4.8 Hardened concrete test result

Concrete undergoes various states in its formation process. Initially, it is a fluid mixture that can be easily poured and shaped. Through hydration, where water reacts with cement, concrete cures into its durable state. Once fully hardened, it effectively bears heavy loads without compromising stability, making it a reliable choice for diverse construction applications.

4.8.1 Compressive strength test result

During the initial period, concrete behaves as a fluid that is crucial for its workability and ability to be molded into the desired shape when mixed with water. After a few minutes, it begins the initial setting process where it transitions from a liquid to a solid and its hardened properties develop through the hydration process. The addition of calcium nitrate-based additives at 1% and 2% to concrete resulted in improved compressive and flexural strength over time. These enhancements were significant at different curing periods, indicating that the additives had a positive impact on the hardened properties of the concrete. In this study compressive strength of all concrete samples, with and without the calcium nitrate-based additive, was examined at 7, 14, 21, and 28 days of the curing process using an automated compressive strength testing device. The findings, including standard deviation and coefficient of variation, are presented in Table 4.8. According to Indian standards, the permissible coefficient of variance should not exceed 15%.

Table 4. 8 Compressive strength test result

Day	Mix Code	Samples			Mean strength	Present of target mean strength (38.5)	Standard deviation	Coefficient of variation (%)	Increment/ Reduction (%)
		S1	S2	S3					
7	NBC0	24.64	25.75	24.91	25.10	65.12	0.578	2.306	
	NBC1	26.35	27.10	27.57	27.01	70.15	0.615	2.278	7.6
	NBC2	28.33	30.24	29.61	29.39	76.35	0.97	3.311	**17.09**
	NBC3	24.41	23.22	24.36	23.99	62.33	0.673	2.805	-4.42
	NBC4	20.37	20.03	20.34	20.25	52.59	0.188	0.929	-19.32
14	NBC0	31.67	31.24	30.83	31.25	81.16	0.420	1.344	
	NBC1	33.86	31.98	33.40	33.08	85.92	0.98	2.962	5.86
	NBC2	35.64	34.41	34.25	34.77	90.30	0.760	2.187	**11.264**
	NBC3	30.93	30.05	31.26	30.75	79.86	0.625	2.034	-1.6
	NBC4	26.94	27.21	28.33	27.49	71.41	0.737	2.681	-12.03

21	NBC0	36.04	34.87	35.74	35.55	92.34	0.607	1.709	
	NBC1	35.77	36.26	37.09	36.37	94.47	0.667	1.834	2.31
	NBC2	37.46	38.51	38.24	38.07	98.88	0.545	1.432	**7.09**
	NBC3	32.28	33.51	32.38	32.06	83.26	1.061	3.310	-9.82
	NBC4	28.63	29.82	29.55	29.33	76.19	0.623	2.127	-17.50
28	NBC0	37.13	36.62	38.87	37.54	97.51	1.179	3.142	
	NBC1	38.31	37.65	38.79	38.25	99.35	0.572	1.496	1.89
	NBC2	40.52	39.91	40.61	40.35	104.80	0.380	0.943	**7.48**
	NBC3	34.19	34.02	33.71	33.97	88.24	0.243	0.716	-9.51
	NBC4	29.58	30.14	30.39	30.03	78.94	1.179	3.142	-20.01

The research findings indicated notable enhancements in the compressive strength of concrete samples following a 7-day curing period. Samples containing 1% and 2% calcium nitrate-based additives exhibited strengths of 27.01 MPa and 29.39 MPa, respectively, indicating increases of 7.6% and 17.9% compared to the control mix. The 2% value at 7 days represents a significant percentage increment compared to other results due to the additive's ability to improve early strength development. Similarly, the previous study found that using calcium nitrate additive at 1% increased compressive strength of concrete by 21.5% at 7 days of curing, despite temperatures of +20^{o} C (Skripkiūnas et al., 2021). The results from the extracted additive added concrete and the control mix concrete strength at the 7th day of curing in different dosages are illustrated in Figure 4.4.

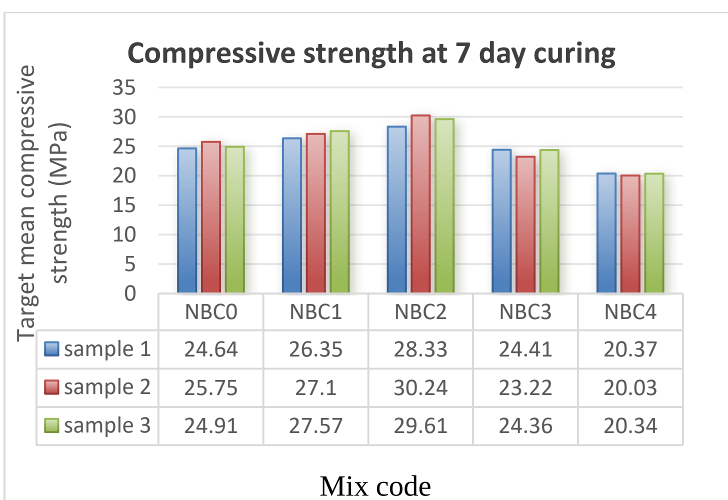


Figure 4. 4 compressive strength result at 7 day curing

At the 14 day of curing 1% and 2% additive concrete have increasing the compressive strength of concrete with mean strength of 33.08MPa and 34.77MPa respectively. At 28-day mark of the curing process, the inclusion of 1% and 2% extracted calcium nitrate-based accelerator in the concrete mixture resulted in a 1.89% and 7.48% increase in compressive strength, respectively, as illustrated in the table 4.8. This improvement highlights the potential benefits of incorporating calcium nitrate-based additive in concrete makes positive reaction with cement compounds. According to Kičaite study, 0.5% calcium nitrate additive increase compressive strength of concrete after 28 curing days, 8.7 % and Skripkiūnas also find 19.6% increment during the study (Kičaite et al., 2017; Skripkiūnas et al., 2021).

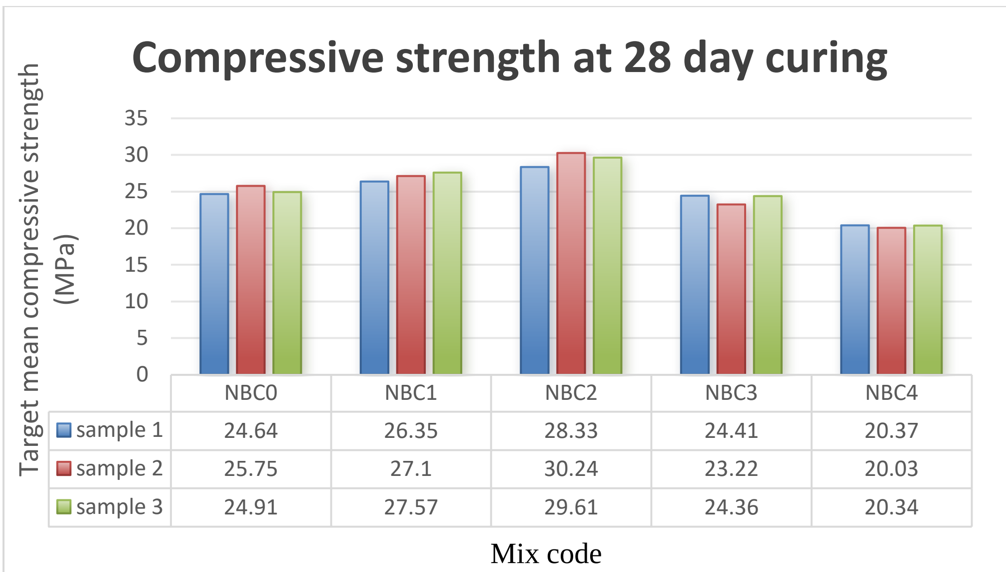


Figure 4. 5 compressive strength test result at 28 day curing

4.8.2 Flexural strength test result analysis

Flexural strength tests are conducted to determine the ability of concrete to resist failure when subjected to bending stress, which helps in evaluating its tensile strength. The modulus of flexural, indicating the maximum stress at the lower fibers of a beam, is vital for constructing concrete pavements in transportation infrastructure. In this experimental study, flexural testing involved 45 beams sized at 100 x 100 x 500 mm after a 28-day curing period as per ASTM C293. Each concrete mix type had three samples analyzed using a flexural strength testing apparatus over intervals of 7, 14, and 28 days. The specimens were loaded until failure, and results were recorded in Mega Pascal (MPa), with the average of three specimens providing a reliable measure of flexural strength.

Table 4. 9 Flexural strength test result

Day	Mix Code	Samples			Mean strength	Standard deviation	Coefficient of variation (%)	Increment/ Reduction (%)
		S1	S2	S3				
7	NBC0	2.39	2.21	2.47	2.36	0.133	5.645	
	NBC1	2.55	2.46	2.33	2.45	0.110	4.517	3.81
	NBC2	2.78	2.61	2.54	2.64	0.123	4.677	**11.86**
	NBC3	2.12	2.22	2.05	2.13	0.085	4.011	-9.75
	NBC4	1.89	2.09	2.13	2.04	0.128	6.306	-13.56
14	NBC0	3.07	3.14	3.19	3.13	0.060	1.930	
	NBC1	3.45	3.18	3.02	3.21	0.217	6.775	2.55
	NBC2	3.35	3.57	3.41	3.44	0.113	3.308	**9.90**
	NBC3	3.15	2.98	2.73	2.95	0.211	7.162	-5.75
	NBC4	2.52	2.70	2.61	2.61	0.09	3.448	-16.61
28	NBC0	4.21	4.62	4.83	4.55	0.315	6.930	
	NBC1	4.74	4.93	4.47	4.71	0.231	4.908	3.52
	NBC2	5.16	5.18	5.00	5.11	0.098	1.932	**12.31**
	NBC3	4.65	3.94	4.71	4.43	0.428	9.668	-2.63
	NBC4	3.78	3.63	3.48	3.63	0.15	4.132	-20.22

The flexural strength results, as shown in Table 4.9, demonstrate variations across different curing periods. During the 7-day curing period, the control mix displayed a flexural strength of 2.36 MPa, whereas the concrete mixes with 1% and 2% of the extracted calcium nitrate-based additive demonstrated increased flexural strengths of 3.81% and 11.86%, respectively. On the other hand, the concrete mixes with 3% and 4% of the extracted additive experienced a decrease in flexural strength by 9.75% and 13.56%. Upon extending the curing duration to 14 days, the control mix's flexural strength slightly improved to 3.13 MPa. Remarkably, the 1% and 2% mixes also exhibited enhanced flexural strength by 2.55% and 9.90%, indicating the positive impact of the extracted additive. However, the 3% and 4% mixes displayed lower flexural strengths compared to the control mix at the 14-day mark.

After the 28-day curing period, notable improvements in flexural strength were observed in the control mix concrete, achieving a peak of 4.55 MPa. Concrete mixes with 1% and 2% of the calcium nitrate-based additive also demonstrated positive advancements, with flexural strength increases of 3.52% and 12.31% respectively. The mixes containing 3% and 4% of the extracted additive observed the reductions in flexural strength by 8.13% and 11.24% compared to the control mix at the 28-day mark. Similar trends were observed by Rusu et al., (2023) for concretes based on white Portland cement and utilizing tap water (stored at room temperature). The flexural result showed a 62.65% increase with the use of 2% calcium nitrate additive. They also successfully demonstrated that calcium nitrate additive can promote an even higher 40.5% increase in flexural strength when used at a dosage of 1% for 28-day curing.

Overall, the results suggest that incorporating 2% of the extracted calcium nitrate-based additive can significantly enhance the flexural strength of the concrete mix, displaying its potential for improving the mechanical properties of the material.

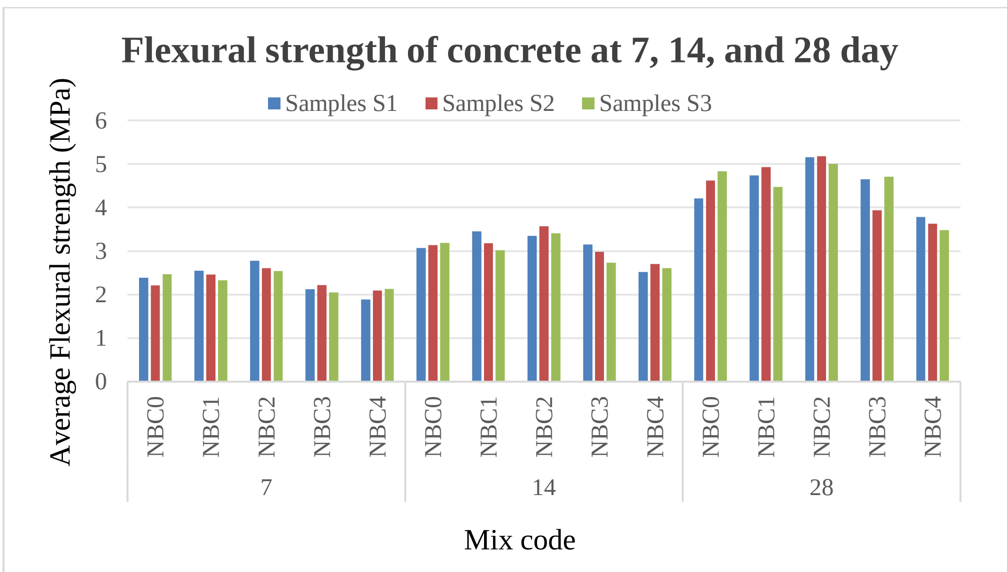


Figure 4. 6 Flexural strength test result at 7, 14, and 28 day curing

4.9 Durability test result analysis

4.9.1 Water absorption test result

The water absorption test results measures the percentage of water absorbed by the concrete specimens after 28 days of curing as per ASTM C 1585. A higher water absorption percentage typically suggests that the concrete has more interconnected voids or pores, which can impact its durability and resistance to various environmental factors. The lower water absorption percentages in concrete mixes generally indicate higher quality and durability, as they suggest lower porosity and better resistance to environmental factors. Conversely, higher water absorption percentages may indicate increased porosity, potentially leading to reduced durability and performance of the concrete. It is essential to consider water absorption test results when evaluating the quality and long-term performance of concrete mixes.

As described in the table 4.10 NBC0, NBC1, and NBC2 have relatively low water absorption percentages ranging from 3.03% to 4.31%, indicating good quality of concrete. This increment might be due to Calcium nitrate based additives effect on the hydration process and pore structure of the concrete as compared to previous research (Polat, 2016). NBC3 has a higher water absorption percentage of 5.91%, suggesting slightly higher porosity compared to the previous mixes. NBC4 exhibits the highest water absorption percentage at 9.34%, indicating the highest porosity among all the specimens tested. The presence of the additive at higher concentrations could potentially interfere with the hydration process of the cement. This interference may result in incomplete or uneven hydration, leading to the formation of weaker zones within the concrete that are more susceptible to water penetration. This higher absorption rate could lead to reduced durability and potentially increased susceptibility to environmental factors.

Table 4. 10 Water absorption test result

Mix code	B-Weight of oven dry (kg)	A-Weight of cube with water(kg)	Water absorption (%) $= \frac{A-B}{B} * 100$
NBC0	7.65	7.98	4.31
NBC1	7.80	8.06	3.33
NBC2	7.91	8.15	3.03
NBC3	7.78	8.24	5.91
NBC4	7.60	8.31	9.34

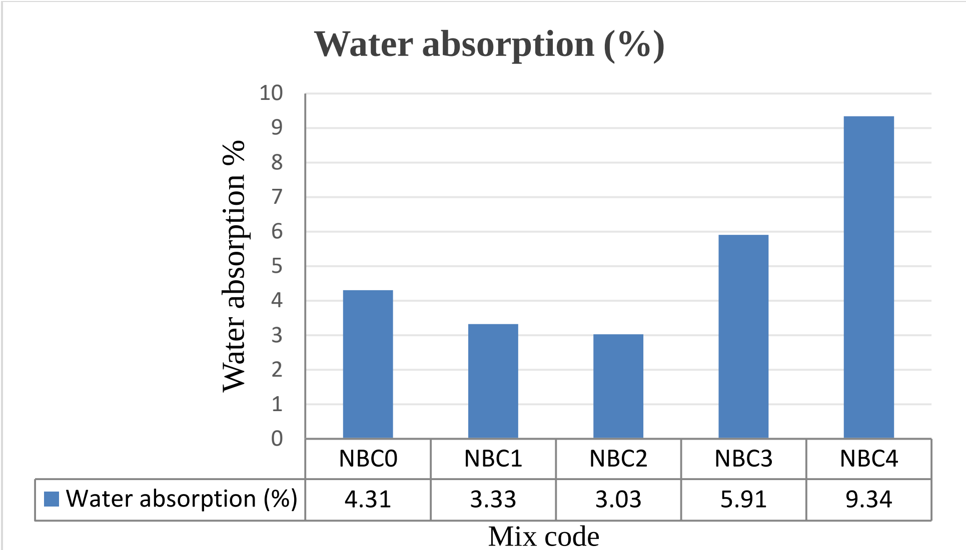


Figure 4. 7 Water absorption test result at 7, 14, and 28 day curing at different dosage

4.9.2 Acid attack resistance test

In this study, the concrete samples were exposed to 5% sulfuric acid for duration of 28 days, following a 28-day curing process in water. The decrease in compressive strength was evaluated using the strength deterioration factor by comparing it to a control exposure containing 0% H_2SO_4.

Table 4. 11 Acid attack resistance result

Mix code	Compressing strength at 0% H2SO4	Compressing strength at 5% H2SO4	Reduction %
NBC0	38.94	37.43	3.87
NBC1	39.11	37.37	4.45
NBC2	41.70	39.74	4.70
NBC3	32.52	30.03	7.65
NBC4	29.61	24.28	18.00

In Table 4.11, the data displays the compressive strength of control mix concrete and concrete mix with the added accelerator when exposed to a 5% concentration of sulfuric acid (H2SO4). Sulfuric acid has a potent and detrimental impact on concrete, showcasing two distinct modes of behavior by initially eroding the Portlandite and calcium silicate hydrate compounds and subsequently targeting the calcium aluminate hydrate element (Rahman et al., 2019). The acid attack resistance of concrete was evaluated following ASTM C 1012.

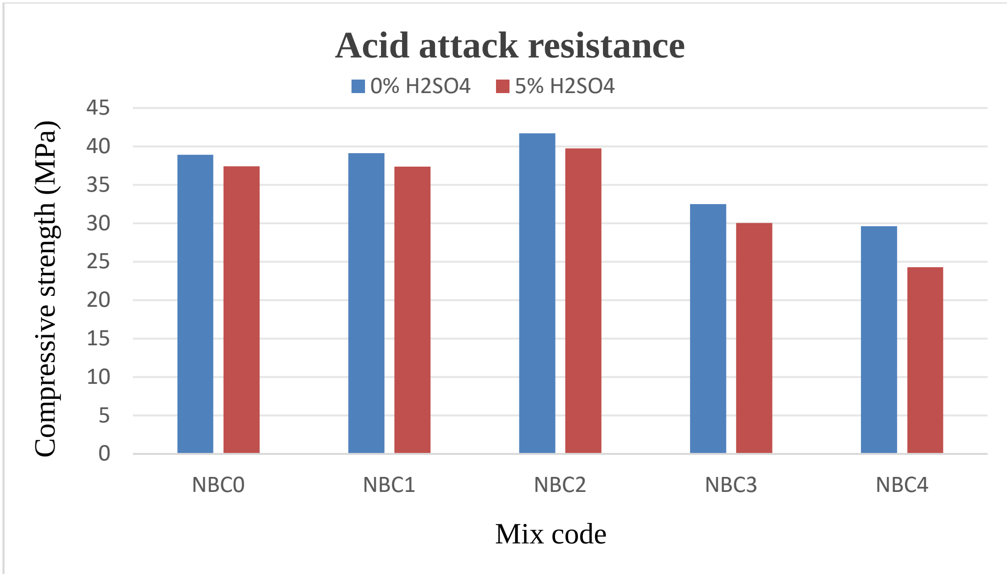


Figure 4. 8 Acid attack resistance test result

A 4% concentration of sulfuric acid had the most significant impact on the concrete with added additives after being exposed for 28 days, resulting in an 18.00% decrease in strength. The chemical stability of the calcium nitrate-based additive itself at 3% and 4% concentrations could play a role in the observed strength reduction. When the additive undergoes chemical reactions or transformations under acidic conditions, it may weaken the overall structure of the concrete, leading to a more pronounced decrease in strength. Calcium nitrate ($Ca(NO_3)_2$) reacts with sulfuric acid (H_2SO_4) to form calcium sulfate ($CaSO_4$) and nitric acid (HNO_3). The formation of calcium sulfate could contribute to the weakening of the concrete structure, as it may lead to the formation of weaker phases and increased porosity.

In contrast, the regular concrete mix experienced the smallest strength reduction of 3.87%. Therefore, additional research may be required to determine the optimal dosage levels in order to improve acid resistance without negatively impacting other properties of concrete. This indicates potential areas for further study in the sustainable production of concrete.

4.10 Chemical analysis result

This study investigates the addition of calcium nitrate as an accelerator to cement concrete made from eggshells and chicken dung. FTIR (Fourier Transform Infrared Spectroscopy) and XRD (X-ray diffraction) are two powerful analytical techniques that should be used to assess the effectiveness and chemical composition of the synthesized accelerator.

4.10.1 Fourier Transform Infrared Spectroscopy (FTIR) Analysis

This study utilizes Fourier Transform Infrared (FTIR) spectroscopy to investigate the chemical interactions and structural changes in concrete samples mixed with cement concrete containing eggshell and chicken dung. The FTIR spectra for the bio treated specimens are shown in Figure 4.4 A, B, and C. The evaluated frequency vibrations were in the mid-infrared (400 to 4000 cm−1).

The control sample, which does not contain any eggshell or chicken manure additive, is represented by the IR spectrum (Fig. A. concrete sample 0%). The absorption bands observed at 1641 cm^{-1} are linked to C=C stretching, which may suggest that the concrete contains amide groups or unsaturated hydrocarbons. The presence of amides may indicate a natural organic content or proteinaceous material in the concrete. The band observed at 1411 cm^{-1} is indicative of either C=C stretching in aromatic rings or C-H bending in alkanes, suggesting the presence of fundamental organic components in the concrete that may originate from naturally occurring organic matter. The absorption at 971 cm^{-1} is commonly associated with C-H bending out-of-plane in terminal alkenes, which may be part of the naturally occurring organic components in the concrete.

Table 4. 12 FTIR result of control concrete sample

Frequency (cm^{-1})	Wavenumber (cm^{-1})	Bond	Functional group
2000-1500	1641	–C=C– stretch (medium)	alkenes
1500-1000	1411	C–C stretch (in–ring) (medium)	aromatics
1000-500	971	=C–H bend (strong)	alkenes

The IR spectrum (Fig. B. concrete sample 2%) denotes the concrete sample with a 2% additive of eggshell and chicken manure. The absorption bands detected at 1737 cm^{-1} suggest the presence of carbonyl-containing compounds such as aldehydes or esters. This indicates that these compounds may have been added to or strengthened within the concrete-cement matrix as a result of the additive. The band at 1363 cm^{-1} suggests C-H bending in alkanes, particularly in methyl groups, possibly indicating an increase in organic molecules like esters due to the additive. The presence of a C-O stretching absorption band at 1215 cm^{-1} is indicative of ethers or esters in the sample. The presence of this band suggests that the mixture may have increased or introduced ester bond formation, most likely due to the organic component of the eggshell or chicken manure. However, as shown in Figure A, the band at 973 cm^{-1} suggests some unsaturated hydrocarbon content, possibly indicating the presence of terminal alkenes or out-of-plane deformations. Variations in the spectrum compared to the control sample (Figure A) suggest the introduction of organic compounds as a result of mixing. The presence of ester-related bands suggests the possibility of chemical reactions occurring between organic content in the eggshell and chicken dung, leading to the formation of new compounds.

Table 4. 13 FTIR result of concrete sample with 2% extracted additive

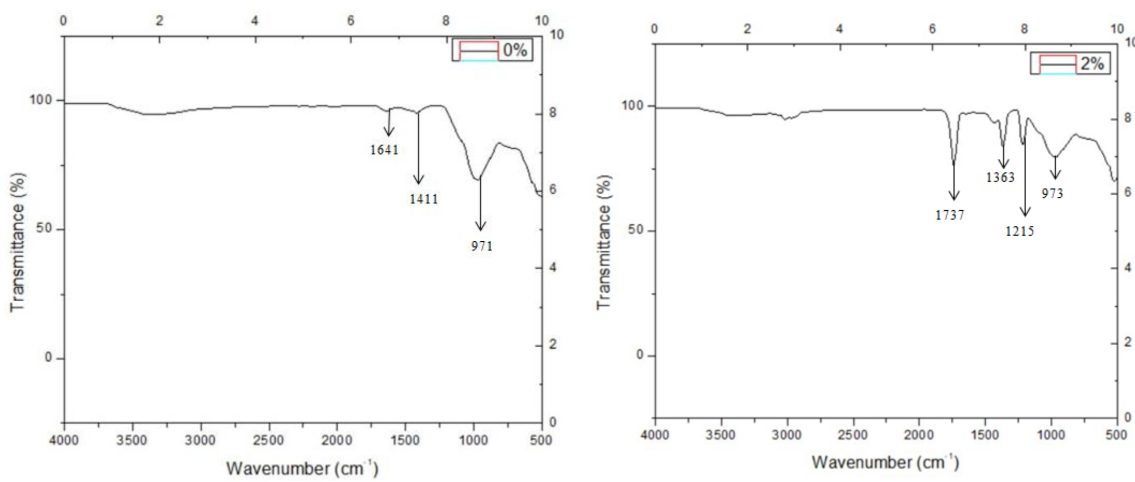
Frequency (cm^{-1})	Wavenumber (cm^{-1})	Bond	Functional group
2000-1500	1739	C= O (strong)	Carbonyl
1500-1000	1363	C–H rock (medium)	alkanes
1500-1000	1215	Medium C–H	Alkane
1000-500	973	=C–H bend (strong)	alkenes

The IR spectrum (Fig. C. sample liquid one) revealed band at 3331 cm^{-1} in the infrared spectrum is associated with O-H stretching vibrations, which are commonly found in water molecules, phenols, and alcohols. It may also indicate the presence of N-H stretching from amides or amines, suggesting a significant concentration of these functional groups in the liquid sample. The infrared band at 1739 cm^{-3}, which signifies C=O stretching in esters or aldehydes, implies that carbonyl compounds, likely derived from the breakdown or reaction products of organic additives, are present in the liquid phase. The band at 1634 cm^{-1} suggests the existence of unsaturated compounds or species containing amides in the liquid. This band is associated with C=C stretching in alkenes or aromatic rings, or amide C=O stretching. The presence of nitro groups (NO_2) with symmetric stretching can also be inferred from the band at 1348 cm^{-1}, which is caused by C-H bending vibrations, particularly in methyl groups. This suggests that the liquid contains various organic compounds with methyl and nitro functionalities. The absorption band at 1215 cm^{-1} is linked to C-O stretching vibrations, found in alcohols, ethers, and esters, indicating the presence of numerous oxygen-containing organic molecules in the liquid sample. A more complex mixture of organic compounds is observed in the liquid sample (Fig. 4.4C), suggesting that some of the organic material from the mixture may have dissolved or leached into the liquid phase, potentially impacting the overall characteristics of the concrete-cement mixture.

Table 4. 14 FTIR result of extracted calcium nitrate based additive (L)

Frequency (cm^{-1})	Wavenumber (cm^{-1})	Bond	Functional group
4000-3500	3331	N–H (narrow, strong)	amine
2000-1500	1739	C= O (strong)	Carbonyl
2000-1500	1634	C=C (medium)	Alkene
1500-1000	1348	NO2 stretch (medium)	Nitro
1500-1000	1215	Medium C–H	alkane

Overall, the FTIR results demonstrate the chemical interactions between the concrete and the organic additive made from eggshell and chicken dung in the three samples (liquid, 2% additive, and control). The additive samples (Figs. 4.4B and 4.4C) display the emergence of additional absorption bands, indicating the formation of new chemical species such as esters and other organic molecules. These interactions are likely a result of the concrete and cement components reacting with organic acids and other functional groups present in manure and eggshell.



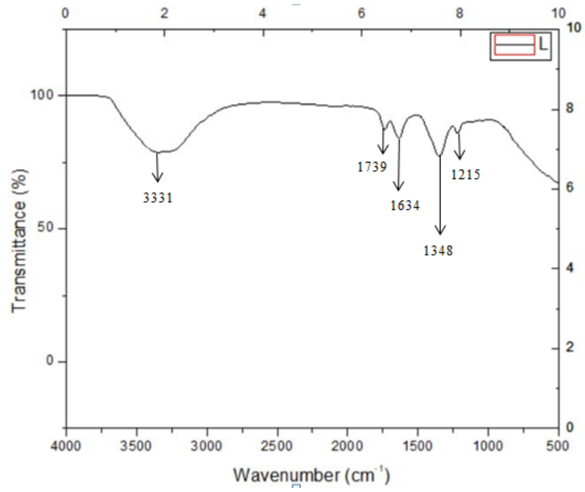


Figure 4. 9 The FTIR images of concrete samples additive of cement concrete from eggshell and chicken manure (a) concrete sample 0%, (b) concrete sample 2%, and (c) sample liquid one.

4.10.2 X-ray diffraction analysis

The crystalline structure of the components in the calcium nitrate-based accelerator is determined using XRD. This method is particularly useful for identifying crystalline phases, such as calcium carbonate, nitrate, or other minerals that may be present due to the natural origin of the raw materials. The presence and purity of calcium nitrate is confirmed by analyzing the XRD patterns, which is crucial for assessing the effectiveness of the accelerator. Calcium hydroxide, calcium silicate hydrate, calcium aluminum silicate, and ettringite are identified in the XRD investigation.

Calcium aluminum silicate (Al3CaO.5Si3O11) is formed when calcium carbonate and aluminum silicates react. It is the main peak in the study result that appears in the XRD pattern of concrete. Calcium silicate hydrate (C-S-H) crystals are formed when silica reacts with calcium during the hydration reaction of cement and water. During cement hydration calcium hydroxide (CH) is also formed. This reaction occurs as a result of the excess calcium ions released from the dissolution of cement compounds (Bullard et al., 2011).

Ettringite is a mineral compound that forms in concrete when calcium aluminate hydrates react with sulfates present in the environment (Balonis et al., 2011).

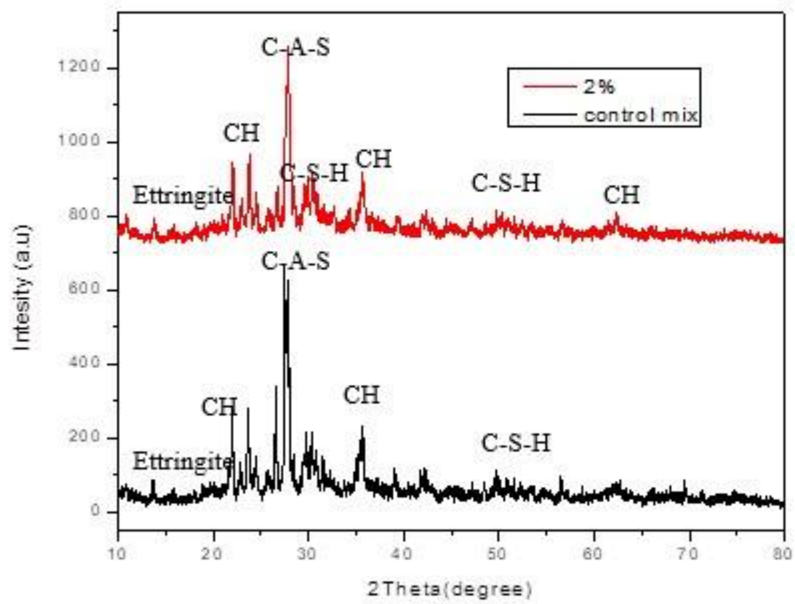


Figure 4. 10 X-ray diffraction patterns result. CH, calcium hydrate; C-S-H, calcium silicate hydrate; CAS, calcium aluminium silicate

The XRD patterns of the concrete samples are shown in Figure 4.5. The peaks indicate the presence of different compounds and their positions correspond to the 2Θ angles. At the control mix, the peak values were recorded at an angle (2θ) of 14.01°, 21.9°, 26.52°, and 27.52, and 35.56° for ettringite, calcium hydrate, calcium silicate aluminum, calcium silicate hydrate, respectively. For mix NBC2 (2%), the peak diffraction values were recorded at an angle (2θ) of 11.2°, 22.05°, 26.72°, 27.91° for ettringite, calcium hydrate, calcium aluminum silicate (CAS), calcium silicate hydrate, respectively.

The concrete containing additives showed a similar peak to the control sample, but at an angle of 27.91° there was a noticeable difference compared to the control. This suggests that the added additive allows the concrete mixture to produce more C-S-H crystals. C-S-H crystals is responsible for strength formed by formed by heat released from a reaction between calcium aluminum silicate and nitrate-based ettringite, which also release heat into the matrix when they react with sulfate ions (Balonis et al., 2011).

A thorough understanding of the chemical composition and structural characteristics of the calcium nitrate-based accelerator is achievable through the combination of FTIR and XRD analysis. FTIR is used to confirm the presence of nitrates and other functional groups by examining molecular vibrations and bonding environment. XRD is used to ensure that calcium nitrate is in the correct crystalline form for use as an accelerator in cement concrete by displaying the crystalline phases.

4.11 Micro structure of concrete Electron Microscopy (SEM)

Microstructural analysis of control mixes with 2% calcium nitrate base additive was examined using SEM. Figure 4.6 shows SEM analysis was conducted on Control and NBC2 due to their high compressive and flexural strength compared to the control mix. The SEM images were captured after 28 days of curing, with each mix examined at (x1500) magnification to study the concrete microstructure. Calcium hydroxide is identified by its relative brightness and hexagonal habits in the concrete (Maroliya, 2012).

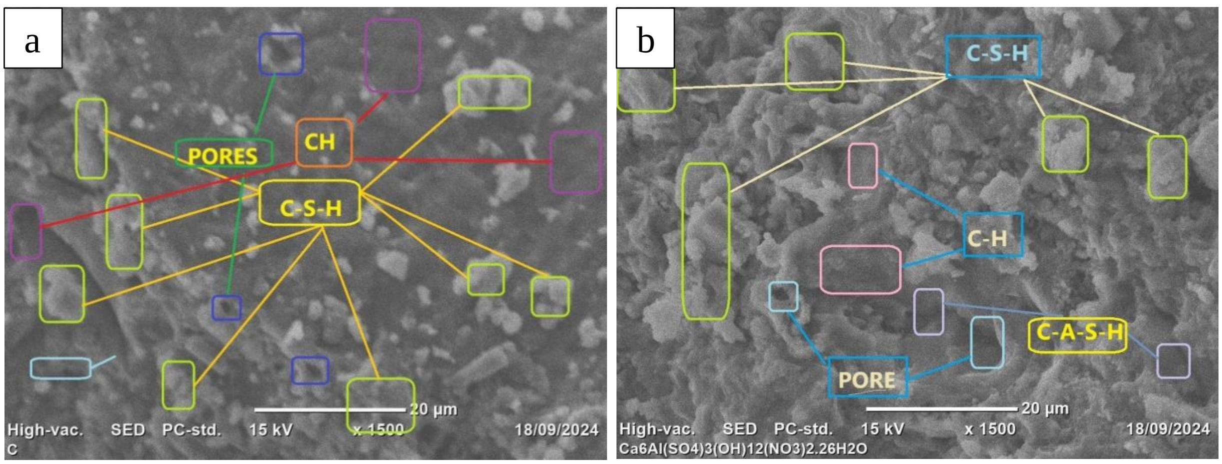


Figure 4. 11 SEM image of a, control concrete b, concrete with 2% additive

Figure 4.6(a) image displays various appearances of pore structures, calcium hydrate, and calcium silicate hydrates. The pore structures are small in Figure 4.6(b), with large amounts of calcium silicate hydrate, calcium silicate aluminum crystal, and calcium hydrate gel. As a result, the concrete with additive in image (b) is denser compared to the control concrete shown in image (a). This could account for the maximum compressive strength achieved at this at 2% additive addition. Similar result of Scanning Electron Microscopy (SEM) image was presented in the previous study (Bibi et al., 2020).

4.12 Cost Analysis of Extracted Calcium Nitrate Base Concrete

Analyzing the cost implications of waste materials, such as eggshells and chicken manure, presents challenges due to the unique circumstances. The researchers gather eggshells from hotels at no expense, as these establishments view them as valueless waste products. Similarly, the collection of chicken manure from small poultry farms involves no financial transaction. Consequently, the prices listed in Table 4.15 primarily reflect the costs incurred for transportation to collect these waste materials. Subsequently, the upcoming section is provide a detailed breakdown of the cost analysis for the concrete mixtures, taking into account the prevailing market rates for the various components involved.

Table 4. 15 Unit cost of material for concrete ingredients

Item No.	Materials	Unit	Quantity	Birr(ETB)
1	Cement	Quintal	1	1800.00
2	Fine aggregate	kg	1	1.17
3	Coarse aggregate	kg	1	0.81
4	Additive	lt	1	12.00
5	Water	kg	1	0.03

Table 4. 16 Cost for extracted additive process

Item	Unit	Quantity	Rate	Cost (birr)
Transport cost for eggshell	No	4	5	20
Transport cost for chicken manure	No	5	15	75
Firewood	Pic	2	30	60
Assistant	Hr	5	100	500
Lab (photometric)	Sample	1	1,200	1200
Lab (geological survey)	Sample	1	890	890
Lab (FTIR)	Sample	3	300	900
Total cost				3,645

Table 4. 17 Cost of 1 m3 of control mix concrete

Materials	Amount	Cost (birr)
Cement (kg/m^3)	425.29	7,655.22
F. aggregate (kg/m^3)	714.08	835.38
C. aggregate (kg/m^3)	1062.78	860.85
Water (lt/m3)	178.03	5.34
Total cost		9,356.79

Table 4. 18 Total cost of extracted additive concrete for 1m3

Mix code	Amount of additive (lt/m3)	Cost of additive	Total cost (birr)
NBC1	4.25	2,213.04	11,569.83
NBC2	8.51	4,431.28	13,788.07
NBC3	12.76	6,644.31	16001.1
NBC4	17.01	8,857.35	18,214.14

The results in Tables 4.16 indicate that the cost of the process of extracting calcium nitrate-based additive is shown. The laboratory cost is higher than all other costs. In this study, only seven liters of additive were extracted. Therefore, the total cost of 3,645 birr is divided by 7, resulting in a cost of 520.71 birr per liter of extracted additive. If more of this additive is extracted, the cost will decrease because the laboratory sample remains the same, but the total cost will be divided by a larger number compared to this case.

One of the study objectives was to determine the optimal amount of extracted calcium nitrate-based additive to use as an accelerator. The study findings in Tables 4.8 and 4.9 show that a dosage of 2% of the extracted additive led to a more effective concrete mix, with higher maximum compressive strength and flexural strength by 7.48% and 12.31%, respectively. Compared to conventional concrete, the use of the extracted additive enables early strength development, potentially reducing the time required for the concrete to reach its maximum strength. Expediting the concrete strength development process through the application of the extracted additive at the optimal dosage offers cost-saving opportunities for concrete producers. By decreasing the curing time and speeding up the construction schedule, the optimized additive dosage can contribute to cost optimization by reducing labor costs, shortening project duration, and enhancing overall project efficiency.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the experimental study the extraction of calcium nitrate additive and the evaluation of concrete's physical, chemical, and microstructural characteristics, the following findings are made.

The experimental research conducted on the extraction of calcium nitrate additive from waste eggshells and chicken manure has shown promising results for potential concrete additive purposes. The synthesis process yielded 48.02% calcium oxide from the eggshells and confirmed the presence of 11.6% nitrates and 4.6% nitrites in the chicken manure solution. FTIR analysis identified significant changes in the chemical composition of the concrete-cement mixture with the addition of the organic additive, suggesting potential impacts on performance and durability.

The addition of 2% extracted calcium nitrate base additive (NBC2) shows 17.09% and 7.48% compressive strength enhancement at the 7th and 28th days of curing as compared to the control mix. 12.31% enhancements were recorded in the flexural strength test of NBC2 as compared to the control mix at the 28th curing days. 3.03 was the minimum value for water absorption property at NBC2 compared to the control. The reduction of weight for acid attack resistance test was 3.87% on the control and 4.70% reduction for NBC2. This result shows that concrete with extracted additive have low acid resistance capacity.

The concrete sample with 2% extracted additive displayed a denser SEM image compared to the control mix. Additionally, more C-S-H crystals were observed in the NBC2 mix than in the control mix. The SEM image of NBC2 showed improvement, with common phases including calcium hydrate, calcium aluminum silicate, and calcium silicate hydrate crystal identified in the XRD result. Through comprehensive experimental investigations including compressive strength, flexural strength, water absorption, and microstructure analysis, it was determined that the optimal amount of extracted calcium nitrate-based additive to enhance concrete properties is 2%.

5.2 Recommendations

Based on the conclusions stated earlier, the following recommendations are proposed:

✓ Calcium nitrate based additive can be used and commercialized as accelerator since they exist as waste in our environment. This approach can decrease the use of version and nonrenewable resources, resulting in economical ecofriendly.

✓ Physical property and water absorption of concrete can be enhanced with the use of calcium nitrate-based additive when using NBC2 mix (2%) for better durability with comparable strength.

✓ While extracted additive showed improved physical properties, further research may be needed to optimize the dosage levels for enhanced acid resistance without compromising other concrete properties, highlighting avenues for future exploration in sustainable concrete production.

✓ Based on previous research, it has been noted that Calcium nitrate exhibits greater effectiveness in cold weather conditions. In this study, the extracted calcium nitrate-based additive was utilized solely at room temperature. Therefore, it is recommended that future research endeavors explore the evaluation of this additive at varying temperatures to gain a comprehensive understanding of its performance across different thermal conditions.

✓Nowadays, the Ethiopian government is focusing on initiatives that involve poultry farms. By integrating and utilizing the study results to create products, we can contribute to circular economy waste management, effectively utilizing resources from start to finish.

✓It is currently recognized that there are young forces in our nation that have finished their higher education but are still unemployed. However, if our citizens are interested, they can develop the product and enhance the research results to generate a market.

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APPENDIX

APPENDIX 1: Procedure for concrete material

APPENDIX 1a: Oxide composition of eggshell

	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: Tsegaye Ademasu
Sample type: Rock
Sample Preparation:-200 Mesh
Date Submitted:13/8/2024)

Issue Date:-9/02/2024
Request No:- GLD/RO/157/24
Report No:- GLD/RN/3774/24
Number of Sample:-One(01)

Analytical Result: In percent (%) Element to be determined Major Oxides & Minor Oxides.
Analytical Method: $LiBO_2$ FUSION, HF attack, GRAVIMETERIC, COLORIMETRIC and AAS

Collector's code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H2O	LOI	Weight of Sample
TA-06	1.00	<0.01	0.04	48.02	0.58	<0.01	<0.01	<0.01	0.20	0.06	1.04	48.50	600gm

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

- LOI = Loss on Ignition

Analysts
Haimanot Bayeh
Kindie Kasahun
Melkamu Debalkie
Shashe Haile

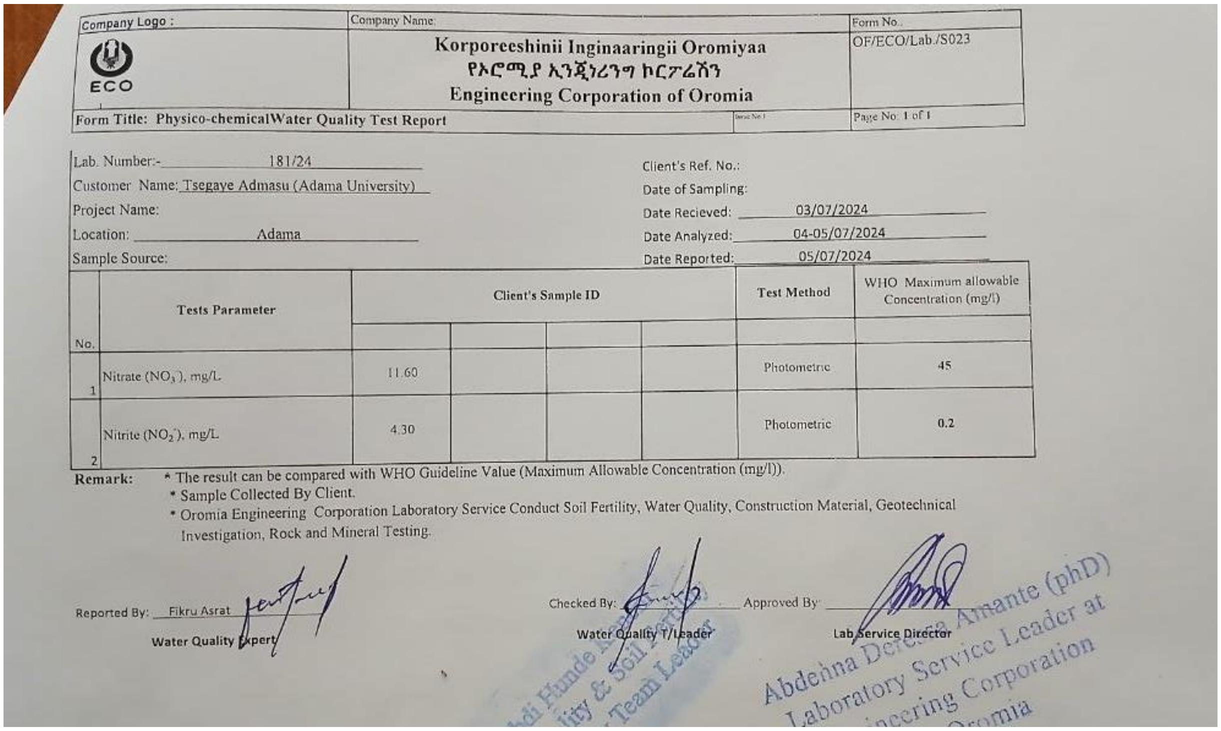
Checked By
Nigist Fikadu

Approved By
Lidet Endeshaw

Quality Control
Gosa Haile

Geochemical Laboratory Desk Page 1

APPENDIX 1b: Physico-chemical water quality test report



Company Logo: ECO	Company Name: Korporeeshinii Inginaaringii Oromiyaa የኦሮሚያ ኢንጂነሪንግ ኮርፖሬሽን Engineering Corporation of Oromia	Form No.: OF/ECO/Lab./S023
Form Title: Physico-chemicalWater Quality Test Report		Page No: 1 of 1

Lab. Number:- 181/24
Customer Name: Tsegaye Admasu (Adama University)
Project Name:
Location: Adama
Sample Source:

Client's Ref. No.:
Date of Sampling:
Date Recieved: 03/07/2024
Date Analyzed: 04-05/07/2024
Date Reported: 05/07/2024

No.	Tests Parameter	Client's Sample ID				Test Method	WHO Maximum allowable Concentration (mg/l)
1	Nitrate (NO_3^-), mg/L	11.60				Photometric	45
2	Nitrite (NO_2^-), mg/L	4.30				Photometric	0.2

Remark:
* The result can be compared with WHO Guideline Value (Maximum Allowable Concentration (mg/l)).
* Sample Collected By Client.
* Oromia Engineering Corporation Laboratory Service Conduct Soil Fertility, Water Quality, Construction Material, Geotechnical Investigation, Rock and Mineral Testing.

Reported By: Fikru Asrat
Water Quality Expert

Checked By:
Water Quality T/Leader

Approved By:
Lab Service Director

APPENDIX 1c: Test Procedure for Silt Content

1) Into the graduated cylinder with a 1000 ml capacity, 300 ml of sand was added.
2) Approximately 3/4 of the jar was filled with water.
3) For almost a minute, the jar was shaken actively.
4) To permit the silt to settle on the sand layer, the jar was left for an hour.
5) A measurement was made of the amount of silt that was forming a distinct layer on top.
6) Equation 3.a was utilized in the computation of the silt content.

Silt content = Silt deposited above the sand (V1) / Amount of clean sand (V2) x 100%

APPENDIX 1d: Procedure for Grading Fine Aggregate

1) The two-kilogram fine aggregate was carefully weighed for the sieve analysis test.
2) Quartering the sample was done.
3) Taking 500g of the quartered sample.
4) The data was accurately recorded and the empty sieves were weighed.

5) After setting the pan on the bottom, the other sieves with progressively larger openings were positioned on top of the pan.
6) Put the 500 g sample on top of the sieves, which had bigger openings.
7) Using a sieve shaker, bang the material for approximately ten minutes.
8) The weight retained on each sieve was computed and measured, along with the aggregate kept on each sieve.
9) The fineness modulus was calculated and the gradation chart was completed.

$$\text{Fineness modulus} = \sum_{n=1}^{7}(Cummulative\ retained\ by\ mass/100)$$

Appendix 1e: Test procedure for Sieve Analysis for Coarse Aggregate

Sieve Analysis for Coarse Aggregate

1. The 20 kg of coarse aggregates were weighed.
2. Quartering was the method that was used to choose a representative sample.
3. Two kilograms were obtained from the quartered sample.
4. Accurately collected the data after weighing the empty sieves.
6. Positioned the 2 kilograms of sample on the top sieves with larger openings.
7. Agitated the sample for approximately 10 minutes in a sieve shaker.
8. Measured each sieve along with the aggregate retained on it, and calculated the retained weight on each sieve.
9. Completed the gradation chart and calculated the fineness modulus. The acceptable range of fineness modulus for coarse aggregate as per ASTM C33 is 5.5-8.

$$\text{Fineness modulus} = \sum_{n=1}^{11}(Cummulative\ retained\ by\ mass/100)$$

Appendix 2: Procedures for combining the synthesis of calcium carbonate from waste eggshells and nitrates from chicken manure

Material Proportion:

- 100 g of calcium-rich eggshell slurry (from 3.7)
- 200 mL of nitrate-rich filtrate (from 3.8)

Procedure:

- The solution rich in nitrates obtained from the fermentation process of chicken manure was filtered.

- In a clean container, 200 mL of the nitrate-rich solution (from step 3.8) was mixed with 100 g of the eggshell slurry (from step 3.7).
- The mixture was stirred to ensure thorough interaction between the calcium ions (Ca^{2+}) and the nitrate ions (NO_3^-).
- The resulting solution was filtered in order to collect the precipitated calcium carbonate.
- The calcium carbonate was dried at low heat (below 50°C) to obtain a fine powder.

Appendix 3: Concrete mix design for C-30

Step 1: Determining the necessary mean compressive strength from the characteristic strength of 30 MPa.

The required average compressive strength might be selected using the following formulas in the event that field test records are not available to calculate a standard deviation.

f'cr = f'c + 7 MPa If the designated compressive strength is less than 21 Mpa

f'cr = f'c + 8.5MPa If the specified compressive strength falls between 21 to 35Mpa

f'cr = 1.1f'c + 5 MPa If the given compressive strength exceeds 35 Mpa

The target average strength for C-30 grade concrete is determined by utilizing:

fck = f'ck + 8.5 = 30 + 8.5 = 38.5 MPa.

Step 2: Select slump Value

A provided slump of 2–10 cm is appropriate for C–30 concrete.

Step 3: Determine Maximum Aggregate Size:

The maximum size aggregate for our investigation was 20 mm, and in this instance, the nominal size aggregate was 19 mm to potentially improve the compressive strength of the concrete.

Step 4: Determination of Water and Air Content:

Table APPENDIX 2. 1 Mixing Water for different Slump and Maximum Size Aggregate

Non-air entrained concrete								
2-10	205	200	**185**	180	160	155	145	125
8-10	225	215	200	195	175	170	160	140
15-18	240	230	210	205	205	185	180	170
Amount of entrapped	3	25	**2**	15	1	0.5	0.3	0.2
Water (kg/m²) of concrete for indicated maximum size aggregate in mm								
Slump (cm)	10	12.5	**20**	25	40	50	70	150

Based on the provided data from the table, for non-air entrained concrete with a slump range of 2-10, the water content required in 1 cubic meter of concrete is determined to be 185 kg. This specific water-to-cement ratio is crucial for achieving the desired workability and strength properties in the concrete mix.

Step 5: Establish the water-cement ratio

Identify the water-cement ratio as the proportion of water weight to cement weight in a concrete mixture.

Table APPENDIX 2. 2 Average Compressive Strength with water Cement Ratio

Compressive strength at 28 days (MPa)	Water cement ratio (by mass)
45	0.38
40	0.42
35	0.47
30	0.54
25	0.61
20	0.69
15	0.79

The water-cement ratio for a concrete mix with a mean strength of 38.5 MPa cannot be directly obtained from the ACI table. To determine the appropriate water-cement ratio, interpolation is required between the values corresponding to 35 MPa and 40 MPa strengths in the table. This method allows for a more accurate estimation of the water-cement ratio for achieving the desired concrete strength.

40 0.42

38.5 X

35 0.47

By interpolation, $\frac{40-38.5}{0.42-x} = \frac{38.5-35}{x-0.47}$

= 1.5x - 0.705=1.47 - 3.5x

= 0.435 therefore, the minimum water cement ratio is 0.435

Step 6: Estimation of cement content

Cement content = water content / water cement ratio = 185/ 0.435 = 425.29 kg/m³

Step 7: Estimating the Bulk Volume Per Unit Volume of Concrete

The determination of the concrete mix design is influenced by the fineness modulus, which is 2.97, and the maximum size aggregate of 20 mm.

Table APPENDIX 2. 3 Volume of Coarse Aggregate per unit Volume of Concrete

Nominal maximum size of aggregate (mm)	2.60	2.80	3.00
10	0.50	0.46	0.44
12.5	0.59	0.55	0.53
20	0.66	0.62	0.60
25	0.71	0.67	0.65
40	0.76	0.72	0.7
50	0.78	0.74	0.72
70	0.81	0.77	0.75
150	0.87	0.83	0.81

The table does not provide the direct value for the bulk volume of dry rodded aggregate. However, utilizing interpolation is a viable method to determine this volume, especially considering the fineness modulus of 2.97 falls within the range of 2.8 and 3 for a 20 mm maximum size aggregate.

2.8 0.62

2.97 X

3.0 0.60

By interpolation, (2.8-2.97)/(0.62-x)=(2.97-3.0)/(x-0.6)

= -0.0186 +0.03x = 0.102 – 0.17x

= 0.64 therefore, the dry volume of aggregate per volume of concrete is 0.435

Step 8: Calculate the weight of coarse aggregate (WCA) per m^3 of concrete.

To determine the weight of coarse aggregate (WCA) per cubic meter (m^3) of concrete, one must consider the density of the coarse aggregate and the desired volume ratio in the concrete mixture. By multiplying the volume of coarse aggregate (in cubic meters) by its density, the weight of coarse aggregate per cubic meter of concrete can be accurately determined.

WCA= bulk volume x bulk density of coarse aggregate

WCA= 0.64 x 1,680.95

= 1,075.80kg / m^3

Step 9: Determining the solid volume of coarse aggregate.

Solid volume of coarse aggregate = $\frac{\text{WCA}}{\text{specific gravity}}$

= $\frac{1{,}075.80\text{kg / m3}}{2.67}$

= 402.92kg / m^3

Step 10: Calculating the solid volume of cement, water, and air

Volume of cement (VC) = $\frac{\text{weight of cement}}{\text{specific gravity of cement}}$

= 425.29/3.15 = 135.01kg /m^3

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

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

Step 11: Calculating solid volume of sand

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

= 1000 - (402.92 + 135.01 + 185 + 20)

= 257.07kg /m^3

Solid weight of sand= dry volume of sand x specific gravity = 257.07kg/m^3 * 2.70

= 694.09kg / m^3

Step 12: Adjustments for moisture in the aggregate

Fine aggregate adsorption = 2.88% and coarse aggregate absorption = 1.21%

Water absorbed by coarse aggregate = 1,075.80kg * 0.0121 = 13.02kg / m^3

Water supplied by fine aggregate = 694.09kg / m^3 * 0.0288 = 19.99kg / m^3

Amount of water needed = 185kg / m^3 + 13.02kg / m^3 – 19.99kg / m^3 = 178.03kg / m^3

Cement= 425.29 kg/m^3

Fine = 694.09kg / m^3 + 19.99kg / m^3 = 714.08kg / m^3

Coarse aggregate = 1,075.80kg / m^3 – 13.02kg / m^3 = 1062.78kg / m^3

Hence, the estimated batch weight for 1 cube of concrete is given in Table 3.5.

Table APPENDIX 2. 4 Calculated Batches for 1m 3 of Concrete

Water	178.03 kg / m^3
Cement	425.29 kg / m^3
Fine aggregate	714.08 kg / m^3
Coarse aggregate	1062.78 kg / m^3

Table APPENDIX 2. 5 Mix Ratio for C-30 Concrete Grade

Ingredients	Cement	Fine aggregate	Coarse aggregate
Amount/ m^3	425.29/425.29	714.08/425.29	1062.78/425.29
Ratio	1	1.68	2.50

Based on the mix proportion given above, the quantity of each concrete ingredient can be calculated for one cube standard mold.

Wet volume for 1 mold -length x width x height = 0.15 * 0.15 * 0.15 = 0.00375m^3

Dry volume wet volume x 1.55 = 0.00375m^3 * 1.55 = 0.0058125m^3

Sum of ratio = 1 + 1.68 + 2.50 = 5.18

Weight of cement = 1/sum of ratio x dry volume x unit weight of cement

= 1/5.18 * 0.0058125 * 1440 = 1.62kg

Weight of FA = 1.68/sum of ratio x dry volume x unit weight of FA

= 1.68/5.18 * 0.0058125 * 1,492.86= 2.81kg

Weight of CA = 2.5/sum of ratio x dry volume x unit weight of CA

= 2.5/5.18 * 0.0058125 * 1,680.95= 4.72kg

Weight of water = Amount of water needed * dry volume = 178.03 * 0.0058125 = 1.03kg (L)