EXPERIMENTAL INVESTIGATION OF WHEAT STRAW ASH AND EGGSHELL POWDER COMPOSITE AS PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

Abdulsemad Jemal

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

Presented in fulfilment of the Requirement for the Degree of Master's in Civil Engineering (Specialization in Construction Engineering and Management)

Office of Graduate Studies

Adama Science and Technology University

November, 2024 GC

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Advisor: Dr. Fikreyesus (Ph.D.)

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DECLARATION

I now declare that this Master Thesis entitled "**Experimental investigation of wheat straw ash and eggshell powder composite as partial replacement of cement in concrete**" is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

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RECOMMENDATION OF ADVISORS/ SUPERVISORS

I, the major advisor/supervisor of this research proposal, hereby certify that I have closely advised/supervised the student while developing this thesis and read the draft thesis entitled "**Experimental investigation of wheat straw ash and eggshell powder composite as partial replacement of cement in concrete**" Prepared under my guidance by Abdulsemad Jemal. Therefore, I recommend submitting the thesis to the department for further review and evaluation.

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APPROVAL PAGE OF THESIS

I, the advisor of thesis entitled "**Experimental investigation of wheat straw ash and eggshell powder composite as partial replacement of cement in concrete**" and developed by Abdulsemad Jemal, hereby certify that the reccomendation and suggestions made by board of examiners are appropriately incorporated in to the final version of thesis.

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We, the undersigned, members of the Board of Examiners of the Thesis by **Abdulsemad Jemal** have read and evaluated the thesis entitled **"Experimental investigation of wheat straw ash and eggshell powder composite as partial replacement of cement in concrete"** and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfilment of requirement of the degree of Master of Science in Civil Engineering.

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ABSTRACT

Concrete remains crucial for the construction industry and plays a vital role in a country's development by meeting infrastructure demands and enhancing capacity. Cement, as the primary component of concrete, is widely utilized worldwide. However, the adverse effects of cement production on natural resources, and environmental, and energy utilization have driven the construction industry's interest in supplementary cementitious materials. Therefore, substituting cement with supplementary materials offers an opportunity to reduce cement demand in the construction sector. Research objective is to investigate the potential use of a blending eggshell powder and wheat straw ash partially replacing cementitious material on mechanical and durability properties in C-25 Concrete with 5%, 10%, 15%, 20%, and 25% of OPC with eggshell and wheat straw ash composite of mix-1(0-0), mix-2(5-5), mix-3(5-10), mix-4(10-5), mix-5(10-10), mix-6(15-5) and mix-7(15-10) of eggshell powder-wheat straw ash respectively investigated. The chemical composition of eggshell powder and wheat straw ash was examined and the summation of major oxide (SiO2, Al2O3, and Fe2O3) is 86.97 %, for wheat straw ash and classified under class F pozzolanic materials and Concrete mix design as per ACI standard. The result also shows that the workability of concrete decreases as the eggshell powder and wheat straw ash replacement increases. From 28- and 56-day results Mix-1(Control) and Mix-6(15%ESP-5%WSA) attain the target mean compressive strength(33.5Mpa) of C-25 concrete according to the ACI standards. As per IS 456 2000 the flexural strength of concrete is computed and attains the requirement for flexural strength of 3.5Mpa for C-25 concrete except for mix-7, and blended concrete improved its resistance to sulphuric acid attack which proved the durability of concrete enhanced due to replacement. SEM results showed that the inclusion of WSA reduced the free lime content due to the pozzolanic reactions and displayed the formation of dense concert as the inclusion of supplementary material. XRD result also displayed Portlandite (CH) is decreased as the inclusion of supplementary material and also the formation of ettringite is hindered.

Keywords/terms: *Cement; Concrete: Wheat straw ash; Eggshell powder; Supplementary cementitious material.*

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LIST OF ACRONYMS

ESP	Eggshell powder
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BFSC	Blast Furnace Slag Cement
BS	British standard
CA	Coarse aggregate
FA	Fine aggregate
GGBS	Ground granulated blast furnace slag
LOI	Loss of Ignition
OPC	Ordinary Portland Cement
PCC	Plain Cement Concrete
PC	Portland Cement
PPC	Portland Pozzolana Cement
SCM	Supplementary Cementitious Material
SEM	Scanning Electron Microscope
XRF	X-Ray Fluorescence
XRD	X-Ray Diffraction
WSA	Wheat straw ash
C-25	Concrete characteristic compressive strength of 25 Mpa
MPa	Mega Pascal

LIST OF CHEMICAL FORMULAS

Al	Aluminium	C4AF	Tetra Calcium Alumino Ferrite
Al_2O_3	Aluminium Oxide	C-S-H	Calcium Silica Hydrate
Ca	Calcium	CH	Calcium Hydroxide
CaO	Calcium Oxide	CO2	Carbon Dioxide
$CaCO_3$	Calcium Carbonate	MgCO3	Magnesium carbonate
Fe	Iron	Ca_3SiO_5	Alite
Fe_2O_3	Iron Oxide	Ca_2SiO_5	Belite
K2O	Potassium Oxide	Ca_2AlFeO_5	Ferrite
MgO	Magnesium Oxide	$Ca_3Al_{12}O_6$	Aluminate
Na2O	Sodium Oxide	H_2SO_4	Sulpharic acid
Si	Silicon	SO_3	Sulphur Trioxide
SiO_2	Silicon Oxide	Ca3(PO4)2	calcium phosphate

CHAPTER ONE

1. INTRODUCTION

1.1 . Background of Study

The construction industry is crucial for a country's economic growth and long-term national development by enhancing capacity, and effectiveness, and meeting the infrastructure demands (Ofori, 2015). Concrete remains crucial for economic growth worldwide, as it is extensively utilized in construction projects, infrastructure development, and urbanization, driving economic progress at both local and global levels (Mukherjee & Vesmawala, 2013).

Concrete is a composite material composed of aggregates (sand, crushed stone) and a cementitious binder. Cement is the primary binder, and the cement industry is vital for the nation's construction sector, providing the necessary materials for infrastructure development and supporting economic growth (Tinni & Consulting, 2013). Cement finds extensive application in the construction industry, primarily in the form of mortar and concrete, due to its binding properties and ability to provide strength and durability to structures (Devi et al., 2017). Cement is a crucial component in civil engineering and building structures, playing a vital role in the economy. However, the production of cement is associated with challenges such as resource consumption, energy usage, and air emissions (Arachchige et al., 2019). Additionally (Onaizi & Huseien, 2021) and (Mohamad et al., 2021) Stated that Enhancing cement plant manufacturing technology is vital for cleaner production and mitigating the environmental impacts of cement production.

Cement, as the main ingredient in concrete, holds the distinction of being the most widely used material worldwide. The substitution of cement with supplementary materials, such as calcined clay and limestone, presents a significant opportunity to reduce cement demand by approximately 27%. Additionally, this substitution strategy plays a critical role in analyzing and implementing emissions reduction strategies in the construction industry (Shanks et al., 2019). By incorporating supplementary cementitious materials and maximizing the clinker content, the cement production process can be enhanced across the value chain, leading to improved efficiency and performance without compromising quality (Habert et al., 2020).

Feasibility tests, and chemical, physical, and mechanical analyses, were conducted to evaluate the potential of utilizing naturally occurring pozzolan as an additive in cement mortar. The findings suggest that, when used within specific mixture percentage limits, replacing a portion of cement with pozzolan does not compromise the mechanical strength of the mortar. This indicates the viability of incorporating pozzolan as a cement mortar additive (Chaar et al., 2011). Pozzolanic materials have a positive impact on cement properties. When pozzolanic materials react with cement, they fill the voids between cement grains and form a dense calcium silicate hydrate. This pozzolanic reaction product, along with micro filling, contributes to refining the pore structure in the bulk paste matrix and interfacial transition zone of concrete. Consequently, the strength, transport properties, and durability of concrete are enhanced, leading to improved overall performance (Rathi & Modhera, 2007).

A study proposes using low-lime non-hydraulic calcium silicates as a partial substitute for conventional cement to enhance the sustainability and performance of concrete (Ashraf & Olek, 2016). The mechanical properties of concrete were examined by incorporating Hydraulic Lime as a partial substitute for cement in lime concrete and lime mortar. The results demonstrated an increase in compressive strength with an increasing relative percentage of lime to cement up to 15%, followed by a gradual decrease afterward (Maurya & Faldu, 2019).

Researchers are exploring efficient cement substitutes, including industrial and agricultural wastes, which offer prospective advantages. Utilizing these materials as supplementary or replacement components can lead to significant energy savings and reduced cement consumption. Wheat straw ash, an agricultural waste, shows promise as a cement substitute material (Shar et al., 2019). In recent years, extensive research has focused on incorporating waste materials in the concrete industry. Eggshell powder has emerged as a cement substitute in concrete manufacturing. Studies have shown that adding eggshell powder significantly enhances the mechanical strength of concrete, highlighting its potential as an effective and sustainable ingredient in construction materials (Tan et al., 2018).

Generally, the construction industry plays a vital role in economic development through meeting infrastructure demands and enhancing capacity and effectiveness. However, cement production, a key component of concrete, presents challenges related to resource consumption, energy usage, and air emissions. To mitigate these issues, researchers have explored cement substitutes like calcined clay, limestone, pozzolans, low-lime non-hydraulic calcium silicates, industrial/agricultural waste materials, and eggshell powder. These substitutions show promise in reducing cement demand, improving concrete's mechanical properties, and enhancing sustainability. Among these alternatives, utilizing partial cement materials like eggshell powder and wheat straw ash offers a viable solution. Incorporating these materials in concrete production reduces cement consumption while addressing sustainability challenges, contributing to energy savings and improved efficiency and quality in construction projects.

The adverse effects of concrete production on natural resources, environmental sustainability, and energy utilization have driven the construction industry's interest in supplementary cementitious materials. While previous studies have separately demonstrated the potential of eggshell powder and wheat straw ash in concrete, there is a lack or limited research investigating their combined use as a ternary material to partially replace cement which evaluate by incorporating wheat straw ash and eggshell powder as partial replacements for cement that investigate the aspects of fresh concrete (workability) and hardened concrete properties, including compressive strength, flexural strength, and durability in C-25 concrete.

Therefore, using partial cement materials like eggshell powder (ESP) and wheat straw ash (WSA) offers an alternative solution, reducing cement consumption and addressing challenges in concrete production.

1.2. Statement of the problem

The mechanical performance of concrete was assessed in terms of its compressive strength, modulus of elasticity, split tensile strength, and flexural strength from the incremental investigation of wheat straw ash as a partial replacement material for cement. The results from this research showed sufficient compressive strength, split tensile strength, and flexural strength (Bheel, Ibrahim, et al., 2021). Tests conducted on wheat straw ash as a partial cement replacement reveal its potential as a pozzolanic material due to the presence of amorphous silica. Notably, WSA exhibits a high-water absorption capacity, which helps mitigate concrete shrinkage over time. This characteristic makes it a valuable candidate for partially replacing cement in concrete production (Khan et al., 2019). In some instances, discarded eggshells have been used as a substitute for cement due to their calcium content. To assess the feasibility of using eggshells as a cement alternative, various combinations of eggshells and silica fumes were tested, Compressive, tensile, and flexural tests were conducted on cast concrete to determine the optimal combination and potential impact on strength. Results showed that eggshell powder, without silica fume, increased the concrete's compressive strength. Furthermore, the addition of silica fume further improved concrete performance. However, considering the economic aspect, replacing cement with eggshell powder alone is necessary to achieve increased strength (Parthasarathi et al., 2017).

The use of alternative materials in concrete production has gained significant attention due to their potential to enhance the performance and sustainability of concrete structures. However, there is a research gap surrounding the utilization of a blend of eggshell powder and wheat straw ash as cement replacements in concrete. Currently, there is a lack of comprehensive studies investigating the optimal mixture proportions for these additives, their impact on the compressive strength, flexural strength, durability, and microstructure of concrete, as well as their long-term performance and sustainability. Understanding the effects of incorporating eggshell powder and wheat straw ash in concrete would provide valuable insights for the construction industry. Therefore, this research aims to address these gaps by analyzing the compressive strength, flexural strength, durability, and microstructure of concrete containing various proportions of eggshell powder and wheat straw ash, as well as evaluating their long-term performance and sustainability. This investigation will contribute to the knowledge base and guide the development of eco-friendly and high-performance concrete mixtures.

1.3. Objectives of the Study

1.3.1. General objective

The main objective of this study is to investigate the potential of using composite materials of wheat straw ash and eggshell powder as a partial replacement for cement material by analyzing the mechanical and durability properties of C-25 concrete.

1.3.2. Specific objectives

1. to characterize wheat straw ash and eggshell.
2. To investigate the effect of incorporating the wheat straw ash and eggshell composite on fresh concrete properties and the mechanical properties (compressive, flexural, and durability) of hardened concrete using eggshell and wheat straw ash composite.
3. To analyze the microstructural characteristics of the wheat straw ash and eggshell composite-based concrete.

1.4. Scope of the study

As per review, cement is becoming a challenging construction material in terms of environmental sustainability, economy, etc. so, it requires an attention to solve the challenges in the construction industry and make it effective, efficient, and sustainable. As a result, the goal of this research is to investigate the mechanical strength of concrete, such as compressive strength, flexural strength, tensile strength, and microstructural properties, as well as the workability, water demand, and setting time of fresh concrete.

1.5. Significance of the study.

This study highlights the successful utilization of eggshell powder and wheat straw ash as sustainable and cost-effective waste materials based on previous study. It investigates the enhancement of mechanical properties, the impact on fresh and hardened concrete, and the microstructure of concrete by incorporating different proportions of wheat straw ash (5%, and 10%,) with 5%, 10%, and 15% eggshell powder. The findings demonstrate the potential benefits and effectiveness of these materials in improving concrete performance and sustainability.

1.6. Organization of research report

This Paper will have five chapters.

CHAPTER ONE: This chapter is introductory and is focused on the background of the study, the statement of the Problem, the objective of the study scope of the study, the expected result, the Significance of the study, and the organization of the study.

THE SECOND CHAPTER is a literature review focused on the effects of eggshell powder and wheat straw ash, the reaction mechanism chemical composition and their effect, characterization, chemical composition, etc.

CHAPTER THREE: research methods, material, mixing method, testing procedure and technique to be demonstrated during casting.

CHAPTER FOUR: Results and Discussions.

CHAPTER FIVE: Summary of Findings, Conclusions, and Recommendations.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

This chapter explores the effects of cement production. It also discusses potential options for the future of cement and the selection of suitable materials for partial cement replacement. The chemical composition of various agricultural and poultry waste is examined, along with the effects of lime and silica in concrete. The chapter delves into the reaction mechanism, chemical compounds, and their impacts on concrete. Furthermore, it investigates the effects of agriculturally based calcium and silica in concrete, as well as the effects of wheat straw ash and eggshell powder on concrete. The properties of eggshell powder and its influence on fresh concrete are studied, along with the impact of wheat straw ash on fresh concrete and the microstructure of concrete. Lastly, the chapter investigates the effects of wheat straw ash on the durability of concrete and explores the combined effects of wheat straw ash and eggshell powder in a mortar.

2.2. Concrete and its constituents.

The characteristics of concrete are influenced by the specific raw materials chosen, including the size and quantity of particles, as well as the ratio of its components. These factors play a crucial role in determining the properties of the final concrete product. By carefully selecting and controlling these raw materials, such as aggregates, cement, water, and additives, engineers and constructors can manipulate the strength, durability, workability, and other desired characteristics of the concrete. The particle size distribution and the proportion of each component in the mix are particularly important factors that directly impact the overall performance and behavior of the concrete (Mačiulaitis et al., 2010).

2.2.1. Cement

Gashaahun, (2020) Stated that cement is a key component in the construction industry, serving as the primary ingredient in the production of concrete. OPC, also known as Ordinary Portland Cement, is manufactured by blending limestone and clay, both of which are naturally sourced materials. Through a high-temperature process, these components undergo chemical reactions that ultimately produce the cementitious properties of OPC (K. Rajendra et al., 2013).

Table 2.1: Chemical composition of ordinary Portland Cement (OPC)

Constituent	**Ordinary Portland cement % by weight as per** (Basit et al., 2019)**,** (Dunuweera & Rajapakse, 2018)**, and** (Bediako & Amankwah, 2015)
Lime (CaO)	60-67.1
Silica (SiO_2)	17.2-25.1
Alumina (Al_2O_3)	4.0-8.0
Iron Oxide (Fe_2O_3)	0.51-6.2
K_2O, Na_2O	less than 2
Magnesia (MgO)	0.1-4.0
Sulphur Trioxide (SO_3)	0.5-2.4

The (ASTM C150-07, 2015) The standard specification covers eight types of Portland cement and their classifications with their purpose are stated below table

Table 2.2: Types of Portland cement and their purposes

Types of cement	Purpose
I	For use when the special properties specified for any other type are not required.
IA	Air-entraining cement for the same uses as Type I, where air-entrainment is desired.
II	For general use, especially when moderate sulfate resistance or moderate heat of hydration is desired.
IIA	Air-entraining cement for the same uses as Type II, where air-entrainment is desired.

III	For use when high early strength is desired.
III A	Air-entraining cement for the same use as Type III, where air-entrainment is desired.
IV	For use when a low heat of hydration is desired.
V	For use when high sulfate resistance is desired

2.2.2. Aggregate

Aggregates used in concrete, classified as Fine Aggregate (FA) and Coarse Aggregate (CA), are inert materials. Fine aggregates, commonly known as sand, are typically dredged from riverbeds, while coarse aggregates are obtained by crushing rocks such as granite, limestone, or basalt. These aggregates provide the structural strength and stability to concrete, contributing to its overall performance and durability (K. Rajendra et al., 2013). As per ASTM C 33 A nominal maximum size aggregate up to 6 in. (150 mm) should be considered, if a large size aggregate is available, economical, and placing conditions permit. Because the larger aggregate provides less surface area to be coated by cement paste, a reduction in the quantity of cement and water can be realized for the same water-cement ratio.

2.2.3. Water

Water plays a fundamental role in concrete, being essential for cement hydration, which leads to hardening and strength development. It affects the behavior of concrete throughout its lifespan, influencing both the fresh stage and the hardened state, ultimately determining its strength and durability properties (Hover, 2011). As per Kucche, Jamkar and Sadgir, (2015) the chemical reaction between water and cement has an influence on the setting time, and compressive strength, and can result in the softening of concrete. Interestingly, using impure water in the concrete mixing process is considered beneficial for enhancing strength during the initial stages, but it may lead to a decrease in long-term strength. As per (BS:EN:1008:2002) Potable water is considered suitable for use in concrete without the need for testing. On the other hand, water obtained from processes within the concrete industry, which is typically suitable for concrete use, should still meet specific requirements and undergo testing. Water from underground sources, natural surface water, and industrial wastewater may be suitable for concrete, but testing is necessary. However, seawater, brackish water, and sewage water are generally not recommended. In general, water that complies with the European Directive 98/83/EC, which defines potable water, is considered suitable for use in concrete.

2.3. Options for the future of cement

Blending Portland cement clinker with increasing amounts of other cementitious materials is the most practical approach. Blended cement with good performance at substantially lower amounts of clinker can be achieved by partially replacing clinker with calcined clays coupled with limestone (Scrivener, 2014). Cement will continue to be the primary material for meeting global housing and modern infrastructure demands. As a result, the global cement industry is encountering increasing difficulties in lowering its CO2 emissions and saving energy and material resources. The utilization of alternative materials, whether as fuel or raw materials, and increased energy efficiency are the primary levers for cement makers, according to the International Energy Agency. As a result, although the usage of alternative fuels has already grown dramatically in recent years, there is still room for growth. Reducing the clinker factor is still a top aim in cement (Schneider et al., 2011). The global demand for construction has led to increased concrete usage, but traditional materials used in concrete production have become quite challenging. This has prompted research into more sustainable alternatives. Several studies have investigated the use of agricultural waste from industries like palm oil, coconut, sugarcane, and paddy in concrete production. Promising results have shown the potential for utilizing these waste materials. Reusing agricultural waste in concrete, not only conserves waste but reduces disposal (Lee, 2016).

2.4. Selecting material for partial cement replacement

to create affordable, environmentally friendly concrete from waste materials that are readily available locally, such as glass waste, powdered marble dust, ceramic waste, quarry dust, GGBS (ground granulated blast furnace slag), fly ash, rice husk ash, silica fume, silt, clay, sewage sludge ash, various sludge, etc. When used in part instead of cement, it might be more cost-effective than conventional concrete, and the issue of dampening down the waste generated by various businesses is also resolved (Patel, 2015). Three key problems related to sustainable development should be considered when choosing sustainable materials with low environmental impact: the environment, equity (the problem of poverty and the equitable distribution and use of natural resources), and futurity (the effects of development) (Ljungberg, 2007). Every new project will need to analyze the specifics of the local materials through a unique investigation of what is available (Morel et al., 2001). Wheat straw ash is a byproduct of the agricultural business. It is created when wheat straw is left behind after harvesting. Every year, this results in massive amounts of wheat straw being generated. The goal of this research is to utilize this waste material to replace cement. The use of wheat straw as a partial substitute for OPC in concrete was investigated in this study. Wheat straw is one of the most common types of agricultural waste, and it is frequently abandoned and burnt year after year, causing environmental problems (Shar et al., 2019). The disposal of agricultural waste is a serious environmental problem. The use of agricultural wastes in the production of cement blocks may reduce global problems (Info, 2021). Agricultural production is the main source of foreign exchange and supplier of raw materials and markets to domestic industries in Ethiopia, and agricultural waste is abundant (Bekabil, 2014).

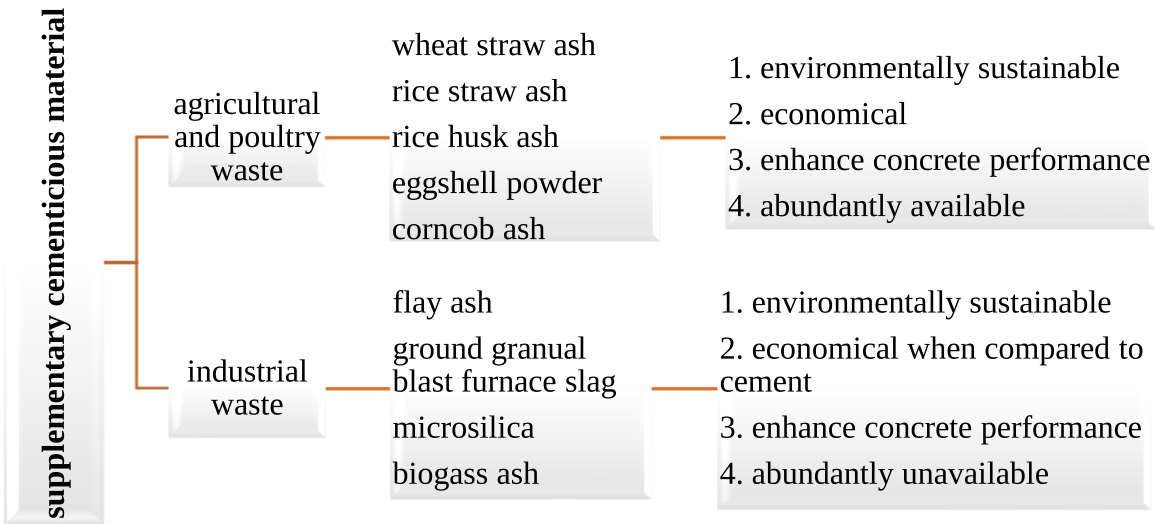

Figure 2.1: Developed sustainability analysis

in Ethiopia except for barley, rice, and oats which showed a decreasing trend, the productivity of all cereal crops showed a significant increasing trend and wheat production is the leading crop next to teff (Gizaw & Assegid, 2021).

After reviewing previous research papers, based on environmental sustainability, economic standpoint, performance, and local availability of supplementary material, wheat straw ash, and eggshell powder are selected for this research.

Table 2.3: Chemical composition of various agricultural and Poultry waste

Compound		SiO_2	K_2O	MgO	Fe_2O_3	Al_2O_3	CaO	Na_2O_3	Loi (loss on ignition)	Reference
Wheat straw ash	WSA in %	73.95	11.51	1.81	1.15	0.91	5.21	_	_	(Babar et al., 2022)
	WSA in %	67.83	5.43	3.00	4.36	5.11	10.66	0.47	_	(Bheel, Sohu, et
	WSA in %	68.83	1.11	3.55	0.46	2.67	9.02	12.37	_	(Darweesh, 2020)
	WSA in %	61.71	3.28	2.69	2.59	3.74	7.85	2.46	7.33	(Qudoos et al.,
Eggshell powder	ESP in %	0.67	2.52	_	_	_	96.76	_	0.116	(Oliko et al., 2020)
	ESP in %	0.61	0.22	0.36	0.63	0·07	62·35		32.1	(Beng Wei et
	Rice Husk	91.9	2.78	0.21	0.41	0.25	0.38	0.05	2.93	(Sivakumar &
	Rice Straw Ash in%	76	9.89	2.65	0.63	0.69	4.96	1.36	_	
	Biogas ash in %	87.40	0.47	0.69	4.9	3.6	2.56	0.15	8.25	(Ayub & Visvanat

	Corncob ash	66.38	4.92	2.06	4.44	7.18	11.57	0.41	_	(Adesany & a

As low as one part per million to 100%. XRF (X-ray fluorescence) analysis is fast, accurate, and non-destructive, with minimum sample preparation required (Babar et al., 2022).

2.5. Effects of lime and silica in concrete

Experimental investigations were conducted to examine the effects of lime on the mechanical and durability properties of concrete mixtures made with blended cement like Portland Slag Cement (PSC) and Portland Pozzolana Cement (PPC). The study found that incorporating hydraulic lime and replacing up to 7% of the cement content with lime resulted in enhanced compressive strength for both PSC and PPC concretes. Additionally, the addition of lime led to an increase in flexural strength, with the optimum lime content of 7% identified for maximum flexural strength in both types of cement. The workability of the concrete decreased with lime addition, but this could be compensated by using a superplasticizer. Furthermore, the inclusion of lime up to 7% improved the acid and sulfate resistance of the concrete to some extent (Acharya et al., 2016). This analysis focuses on the influence of exchanges on the interaction between the contact zone of the "cement-mineral surface" and cement hydration activity. The impact of filler surfaces on the structure of concrete is also examined, specifically regarding its plastic strength. The study reveals that the inclusion of quartz-containing fillers in the range of 15% to 40% by weight of cement enhances the plastic strength of cement paste and accelerates the hydration processes. The accumulation of hydrates intensifies, while the formation time of the cement stone's structure decreases. These findings are supported by X-ray phase analysis of cement stone samples. Through magnetic separation of waste and quartzitic sandstone, a significant presence of low and high-basic-capacity hydro silicates was discovered. These investigated materials can serve as fine fillers in cement concrete, leading to composites with improved physico-mechanical properties and durability (Yadykina et al., 2019).

2.6. Reaction mechanism of chemical compounds and their effects

Pozzolanic materials, which are typically siliceous or siliceous and aluminous substances, are added to cement mixtures. These materials possess little or no inherent cement value. However, when they come into contact with Calcium Hydroxide [Ca (OH)2] in the presence of moisture at room temperature, they exhibit cementitious properties. This interaction leads to the formation of Calcium Silicate Hydrate (CaO, SiO2, H2O) and Calcium Hydroxide Ca (OH)2 through the hydration of Tri-Calcium Silicate and Di-Calcium Silicate. The C-S-H gel, or calcium silicate hydrate, significantly enhances the strength of the concrete. On the other hand, Calcium Hydroxide [Ca (OH)2] is an undesired substance with no cementitious value. It dissolves in water and leaches out, causing the concrete to become porous. However, by incorporating finely divided pozzolanic materials, the insignificant and non-cementitious calcium oxide can be transformed into insoluble cementitious compounds. By consuming calcium hydroxide, there might be an excess of silicon dioxide. If additional Calcium Hydroxide is available, there is a possibility that the formation of C-S-H gel will continue, leading to increased strength. This possibility has been thoroughly investigated in the current research (Acharya et al., 2016).

Table 2.4: Effects of agriculturally based calcium and silica in concrete.

Reference	Material used	Methodology	finding
(Oliko et al., 2020)	Eggshell of 10% with 15, and 20% of rice straw ash	The rice straws were dried, incinerated at 650 ^{0}C for 1:30 hours, and sieved through 600µm, 425µm BS, and finally 75µm BS sieves. Eggshells were cleaned, dried under the sun, and incinerated at 900°C for 2 hours.	1. Concrete samples with 15% partial cement replacement using rice straw ash showed a decrease in compressive strength, whereas those with 15% partial cement replacement using rice straw ash and 10% eggshell ash exhibited an increase in strength of 25.3%, 26.7%, and 29.2% at 28, 56, and 90 days respectively. Similarly, concrete samples with 20% partial cement replacement using rice straw ash and 10% eggshell ash showed a strength increase of 5.34%, 3.26%, and 3.88%.

			2. Rice straw ash replaces cement by up to 10%. 3. The addition of rice straw ash to concrete improves its resistance to acid solutions and sulfate attacks. At a 10% replacement level, it exhibits lower mass loss and compressive strength reduction compared to control specimens cured for 56 days in water and exposed to a 0.5% dilute sulphuric acid bath for 30 days. This makes it a suitable choice for concretes subjected to acidic environments.
(Husain et al., 2024)	The samples were mixed with eggshell ash and RHA admixture with different proportions (2%:8%, 4%:6%, 6%:4%).	Eggshells were collected from nearby restaurants, incinerated at 500˚C, ground, and sieved through a 75 µm sieve. Simultaneously, RHA was acquired from a pre-burnt factory.	1. Slump is increased 2. 6% eggshell ash and 4% RHA demonstrate higher compressive strength than all 3. 4% eggshell ash and 6% RHA demonstrate higher flexural, however less than control

2.7. Eggshell powder and its properties

2.7.1 Eggshell powder on fresh concrete

All of the concretes were homogenous, there was no bleeding or segregation, and the mixes were compactable based on observations made during mixing and compaction. Despite the concretes' extremely low slump values ranging from 5 to 12 mm. Since the ESP concretes had no discernible effect on the behavior of the concrete in the fresh state, their fresh-state performance was equivalent to that of the control concrete. Additionally, it was found that when the amount of ESP replacement increased, the densities of the concrete that had been replaced fell because the low-density material had replaced the high-density cement (Yerramala, 2014). A study conducted on the consistency and setting time of blended cement reveals that the water required for standard consistency increases linearly with an increase in substitution content. The graph displays the diverse percentage of cement replacement level (CRL) vs set consistency. Because ashes have a hygroscopic nature and our composite material (fly ash, RHA, and ESP) has a much bigger specific surface area than cement, it needed more water in addition to the Comparison of opening and closing setting times with the percentage of CRL The initial and final setting times tend to reduce if the substitution percentage is increased even higher (Sivakumar & Mahendran, 2014). Using the slum cone method, the workability of fresh concrete using eggshell powder as a cement substitute material was evaluated. The number of tests carried out on each mixing ratio and at each proportion of ESP, three times workability is checked and finally average of three results are taken as slump loss at a particular percentage of ES and Fresh concrete becomes less workable as the percentage of ESP rises (Ayoub Memon et al., 2019). To examine the impact of eggshell powder on the flowability of concrete, the workability was assessed using British Standards (BS). It was found that the workability decreased as the amount of ESP contained in the concrete increased. The reason for this could be the high water absorption of ESP, which uses up water and limits flowability (Jhatial, Sohu, Memon, Bhatti, et al., 2019). As per BS 12:1991, a setting time test was performed on the ESP paste. The cement's setting time is shortened when ESA is added to regular Portland cement (OPC), according to the results. The study's conclusions include the following: ESA is an accelerator, the higher its content, the faster the rate of setting; all ESA contents used in this analysis meet BS 12:1991's standards for both the start and final setting times (M.O.A Mtallib & Rabiu, 2009). The cement's setting time is lowered when eggshell ash is added, according to the setting time results. All percentages of eggshell ash employed in this experiment showed that the rate of setting and application increased with the amount of eggshell ash. The initial and final setting times satisfy Malaysian Standard's setting time standards (Surshuwlhv et al., 2016).

Table 2.5: Calcination methods of eggshell powder and main constitutes

Ref	Methods	Description	Main constitute
(Awogbemi et al., 2020)	Raw Sample	The waste chicken eggshells were washed in hot (40 ^{0}C) tap water to remove any dirt and a portion was dried in an oven maintained at 100 ^{0}C for 3 h to eliminate any left-over water in the eggshell. The dried eggshells were manually crushed using a pestle and mortar and mechanically pulverized using a laboratory grinder. The powder was passed through a 75 µm sieve mesh	79.3% of CaCO3
(Awogbemi et al., 2020)	Boiled Sample	The waste chicken eggshells were washed in hot (40 ^{0}C) tap water to remove any dirt and a portion was boiled for 30 min using tap water and an electric stove. The boiled shells were oven-dried at 100 ^{0}C for 3 h thus removing any leftover moisture in the boiled eggshell. then, manually crushed into smaller pieces, pulverized into fine particles by a laboratory mechanical grinder, and sieved using a 75 µm mesh	99.2% of CaCO3 and 20.2% of Calcite magnesium (CaCO3Mg)
(Awogbemi et al., 2020)	Calcine Sample	The waste chicken eggshells were washed in hot (40 ^{0}C) tap water to remove any dirt and the portion was dried in the oven maintained at 100 ^{0}C for 3 hr ground manually in a mortar, pulverized in a mechanical grinder into a fine powder, and sieved using a 75 µm screen mesh. The sample was thereafter calcined in a furnace maintained at 900 C for 3 h to allow for the total breakdown of the CaCO3	64 % of CaO, 25 % of Ca (OH)2, and 11% of calcium oxalate (C 2H2 CaO5)

(Zaman & Engineering, 2018)	Calcined Sample-2	Following a thorough cleaning with cold water, the eggshells were allowed to naturally dry for seven days. In the meantime, the egg membranes were carefully removed from the shells, and the eggshells were finally dried in an oven at 100 °C for 48 hours. The dried eggshells were then crushed in an attrition mill, and the coarsely crushed eggshells with particle sizes larger than 6 mm were taken for the next step of calcination, which was done in a muffle-type furnace (Protherm PLF, Turkey). The temperature was set at 1100 °C for a fixed soaking period of two hours, and the heating rate was maintained at 3 °C/min to ensure total removal of carbon dioxide (CO2).	80 % of Ca (OH)2, 5% of CaO and 15.3% of others

2.7.2 Physical and chemical properties of eggshell powder and their effects

Specific gravity, fineness modulus, bulk density, and surface area of eggshell powder were measured and analyzed in an experimental investigation. The results showed that the powder had 1.89 specific gravity, 4.1 % fineness modules, a bulk density of 1081 kg/m3, and 290 m2/kg surface area. In addition, based on chemical properties, a percentage of the chemical composition is obtained: 0.09 % of SIO2, 0.44% of Al203, 0.34 % of Fe2O3, 32.51% of Cao, 3.47 % of Loi, etc (Sivakumar & Mahendran, 2014). The chemical composition of eggshells, including calcium carbonate (CaCO3), calcium phosphate (Ca3(PO4)2), magnesium carbonate (MgCO3), and organic materials, was determined through experimental research. The results showed that eggshell powder contained 93.70% of CaCO3, 0.80% of Ca2 phosphate (Ca3(PO4)2), 1.30% of magnesium carbonate (MgCO3), and 4.20% of organic materials (Mishra & Pathak, 2017). A study was conducted to examine the physicochemical properties of nanopowder eggshells (NPES). Homogeneous, aggregated, and spherical crystals were obtained using a scanning electron microscope and transmission electron microscope. The presence of calcite in both NPES and powder eggshell (PES) was analyzed using an X-ray diffractometer (XRD). The chemical compositions of NPES and PES associated with the presence of calcium carbonate were determined by analyzing their Fourier transform infrared (FTIR) spectra. According to the study, there are notable variations in the physicochemical characteristics of conventional eggshell powder and nano powder. After being nanosized, the eggshell powder's size, homogeneity, and ability to adsorb water were all significantly enhanced. Moreover, the eggshell's purity, crystallinity, and chemical composition were unaffected by nanogrinding. NPES has improved physicochemical qualities, as these studies verified (Mijan et al., 2014).

2.7.3 Effects of Eggshell Powder on hardened Concrete

The development of various eggshell powder concretes involved substituting 5–15% of ESP for cement. According to the findings, ESP can successfully replace a portion of the cement used in the manufacturing of concrete. Strength development and transport qualities are covered by the data. According to the findings, the strengths at 5% ESP replacement were higher than those of control concrete, proving that 5% ESP is the ideal content to achieve maximum strength. Additionally, the performance of ESP concretes was comparable to control concrete up to a 10% ESP replacement in terms of transport qualities. The outcomes also demonstrate that adding fly ash to ESP improves concrete performance (Yerramala, 2014a). To discover whether eggshell powder can be used to substitute cement in cement concrete, an abundance of testing has been done. The following conclusions can be taken from the experimental findings: for replacement rates of 5% and 10% eggshell powder (ESP) at 3, 7, and 28 days of curing, compressive strength was higher than that of standard concrete. Up to 15% ESP replacement, split tensile strengths of ESP concretes were equivalent to those of ordinary concrete, however replacements larger than 10% had lower strength than conventional concrete. The split tensile strength of concrete with 10% and 15% ESP was lower than that of normal concrete, although it can be enhanced if reinforcement is added to the concrete. The findings showed that compressive strength and split tensile strength had a solid relationship regardless of ESP percentage substitution (Parthasarathi et al., 2017). In Malaysia, a study investigates the usage of chicken waste in concrete manufacturing by substituting Portland cement with eggshell powder due to the growth of undesirable wastes polluting the environment. Since eggshell mostly consists of 93.70% calcium carbonate (CaCO3), it is recognized as being calcium-rich, similar to what cement has. The suitability of eggshell powder as a partial replacement is examined through an evaluation of both workability and mechanical in 4 distinct batches that are made by replacing Portland cement with 10–30% eggshell powder. As a result, as the amount of eggshell powder increases, the workability decreases by between 30 and 70% while the results of all three destructive tests decrease by between 13 and 48%. In conclusion, the eggshell powder is not appropriate for projects requiring highly stiff concrete, but it might be appropriate for projects requiring less stiff concrete (Ishak & Zamani, 2020).

Table 2.6: Optimum Percentage Replacement with Compressive Strength of ESP.

<table>
<tr><th colspan="6">Optimum percentage replacement</th></tr>
<tr><td colspan="2">Author</td><td>(jhatial.et al., 2019)</td><td>(Ayoub Memon et al., 2019)</td><td>(Ishak & Zamani, 2020)</td><td>(Zhang et al., 2024)</td></tr>
<tr><td colspan="2">ESP</td><td>10%</td><td>7.5%</td><td>0%</td><td>0%</td></tr>
<tr><td rowspan="2">Compressive strength at 28 days (Mpa)</td><td>Control</td><td>44.73</td><td>28.37</td><td>38.38</td><td>54.8</td></tr>
<tr><td>Optimum replacement</td><td>47.35</td><td>30.93</td><td>–</td><td>–</td></tr>
</table>

Sources: jhatial.et al. 2019, Ayoub Memon et al. 2019, Ishak and Zamani 2020, and Zhang et al. 2024

2.7.4 Effects of eggshell on durability

Using eggshells as a replacement for cement in concrete offers benefits such as reducing cement usage and utilizing natural lime. Corrosion of steel reinforcement in concrete leads to cracks and a decrease in the structure's lifespan. The incorporation of eggshell powder in concrete as a partial replacement for cement shows potential as an economical corrosion-resistant material. The utilization of eggshells in concrete has implications for improving durability and reducing the effects of corrosion on reinforcement bars(Deepak & Sargunan, 2019). Eggshell powder used as a cement replacement in concrete offers several benefits, including improved hardened properties, reduced setting time, increased resistance to water penetration and carbonation, and acceleration of the hydration process. However, eggshell-based concrete (ESC) exhibits weakness in chloride and sulfate environments due to the vulnerability of eggshells to these compounds. While there are significant studies on the material, further research is needed to explore the durability properties of ESC. Further research is needed to enhance our understanding of the durability properties of ESC (Chong *et al.*, 2020)

2.8. Wheat straw ash and its properties

Wheat waste after milling, was sometimes mixed with grass and used as a source of food for some animals but the remaining huge amount of waste is either burnt or buried, which causes serious environmental threats. The physical and chemical properties of WSA were affected by geographic location, soil chemistry, change in temperature, and fertilizers used. Ash generated from burning wheat straw in the open is known as wheat straw residue (Khan et al., 2019). It is looked at whether using the ash from the uncontrolled burning of wheat straw in place of some of the cement in concrete is appropriate (Shar et al., 2019). WSA includes a significant quantity of SiO2, which combines with Ca (OH)2 to create CSH gel, and since the pozzolanic process consumes lime, The Ca (OH)2 content of WSA-containing paste is lower than that of pure cement paste (Babar et al., 2022).

2.8.1 Wheat straw ash on fresh concrete

Wheat straw ash was used in the experimental examination of concrete as a partial cement replacement material. Each group will undergo the concrete slump test to ensure consistent concrete quality throughout the construction phase. It was found that as the concrete's WSA content increased, so its workability decreased (Babar et al., 2022). The properties of concrete mixes are influenced by rice, wheat straw ash, and rice husk ash. Increasing the percentage of ash from 5% to 15% causes the density to increase from 2342 to 2466 kg/m2, whereas increasing the percentage of ash from 15% to 20% causes the density to decrease to 2400 kg/m2. The replacement material with 15% WSA had the maximum density value, and the slump test showed a decrease in workability as the proportion of wheat straw ash increased (T A el-sayed, A M erfan, 2017).

Table 2.7: Effects of wheat straw ash in concrete

Reference	Description	Main constituents	Results/ finding
(Bheel, ibrahim, et al. 2021)	The obtained WSA was burned in the open air for approximately 10 h after which it was allowed to cool down for 24 h. After the WSA had cooled down to ambient temperature, the WSA particles were sieved and particles passing through the No. 300 sieve were used.	67.34 % of SiO2 and 10.60% of CaO	1. Decrease in slump test. 2. incorporation of up to 10% replacement of PC was found to enhance the compressive strength, split tensile strength, and flexural strength by 12%, 10%, and 11% respectively.

	Used w/c of 0.5 and 5-20% ash as a partial substitute. The fine aggregate and coarse aggregate used in this study have a minimum and maximum aggregate size of 4.75 mm and 20 mm.		
(babar et al. 2022)	burned in a controlled environment at roughly 600°C for 4 hours in a Mirpurkhas Sindh industrial furnace. WSA was burned, then ground in a Los Angeles (LA) machine and sieved through a No. 200 sieve. X-ray Fluorescence (XRF) test was used to determine the chemical composition of WSA.	73.95 % of SiO_2 and 5.21 of CaO	1. The water amalgamation of concrete decreases as the curing period increases, and the optimal value of water absorption occurs at 10% replacement of WSA. 2. concrete density declines as WSA increases. 3. The optimum compressive strength increases in strength occurs at 10% replacement of WSA

Source: bheel, ibrahim, et al. 2021, and Babar et al. 2022

From test results carried out at 500 ◦C, 600 ◦C, 700 ◦C, and 800 ◦C for 2 h, it was found that beyond 600 ◦C, the amorphous silica transformed into crystalline silica resulting in decreased reactivity of the agricultural waste. The WSA calcined at 600 ◦C was found to satisfy Chapelle and Fratini tests requirements, as well as the PAI requirement of ASTM at 28 days. Therefore, WSA produced at 600 ◦C (WSA600) showed the best pozzolanic performance. The higher the burning temperature, the higher the amount of silica produced. The controlled burning of wheat straw leads to the production of high content of silica (Memon et al., 2018)

2.8.2. Physical and chemical properties of wheat straw ash.

Research experiments on concrete containing 0.25%, 0.50%, 0.75%, and 1% of jute fiber as reinforcement material and 10%, 20%, 30%, and 40% of wheat straw ash (WSA) as a cement replacement for fine aggregates on fresh and hardened concrete the fineness and specific gravity of Wheat straw is 7.80% and 2.21 respectively (Bheel, Sohu, et al., 2021). The standard Portland cement was substituted with wheat straw ash (WSA). Isothermal calorimetry, thermogravimetric analyses (TGA), mercury intrusion porosimeter (MIP), and scanning electron microscopy (SEM) were used to analyze the specimens. The results showed that when the wheat straw ash specimens were ground using a combination of both milling techniques, the specific surface area increased and the particle size was significantly reduced. Additionally, an investigation of the chemical characteristics of wheat straw ash showed that its percentages of SiO_2, AL_2O_3, Fe_2O, CaO, MgO, Na_2O, K_2O, P_2O_5, SO_3, and LOI were 67.5, 3.74, 2.59, 7.85, 2.69, 2.46, 3.28, 1.68, 2.35, and 7.33, respectively (Qudoos et al., 2020).

2.8.3. Effects of Wheat Straw Ash on hardened Concrete

In addition to the control specimens manufactured with regular Portland cement (OPC), other specimens had their cement substituted with 10%, 15%, and 20% by weight of WSA. Locally accessible wheat straw was carefully burned to ash in the oven that was utilized in this study. On the concrete mixture using WSA at various percentages of cement substitution, destructive tests such as the compressive strength, modulus of rupture, and splitting tensile strength were performed and compared with control specimens. The test's finding was that using replacement cement with WSA results in a reduction in compressive strength. While the splitting tensile strength increases with 15% WSA, the modulus of rupture only increases with 10% WSA (Al-Kadhim Hameed et al., 2021). In this study, wheat straw ash, an agricultural by-product, was investigated as a substitute for cement in concrete with varying percentages of replacement (0%, 5%, 10%, 15%, and 20%). The compressive strength of the concrete was measured by evaluating 45 cubical specimens after curing periods of 7, 28, and 90 days. The results indicated that the maximum compressive strength was achieved at a 10% cement replacement with wheat straw ash, while the minimum was observed at a 20% replacement. This research aimed to contribute to energy conservation and reduce cement consumption, thereby mitigating carbon dioxide emissions, and highlighting the potential for sustainable and eco-friendly concrete production methods (Shar et al., 2019). Paste samples containing smaller ash particles exhibited increased hydration activity during the initial stages, leading to higher compressive and flexural strength. Likewise, the addition of finer wheat straw ash particles significantly decreased the calcium hydroxide (CH) content in the paste samples after 28 days of curing. The finer ash particles enhanced the pore arrangement in the mortar samples, leading to a better microstructure, lower overall porosity, and improved ultrasonic pulse velocity readings (Qudoos et al., 2020).

Table 2.8: Optimum Percentage Replacement with Compressive Strength of WSA

Optimum percentage replacement			
Author		(Shar et al., 2019)	(Babar et al., 2022)
WSA in %		0	10
Compressive strength at 28 days (Mpa)	Control	27.31	32.56
	Optimum replacement	–	35.10
Summary		Open burned and sieved through No. 200 sieve	Controlled burned at 600^0c and sieved through No. 200 sieve.

Sources: Shar et al. 2019, and Babar et al. 2022

2.8.4. Wheat straw ash on the microstructure of concrete.

based on research on the particular traits and microstructure of Portland cement pastes mixed with wheat straw by evaluating the heat of hydration and DTA curves, the outcomes of the newly developed hydration products were verified. With an increase in WSA content, the heat of hydration increased, signifying a rise in the rate of hydration. It is concluded that WSA could replace some of the cement without degrading cement paste qualities. Differential Thermal Analysis (DTA) revealed that when the WSA ratio increased, the free lime content progressively decreased. Thus, the WSA serves as both a filler and a pozzolanic. The SEM pictures demonstrated that the presence of WSA in the cement phases had a favorable impact on the cement phases' microstructure (Darweesh, 2020).

2.8.5. Effects of wheat straw ash on the durability of concrete.

The impact of wheat straw ash on concrete durability as a result of harmful alkali-silica interactions was examined in this study. In the study, three amounts of wheat straw ash 5%, 10%, and 15% were taken into consideration as partial cement replacements. To hasten the harmful alkali-silica reaction, the concrete examples were submerged in a tank filled with a

NaOH solution at 40 ˚C after the first cure. The expansion of concrete prisms and the decrease in compressive strength were used to measure the degradation of the alkali-silica reaction. The results of the investigation showed that compared to the control concrete, the wheat straw ash concrete was more resistant to alkali-silica reaction damage. As the amount of wheat straw ash in the concrete increased, so did its durability. Compared to wheat straw ash concrete with a w/c ratio of 0.6, the concrete with a 0.5 ratio demonstrated greater endurance against alkali-silica reaction damage (Al-Akhras, 2013).

2.9. Effects of wheat straw ash and eggshell powder in a mortar

Eggshell powder ash (ESPA) and wheat straw ash (WSA) were used as cement substitutes in the production of green mortar. Thirteen mixtures were created, with one serving as a reference without any replacement, and the remaining twelve incorporating replacements of ESPA and WSA (individually and in combination) for cement. The replacements were made in proportions of 2%, 4%, 6%, and 8% of the weight of the cement.

Table 2.9: Wheat straw ash and eggshell powder analysis in mortar.

Reference	Material used	Methods	Tests	Finding	Drawback
(Powder et al., 2024)	The concrete mixture consisted of opc, sand, aggregate, glenium 54 superplasticizer, wheat straw ash, and eggshell (2-8% content) as components in varying proportions. 0.5 g of superplasticizer by weight of cement was used.	The eggshell waste was cleaned, dried, and treated at 100 °c, then ground to a powder and burned at 500 °c to obtain eggshell powder ash (espa). Wheat straw was burned at 650 °c, ground to a powder, and	The mechanical (compressive and flexural strength), microstructural (sem), and thermogravimetric analysis (tg/dta) properties	The inclusion of 8% eggshell and 4% eggshell + 4% wheat straw ash resulted in higher mechanical strength compared to other dosages. The waste additions showed significant improvement	Durability analysis is necessary due to the potential influence of precipitation and bacterial activity on eggshells, which may cause distortion. The optimal dosage for maximum strength should be determined,

		sieved through a 75 µm-opening sieve.		over the control.	and the impact of combined waste materials should be assessed before incorporating a superplasticizer

Sources: Powder et al. 2024

As per the company, Glenium 54 is used where a ready mix and low w/c ratio are required. It allows the production of very high early and high ultimate strength concrete with minimum void and therefore optimum density.

Table 2.10: Mechanical output of wheat straw ash and eggshell powder in mortar.

Ref	(powder et al. 2024)										
% of replacement		Control	2%	4%	6%	8%	Control	1% ESP+ 1% WSA.	2% ESP+ 2%WSA.	3% ESP+ 3% WSA.	4% ESP+ 4% WSA.
Compressive in 28 days	WSA	30	40.8	45.2	45.6	47.2	30	48.5	49.4	50.8	52
	ESP	30	46	47.2	49.4	51.2					

Tensile in 28 days	WSA	7	7.85	8.4	9	9.8	7	8.4	8.96	10.2	10.92
	ESP	7	8.1	8.7	9.5	10.1					

Source: Powder et al. 2024

Despite demonstrating improvement when used in combination rather than individually as replacements for cement, the effects of eggshell and wheat straw ash in concrete have not been definitively elucidated in this research. The impact of these materials on concrete properties, such as strength, durability, and workability, remains unclear. Further investigation is required to comprehensively understand the chemical reactions, hydration mechanisms, and long-term performance of concrete incorporating eggshell and wheat straw ash. Additionally, the influence of varying proportions of these additives on the microstructure and overall performance of concrete needs to be thoroughly examined. Future research endeavors should aim to provide a comprehensive understanding of the potential benefits and limitations of utilizing eggshell and wheat straw ash in concrete production, enabling informed decision-making for sustainable and high-performance construction practices.

2.10. Literature Review Summary and Gap

Previous literature review of research demonstrated on partial replacement of wheat straw ash and eggshell powder with or without pozzolanic material is reviewed and summarized by the below table.

Table 2.11: Summary of Literature Review on ESP and WSA by Past Studies.

year	Title	Author	Percentage replacement %	Test conducted	Findings
2016	A study on workability and flexural strength of concrete by partially replacing with	(Pradeep Kumar et al., 2016)	Replaced with 5%, 10% and 15% of eggshell powder	Slump test and flexural strength test	As the addition of ESP increases flexural strength decreases

	ESP and manufacturing sand				The durability analysis should be investigated as for ESP is used in the study
2018	Excremental study on M-30 grade concrete with partial replacement of cement with eggshell powder	(Kannam Naidu et al., 2018)	Eggshell powder replaces cement at 0%, 5%, 10% and 15% for grade 25 concrete	Compressive and tensile strength were conducted	The optimum compressive strength is at 10% replacement with 13 % increment, and 5% for tensile strength which shows 13.72% increment. The durability analysis should be investigated as for ESP is used in the study
2020	Properties of Concrete with Eggshell Powder: A Review	(Chong et al. 2020)	A review on eggshell powder as cement partial replacement	This includes improved hardened properties, reduced setting time, and increased resistance to water	Workability decreases as the result of ESP inclusion. Compressive strength is enhanced. Loss in strength and weight is

				penetration and carbonation.	observed under sulphate and chloride solution
2017	Mechanical properties of concrete using eggshell ash and rice husk ash as partial replacement of cement	(Shahadahtul et al., 2017)	Eggshell ash and rice husk ash with different proportion of 2%:8%, 4%:6%, and 6%:4% for Grade-30 concrete	Compressive and tensile strength tests were conducted	RHA which has pozzolanic activity increased the strength further. At 6% of ESP and 4% of RHA shows optimum compressive strength.
2024	Recycling of eggshell powder and wheat straw ash as cement replacement in mortar	(Powder et al., 2024)	Eggshell powder and wheat straw ash are replaced at different proportions from 2%-8% with a 2% span. Glenium 54 superplasticizer is used.	Compressive, flexural microstructural, and differential thermographic analysis is conducted.	Using ESP and WSA combined is a more remarkable rise in compressive strength than using each alone. Non-plasticizers should be investigated and known (bare superplasticizer

					analysis should be conducted)

Source: Powder et al. 2024, Shahadahtul et al. 2017, Chong et al. 2020, Kannam Naidu et al. 2018, and Pradeep Kumar, Selvi, and Jaketia 2016.

Various researchers went through many investigations on the separate use of eggshell powder and wheat straw ash in concrete. Eggshells have a high abundance of calcium oxide which is the main compound in cement and highly contributes to the strength of concrete, however when attacked by an acidic solution compound reacts with a solution and is highly affected which later decreases the strength of concrete. Meanwhile, wheat straw ash is not vulnerable to acidic solutions and demonstrates more capability to withstand acidic solutions than control concrete. Therefore, there is a gap in using this composite material usage in concrete that could be beneficial by merging both special properties to make concrete more useful.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Introduction

The material and methods stated in this chapter will demonstrate overall detailed accounts for implementing procedures to elevate the aim and to achieve the objective stated in the previous chapter. Previously in the literature review chapter, it highlighted research gaps, and past studies related to both eggshell powder and wheat straw ash separably as cement replacement as partial cement material in concrete. Based upon this stance background, this chapter will explain the methodology implemented in this study to address the research gap and achieve the research objectives.

3.2 . Materials

This study is about the utilization of agricultural and poultry-based waste material, namely wheat straw ash and eggshell, as cement replacement combined with ordinary Portland cement, aggregate, sand, and water to form concrete of a grade of 25 Mpa strength.

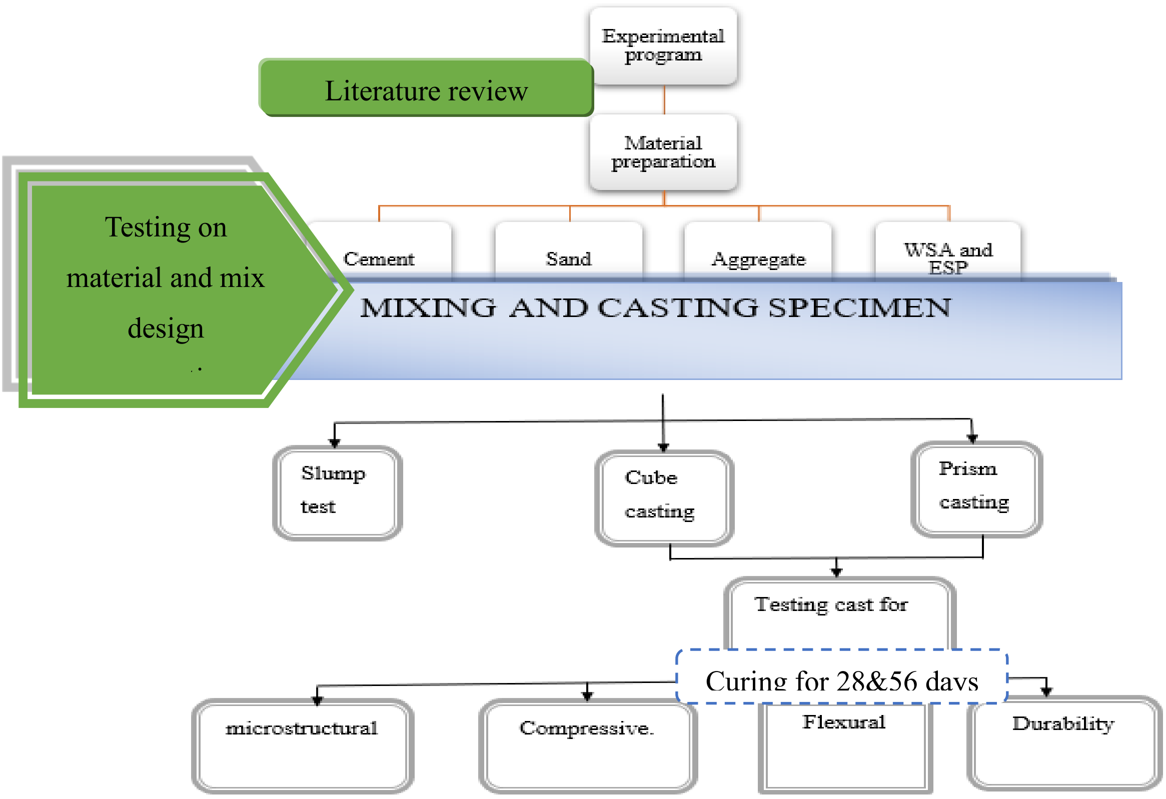

Figure 3.1: Experimental program.

3.2.1. Ordinary Portland cement Ordinary:

Ordinary Portland cement of CES 28, ES 1177 of grade 42.5Mpa with a specific gravity of 3.15 manufactured by the National Cement factory was used for concrete preparation. Ordinary Portland cement is a kind of cement that is manufactured by adding gypsum to the clinker. Ordinary Portland cement (OPC) is the primary binding agent used in concrete casting. OPC is produced by grinding clinker, which is a mixture of limestone clay, shell, and silica into fine powder When OPC is mixed with water, it undergoes a chemical reaction known as hydration. This reaction forms a pace that coats and binds the fine in the courts, creating a solid and durable concrete structure. OPC provides excellent string and versatility for various concrete applications and is the most used type of cement.

Figure 3.2: OPC cement.

3.2.2. Water

Clean tap water is used as a mixing medium. Concrete mixing is a crucial component in casting concrete specimens. It serves as a mixing medium and activates the process of hydration in cement. During hydration, water-reactive cement particles form a paste that binds the aggregate together and gradually hardens over time.

3.2.3. Natural Sand/Fine Aggregate

The fine aggregate used in this research was obtained from the Adama area called Kella in accordance with ASTM C33(2003) standard and should not absorb water more than 5% as per ASTM standard. Fine aggregate commonly referred to as sand is a granular material used in concrete mixtures It contains small particles that are typically smaller than 5MM in diameter and have the most texture. Fine aggregate enhances the workability of concrete and fills the gaps between the larger coarse aggregate. It also contributes to the overall strength and the stability of concrete mixture. The quality and the grading of sand are essential factors as they can influence the workability strength and durability of the concrete.

3.2.4. Coarse aggregate

The coarse aggregate used in this research was obtained from around Adama city and fulfills ASTM C33 standard which is durable, free from vegetable matter, strong, and consumes less than 5% of water. The size of the aggregate used was less than 20mm and more than 5mm and it was made up of crushed stone. Coarse aggregate provides the primary structural framework of concrete imparting strength and stability to the material. The void between the coarse aggregate is filled by the fine aggregate. The selection of appropriate coarse aggregate is crucial as it influences the strength stability and other mechanical properties of caste specimens.

Figure 3.3: Coarse aggregate.

3.2.5. Waste material preparation

Waste materials to be prepared for partial replacement of cement include wheat straw ash and eggshell powder.

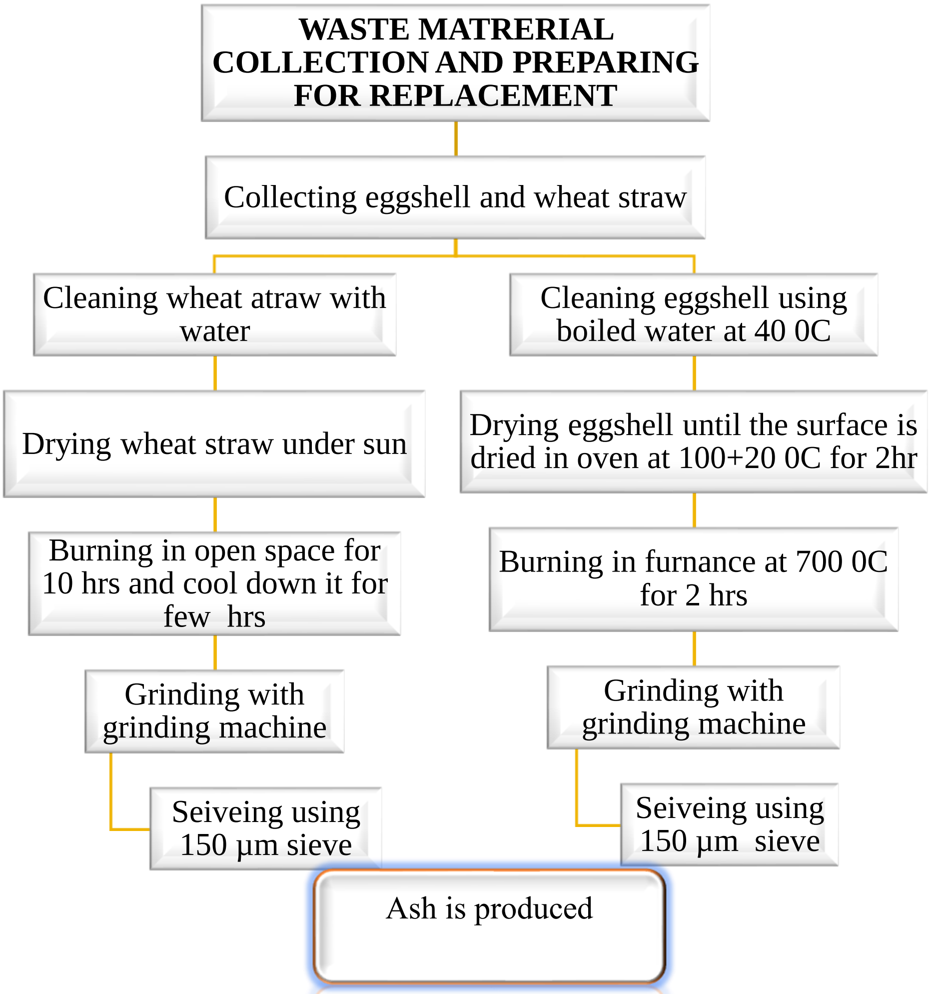

Figure 3.4: Preparation of wheat straw ash and eggshell powder for partial replacement.

3.2.5.1. Wheat straw

Wheat Straw of Local farmers from Sinana, Dodola Woreda, west Arsi zone, Oromia regional state, and have distance of 315 km from the capital was provided and utilized in the study as the area has abundant wheat straw waste from wheat production. Wheat straw ash is a supplementary material in concrete. It is obtained by burning in the processing wheat straw, resulting in ash residue used in our additive in the concrete mixture. The pozzolanic property of wheat is straw ash contributes to the formation of addition, calcium silicate, and hydrate

3.2.5.2. Preparation of wheat straw ash

The obtained WSA was burned outside for about 10 hours, and then it was allowed to cool for 24 hours. WSA particles were sieved after cooling to room temperature, and those that passed through the No. 150 µm sieve size were utilized in place of some of the cement (Bheel, Ibrahim, et al., 2021).

Collected wheat straw and washed to remove any impurities, then dried it, after drying, it was open-burned in a barrel for 24 hrs and waited until it cooled down, the leftover ash was ground to a smaller size and sieved using 150 μm Sieves at Astu lab.

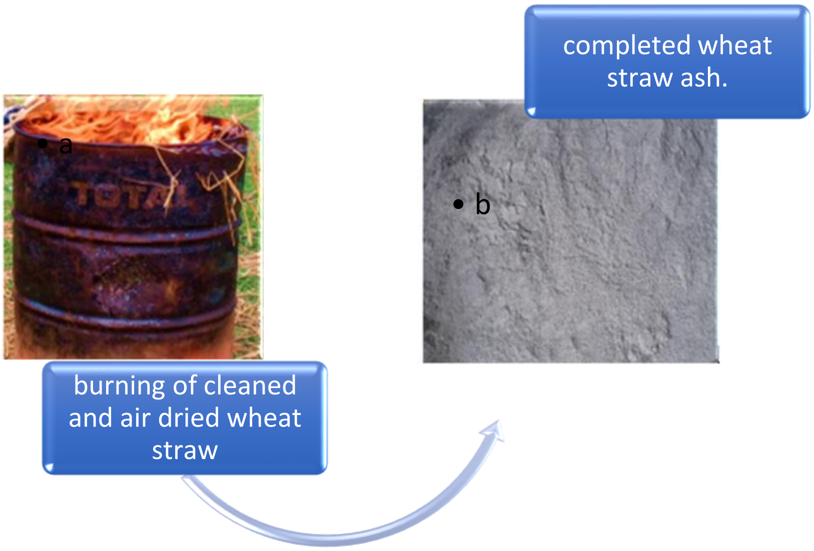

Figure 3.5: The process of preparing wheat straw ash.

3.2.6 Eggshell

The eggshell powder obtained from the waste eggshells of chicken (poultry waste) collected from hotels in Adama City and Heraro City was utilized in this research and is thrown away in open ground by the user. Eggshell powder, a leftover from the processing of eggs, has drawn interest as a possible cement substitute in concrete.

Figure 3.6: Eggshell collected

3.2.6.1. Preparation of eggshell powder

The eggshell that was utilized was cleansed to get rid of impurities, dried in the sun until the surface was dry, and then burned for two hours at 900^0C then pulverized into ash in a ball mill for four minutes (Oliko et al., 2020). The eggshells were taken out of the plant and washed with tap water. Then dried in an oven at 105°C for 24 hours and grinded to create a powder and 60 microns size was used (Tan et al., 2018).

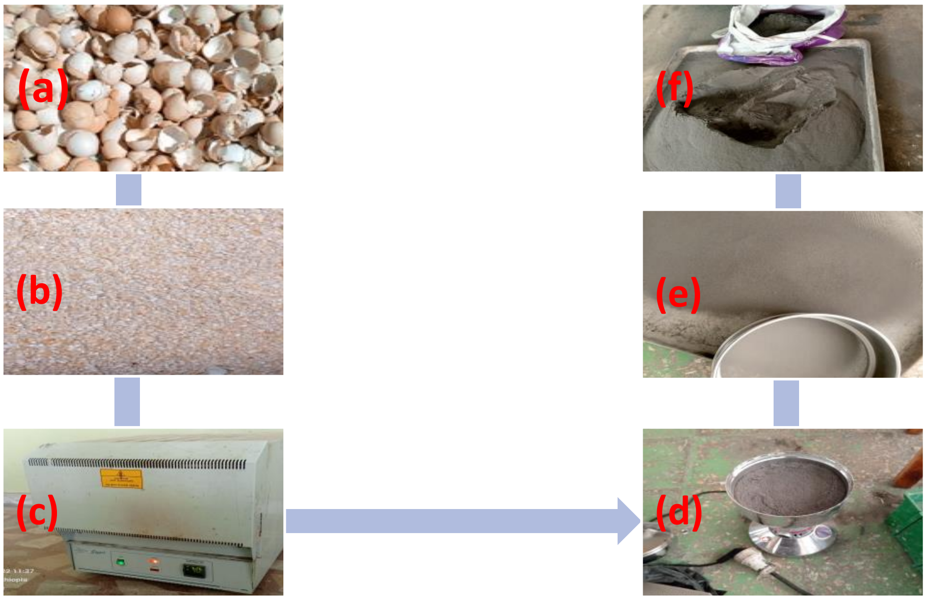

Figure 3.7: Eggshell powder preparation.

After collecting the eggshell from the hotel, immediately washed to remove any impurities, then kept under the sun to dry, then after putting it in the oven at Astu laboratory to remove any leftover moisture for an hour, and ground to a smaller size. Then ground eggshell was taken to the Defence University Department of Chemical Engineering at Bishoftu for calcination in the furnace. Ground eggshell was kept in an oven at 700 150 μm 0C for 2 hours to get rid of all CO_2 and pure average specific gravity of clayey soil was found to be 2.60 that of the wheat straw was 0.34, and that of lime was 3.3powder of CaO was taken back to Astu laboratory, and powder passing through 75 μm Used in concrete as cement partial

3.3. Research Methods

Here it includes the testing of individual concrete forming materials and each of their test followed by the mix design of concrete. Meanwhile, the implementation of concrete batching, mixing, casting, and curing of concrete specimens to acquire the desired output was stated. In addition, the implementation method of fresh and hardened properties of concrete is stated as well. In general, methods that apply to all the above-stated elements for this particular study were addressed under this topic.

3.3.1. Testing on materials

3.3.1.1. Tests on Cement

There are several tests conducted on cement to evaluate cement quality and suitability for use in concrete as per ASTM standards. The test performed in this study includes the specific gravity test and normal consistency test.

A Specific gravity test

The specific gravity of cement was determined using a le-chatelier flask or pycnometer using kerosine as a non-reactive medium. This procedure also applies to sand, dust, and other fine particles which include wheat straw ash and eggshell powder. As per ASTM C188 most ordinary Portland cement varieties have a specific gravity in the range of 3.10-3.15 and this depends on the cement composition and manufacturing process. A detailed procedure for specific gravity is presented in the Appendix:

B, Normal consistency test

The normal consistency test determines the amount of water required to produce a cement pest and it affects the workability, setting time, and other properties of cement pests in general. The cement mixed with different amounts of water to form water was tested using a Vicat apparatus to measure the depth of penetration of a needle into a cement paste. According to ASTM C187, the normal consistency is water percentage by mass of cement, which allows the Vicat needle to penetrate the depth of 10±1mm from the bottom of the mold. A detailed procedure for specific gravity is presented in Appendix A3:

3.3.1.2. Test on eggshell powder and wheat straw ash

Several tests were conducted on both powders for suitability and quality tests to use in concrete as partial replacement, specific gravity test, finesse test, and analyzing the chemical composition of the powder. A detailed procedure for specific gravity is presented in the Appendix:

A) Specific Gravity test

The specific gravity of both powders should be according to ASTM C188 as it is a fine material and the standard provides precise temperature control and procedures to ensure accurate and reproducible specific gravity measurement. Water-free medium kerosine was used as it does not react with powder and Le-chatler apparatus was used for measurement. A detailed procedure for specific gravity is presented in Appendix A2:

B) Fitness test of eggshell powder and wheat straw ash

A fitness test was conducted as per ASTM standard sieve analysis at the ASTU lab for both powders and the least size available in the lab was used for the experiment.

C) Chemical composition analysis

This analysis was implemented to find major and minor compound exits within the sample. To analyze the chemical composition, the sample was taken to the Ethiopian Geological Survey Laboratory located at Mekanis in Addis Ababa Ethiopia for analyzing the compounds in the sample. A detailed procedure for specific gravity is presented in Appendix A1:

3.3.1.3. Tests on fine aggregate

The objective of conducting this test is to ensure the quality and suitability of the material for its specific use. Conducted tests for fine aggregate including tests like silt content, sieve analysis, specific gravity, water absorption, and unit weight of the sample.

A) Silt content

This test was conducted to ensure that the sample fulfills ASTM C117 standards and is suitable for concrete use. To conduct this test water, sand sample, and apparatus like a graduated jar, funnel, spoon, and dish for sand sample were used. A detailed procedure for specific gravity is presented in Appendix A4:

$$\text{Silt content (\%)} = \frac{\text{silt deposit above sand after 24 hrs.(B)}}{\text{Total sand taken(A)}} * 100 \text{.........Equation 3.1}$$

B) Sieve analysis test

This test was implemented in accordance with ASTM standards. This test is conducted to determine the particle size distribution of fine aggregates by separating a sample into various size fractions using a series of sieves. The standard sieve size used for sieve analysis of sand as per ASTM C136 was NO.4(4.75mm), No.8(2.36mm), No.16(1.18mm), No.30(600µm), No.50(300µm), No.100(150µm) and pan. As per ASTM C33 range of fineness modules should be between 2.3-3.1. A detailed procedure for specific gravity is presented in Appendix A5:

Fitness modulus (FMOCA) = summation % of sample cumulative / 100

C) Specific gravity and water absorption of fine aggregate

This test is conducted according to ASTM C128 standard. The specific gravity is the measure of sand particle density compared to water density and it is required for various engineering calculations and concrete mix designs. The water absorption test was implemented to understand the amount of water that the sand particle can absorb and it is highly important to understand water demand in the concrete mix design. A detailed procedure for specific gravity is presented in Appendix A7:

$$\text{Bulk specific gravity} = \frac{\text{weight of oven dried sample}}{\begin{matrix}\text{(weight of pycnometer filled with water+}\\ \text{weight of SSD sample}-\text{weight}\\ \text{of pycnometer filled with sample and water)}\end{matrix}} \ldots\ldots\ldots\ldots \text{Equation 3.2}$$

Saturated surface dry specific gravity (SSD-SG)

$$= \frac{\text{weight SSD sample}}{\begin{matrix}\text{(weight of pycnometer filled with water+}\\ \text{weight of oven}-\text{dry sample}-\text{weight}\\ \text{of pycnometer filled with sample and water)}\end{matrix}} \ldots\ldots\ldots\ldots \text{Equation 3.3}$$

Apparent specific gravity (SSD-SG)

$$= \frac{\text{weight of oven}-\text{drt sample}}{\begin{matrix}\text{(weight of pycnometer filled with water+}\\ \text{weight of oven}-\text{dry sample}-\text{weight}\\ \text{of pycnometer filled with sample and water)}\end{matrix}} \ldots\ldots\ldots\ldots \text{Equation 3.4}$$

$$Absorption = \frac{\begin{matrix} mass\ of\ SSD\ sample - mass\\ of\ oven\ dry\ sample\end{matrix}}{mass\ of\ sample} * 100 \ldots\ldots\ldots \text{Equation 3.5}$$

D) Unit weight test of fine aggregate

The unit weight of fine aggregate is determined according to the ASTM C29/C29M standard. This test is conducted to obtain reliable and consistent data to support, the production, design, and quality control of concrete, mortar, and other construction materials. A detailed procedure for specific gravity is presented in Appendix A6:

$$\text{unit weigth of fine aggregate} = \frac{\begin{matrix}\text{avarage weight}\\ \text{of sand(kg)}\end{matrix}}{\begin{matrix}\text{volume of the}\\ \text{container(m3)}\end{matrix}} \ldots\ldots \text{Equation 3.6}$$

3.3.1.4. Tests on Coarse aggregate

Test on coarse aggregate is done as per ASTM standard for quality and suitability check of sample for use in concrete and another construction activity. This test includes such as sieve analysis, specific gravity, water absorption, and unit weight testing.

A) Sieve analysis test

This test is conducted as per ASTM C136 standard. It is used to determine the grading of material proposed for use and the result is aimed to determine particle size distribution with applicable specification requirements. the size of the test sample of coarse aggregate shall conform to the following as per ASTM C136.

Fitness modulus (FMOCA) = summation % of sample cumulative / 100

Table 3.1: Coarse aggregate sieve analysis requirement as per ASTM C136.

S. No	Nominal maximum size (mm)	Test Sample size, min (Kg)
1	25	10
2	19	5
3	12.5	2
4	9.5	1

B) Specific gravity and water absorption test.

Specific gravity is used to calculate the volume occupied by the aggregate in different mixtures containing aggregate. A water absorption test is conducted to understand the change in the mass of aggregate due to water taking in the pore space within the particle compared to saturated surface dry condition (SSD) when aggregate is in contact with water for a long enough stay. The test was conducted as per ASTM C127-07 standard for batter quality and sustainability of material. A detailed procedure for specific gravity is presented in Appendix B1:

Bulk Specific gravity $= \frac{W1}{W1-W3}$ ....Equation 3.7

Bulk Specific gravity $= \frac{W2}{W2-W3}$ ....Equation 3.8

Water absorption $= \frac{W2-W1}{W1} * 100$.................................Equation 3.9

C) Unit weight test

Unit weight of coarse aggregate was conducted as per ASTM C29 and used to determine the required volume of coarse aggregate in concrete mix design as it assists in determining the required volume of aggregates and the overall concrete mixture proportion.

3.3.1.4. Tests on water

The test is conducted as per ASTM C1602/1602M-22 standard, concrete procedure to ensure the water provided in the concrete mix is of suitable quality and does not adversely affect the concrete's properties or durability.

3.3.2. Concrete mix design

Concrete mix design guidelines in India, Britain, and America were compared, specifically focusing on concrete grades M25, M35, and M45. In the case of M25 ACI guidelines was selected (Chhachhia, 2021)

Therefore, the grade of concrete to be designed is C-25 Mpa, and the mix design was developed according to the guidelines provided in ACI 211.1 standard practice for selecting proportions for normal concrete strength C-25 Mpa. Based on this guideline target mean strength was equal to 33.5 Mpa, and a mix design was obtained accordingly.

Table 3.2: Required average compressive strength from characteristic strength.

Specified characteristics of compressive strength (f'c, Mpa)	**Required average compressive strength /target mean strength (f'cr, Mpa)**
<21	f'c+7
21-35	f'c+8.5
>35	1.1 f'c + 5

As per the above table designed characteristics strength is 25 Mpa. Therefore, the mean strength is as below.

F'ck +8.5…………………………………………………………Equation 3.10

25Mpa + 8.5 = 33.5…………………………………………………Equation 3.11

Also, the water-cement ratio was calculated according to linear interpolation from the table below of the ACI 211.1 standard.

Table 3.3: Estimating water-cement ratio.

Compressive strength 28 days (Mpa)	Water cement ratio by mass for non-air entrained
35	0.47
33.5	?
30	0.54

(30-33.5)/ (0.54-?) = (33.5-35)/ (?-0.47) = 0.491…………………………Equation 3.12

Table 3.4: Mix Ratio for C-25 Concrete Grade.

Ingredient	Cement	Fine Aggregate	Coarse Aggregate
Amount (kg/m3)	376.78/376.78	815.5277/376.78	1025.4/376.78
Ratio	1	2.164	2.721

3.3.3. Sample design

The study on eggshell powder as a partial replacement for cement in concrete, testing replacement levels of 5%, 10%, 15%, and 20% by weight. The results indicated that a 10% eggshell powder (ESP) replacement led to high compressive strength in the concrete, while also providing the benefit of reducing waste disposal (Nandhini & Karthikeyan, 2022). The study used eggshell powder with a particle size range of 50-150 µm at levels of 5%, 10%, and 15%. The results showed that a 10% eggshell powder replacement achieved the optimal strength performance. Additionally, powder with a smaller particle size contributed more significantly to improving the strength of the concrete (Jhatial, Sohu, Memon, & Bhatti, 2019). The study by (Wei et al., 2020) found that while using eggshell powder as a 10% cement replacement demonstrated high strength, exhibited a significant reductions in both strength and weight when subjected to a 28-day acid attack. This indicates that while eggshell powder concrete may have superior compressive strength initially, it may have reduced durability and resistance to chemical attack compared to conventional concrete.

Therefore, the study by (Yerramala, 2014b) Found that combining the use of eggshell powder and fly ash as partial cement replacements was beneficial and improved the overall performance of the concrete. Additionally, the research by (Shahadahtul et al., 2017) Indicated that incorporating another agricultural byproduct, rice husk ash, along with the eggshell powder further enhanced the performance of the concrete mixture.

Table 3.5: Sample design and test duration of specimen.

S. No	mix type	percentage of eggshell powder (ESP) and wheat straw ash (WSA) composite	number of cubes for compressive analysis	number of beams for flexural analysis	total	Tasting date
1	mix-1	Control (0-0)	9	6		28 and 56
2	mix-2	5ESP+5WSA	9	6		
3	mix-3	5ESP+10WSA	9	6		
4	mix-4	10ESP+5WSA	9	6		
5	mix-5	10ESP+10WSA	9	6		
6	mix-6	15ESP+5WSA	9	6		
7	mix-7	15ESP+10WSA	9	6		
		total no of specimen	72	48	120	

3.3.4. Concrete Batching, Mixing and Mixing Procedure

3.3.4.1. Concrete Batching

Concrete batching refers to the process of measuring and combining different ingredients to produce a homogenous concrete mixture. The concrete batching process begins with obtaining and preparing the necessary materials through volume or weighting. Batching by weight method will be used for this specific study because it is found more accurate than batching by volume The cement should satisfy ASTM C150 or ASTM C595 standards requirements, while coarse aggregate and fine aggregate should meet specifications outlined in ASTM C33. For the experiment eggshell powder and wheat straw ash used as partial cement replacement should conform to the relevant ASTM standard such as ASTM C1240. The water must adhere to the quality requirement of ASTM C1602/C1602M. Then the concrete ingredients are batched as per ASTM C94 specification requirements.

Effectiveness analysis of eggshell powder as a partial replacement candidate for cement using an Artificial neural network (AN) method shows that eggshell powder can replace cement by up to 20% and improve its properties (Paruthi et al., 2023). Wheat straw ash was utilized to substitute cement in a varying percentage ranging from 0% to 20%, with increments of 5%.

The finding indicated that the most effective replacement level was determined to be 10% of the ash (Paruthi et al., 2023).

Table 3.6: Percentage replacement analyzation.

Material	Eggshell powder	Eggshell powder + silica fume		Eggshell powder + rice husk ash
author	(Afolayan, 2017)	(Sohu et al., 2022)	(Parthasarathi et al., 2017)	(Afizah Asman et al., 2017)
% replacement	5,10.15,20,25, and 30% of ESP	5,8,11,15, and 20% of ESP along with 5,10, and 15% of FA	5%, 10%, and 15% of ESP with the silica fume by 2.5%, 5%, and 7.5% of the weight of cement	2%:4%, 4%:6%%, and 6%:4% of ESP and WSA respectively
Highest strength % obtained	The control mix exhibits the highest mechanical strength	11% of ESP + 10 % 0f SF	10% of ESP + 7.5% OF silica fume	6%:4% of ESP and WSA
Remarks.	Addition of replacement up to 15% of ESP satisfied required strength grade	The added percentage of silica fume is varied with 5% differences.	strength of the concrete rises with the addition of eggshell powder and silica fume	Since the replacement values are still increasing, it can be concluded that the optimal replacement level has not been reached yet.

For this experiment, eggshell powder and wheat straw ash will be used to replace cement at the dosage of 10%, 15%, 20%, and 25% by the weight of cement, and 0% of replacement also be used as a control mix. Eggshells of 5%,10%, and 15 % addition with 5 and 10 % of wheat straw ash is used respectively.

3.3.4.2. Concrete mixing

The concrete mixing process was carried out using a power drum mixer for ready-mix concrete for seven different mixes with different percentages of eggshell powder and wheat straw ash as partial replacements for cement while keeping other ingredients static.

Table 3.7: Mix sample and percentage replacement of eggshell powder and wheat straw ash.

Batch No	Mix Sample	OPC Cement in %	Eggshell powder (ESP) in %	Wheat straw ash (WSA) in %
1	Mix-1(100-0-0)-Control	100	0	0
2	Mix-2 (90-5-5)	90	5	5
3	Mix- 3 (85-10-5)	85	5	10
4	Mix-4 (80-15-5)	80	10	5
5	Mix-5 (85-5-10)	85	10	10
6	Mix-6 (80-10-10)	80	15	5
7	Mix-7 (75-15-10)	75	15	10

3.3.4.3. Mixing procedure

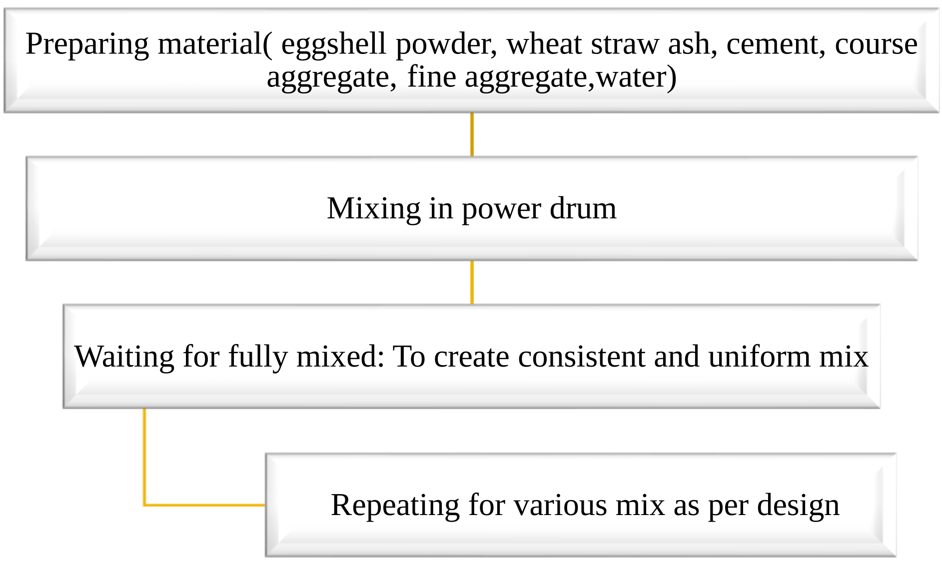

Figure 3.8: Mix preparation process.

3.3.5. Test on fresh Concrete

3.3.5.1. Slump test

The test was performed to evaluate the workability of fresh concrete mixes according to the requirement of ASTM C143/143M standard. It is essential to perform a workability test to understand how the partial replacement of cement with eggshell powder and wheat straw ash affected the flow of fresh properties of concrete in determining the suitability of modified concrete mixes for practical application. The standard slump cone with a 100mm top diameter, 200mm bottom diameter, and 300mm height was deployed for the test. Additionally, a tamping rod with a smooth, straight steel bar of rounded tip was used for compacting the concrete in the slump cone. The fresh concrete is filled 1/3 height of the cone and tamped 25 times for each layer of them uniformly.

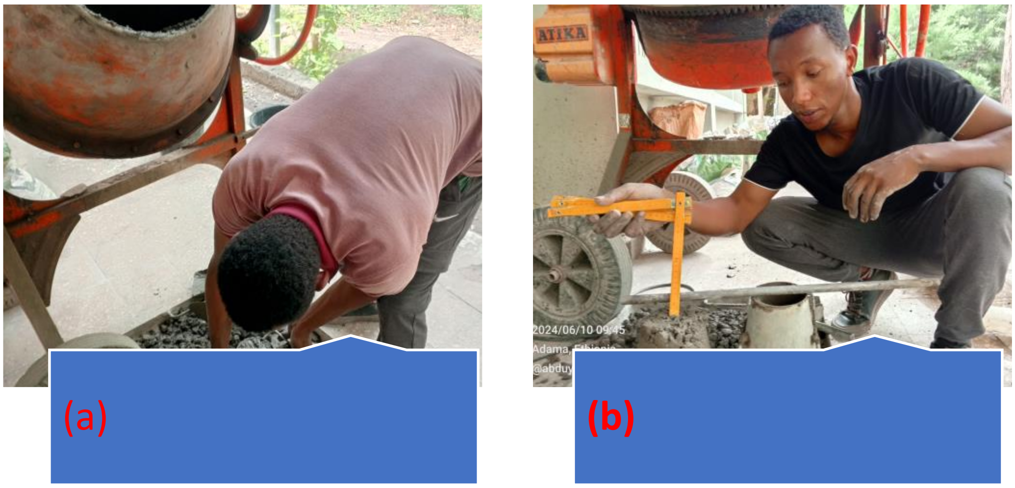

Figure 3.9: Testing workability.

3.3.6. Concrete casting and curing

After preparing the cube and beam/prism according to the requirement of ASTM C31/C32M standard, the mold was coated on the interior surface with releasing agent-like oil to facilitate easy removal of hardened concrete. Concrete of all mix (mix-1, mix-2, mix-3, mix-4, mix-5, mix-6, mix-7) was filled in the mold of 150*150*150mm of cube for compressive strength test and beam of 100*100*500mm size for flexural strength test by keeping on vibrator for homogenous compaction throughout specimens and kept for 24 hrs. after keeping specimen for 24 hours in the mold until it gains some strength, the specimens removed from mold and kept in air for few hours and then after specimens are fully submerged under the water of prepared water tank for 28 days for compressive on cube specimen and flexural test of beam/prism. Three samples of cube specimens from each of the mixes were taken after being kept in water for 28 days and submerged in tanks of sulphuric acid solution for 28 days in the solution for durability test analysis. In general, 120 specimens (72 cubes and 48 prisms) are cast and tested in this experimental analysis.

Figure 3.10: Casting and curing specimen.

3.3.7. Test for hardened Concrete

3.3.6.1 Compressive strength test

A casted cube with a width of 150mm, breadth of 150mm, and height of 150 mm and cured in water for 28 days was tested for compressive strength using a universal testing machine. The cube that was kept in the water for 28 days is removed from the curing tank, wiped, and kept outside for a couple of hours to dry the surface. After the measurement of the specimen dimension is taken. The specimen is made to grip in between the compression flatters and the hydraulic tank valve is closed, Then the load of 140kg/cm3 per minute has a load of 3000KN from the compressive strength machine is gradually applied till the specimen that kept between the compression flatter fails, and the load value obtained when the specimen fails is noted down. The test is conducted at the ASTU laboratory, department of Construction Engineering accordance with ASTM C39/C39M and Test should follow ASTM C109/109M standard. As per Ethiopian standard (EBCS-2-1995) cylindrical of other size may also be used with conversion factors determine from a comprehensive series of test, the conversion factor may be applied to obtain equivalent characteristic strength based on 150mm cubes.

3.3.6.2. Flexural Strength Test

Test Should follows ASTM C 78/78M standard. For flexural Strength tests cast beams with a width of 100mm, a height of 100mm, and a length of 500mm and cured in water for 28 days were tested their flexural strength using a universal testing machine. The cuboid mold prepared and kept under the water for 28 days was removed and kept out to dry. Then flexural strength was measured by the flexural testing machine at a standard loading rate and the obtained result was analyzed using the below formula.

As per Ethiopian standard EBCS (1992-1-1:2014, 2014)the mean flexural strength of reinforced concrete (RC) is depend on mean axial tensile strength and depth of the cross section, and given as fcm=max {(1.6- h/1000) fctm, fctm}, where "h" is total member depth and "fctm" is mean axial tensile strength. Therefore, based on above relationship, other value can obtain.

$F= PL/ (bd^2)$ ………………………………………………………………... Equation 3.13

P=pressure b= breadth d=depth L=length

3.3.6.3. Durability test

To determine the durability test, the Immersed samples in water for 28 days were removed and submerged in 5% sulfuric acid solutions again for 28 days. Then the compressive strength of that submerged in water and that submerged in an acidic solution is compared, and analyzed, and conclusions and recommendations are based on the obtained strength value for their respective mixes. Cube was tested as per ASTM C1012 standard for durability analysis.

3.3.6.4. Microstructural Test

Determining Microstructural testing involves examining the internal structure and composition of a material at a microscopic level. To conduct such tests on concrete, thin sections are prepared by cutting and polishing samples, which are then analyzed using techniques such as optical microscopy, scanning electron microscopy (SEM), and X-ray diffraction (XRD). These tests provide valuable insights into the distribution and arrangement of various phases, including cementitious materials, aggregates, and any incorporated additives. Microstructural analysis helps understand the material's hydration, porosity, interfacial transition zones, and overall integrity. By studying the microstructure, researchers can assess the effects of different ingredients and processing techniques on concrete's performance, aiding in the development of optimized mix designs and enhanced durability.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Introduction

In the previous chapter, the research materials and methods employed in this study were discussed to address the research objective. The current chapter focuses on the presentation and analysis of the results, as well as the subsequent discussion. This section introduces the key findings of the research and offers interpretations of the obtained results. It encompasses the presentation and analysis of various experimental tests conducted. Additionally, the chemical analysis of eggshell powder and wheat straw ash is discussed, along with the properties of cement, eggshell powder, wheat straw ash, fine aggregate, coarse aggregate, and water used in the study. The consistency of the blended paste containing cement, eggshell powder, and wheat straw ash is also observed. Furthermore, the workability, compressive strength, flexural strength, concrete durability, and microstructural properties of the concrete are thoroughly examined and discussed.

4.2. Physical and Chemical Properties Materials

In this study, a comprehensive examination of the physical and chemical properties of various materials was conducted. The chemical analysis encompassed eggshell powder and wheat straw ash, which are key components under investigation. The properties of cement, eggshell powder, and wheat straw ash were analyzed, including their chemical composition. Additionally, the physical properties of the materials were assessed. The fine aggregate and coarse aggregate used in the study were also subjected to characterization, including their grading, unit weight, silt content, etc. Furthermore, an analysis of the water utilized in the experiments was conducted, considering its PH level. These comprehensive evaluations of the physical and chemical properties of the materials provide a solid foundation for understanding their behavior and interactions in subsequent experimental tests.

4.2.1 Eggshell powder, and wheat straw ash

Test results obtained from analyzation of wheat straw ash and eggshell powder are presented below as follows

4.2.1.1. Chemical characterizations of eggshell powder, and wheat straw ash

The chemical composition of cement and partial cement replacing material are presented in bellow table below.

Table 4.1: Chemical composition of eggshell powder, and wheat straw ash.

Oxide composite	Eggshell powder	Wheat straw ash
SiO_2	6.54	78.01
Al_2O_3	1.40	8.60
Fe_2O_3	0.70	0.36
CaO	55.50	2.70
MgO	0.50	1.60
Na_2O	<0.01	0.30
K_2O	0.10	0.80
MnO	0.04	0.4
P_2O_5	0.20	1.46
TiO_2	0.12	0.06
H_2O	0.16	2.40
LOI	35.2	3.31
$SiO_2 + Al_2O_3 + Fe_2O_3$		86.97

Sources: Ethiopian Geological Survey Institution laboratory, Addis Ababa

The chemical composition of ESP shows that CaO, which ranges between 32.5% and 99.8%, is the main component of ESP. However, silica oxide (SiO2) is present in considerably low percentages. Therefore, ESP cannot be a pozzolanic material. In addition, ESP particles contain approximately 3% of organic material in their composites (Hamada et al., 2020). The primary composite of eggshell powder is calcium carbonate (CaCO3), and the resulting products from the decomposition of calcium carbonate are calcium oxide (CaO) and carbon dioxide (CO2), thus indicating that the LOI content of eggshell powder is notably elevated (Zhang et al., 2024). Loss of ignition(LOI) is 45.42% (Yerramala 2014) and 24.52% (Zhang et al., 2024). When finely ground and utilized as a partial replacement for cement, Rice Husk Ash (RHA), abundant in silica, and eggshells, which contain the same amount of calcium oxide as cement, can initiate a pozzolanic response. This reaction involves the interaction of silica with calcium oxide, leading to the creation of calcium silicates that play a crucial role in attaining increased strength (Jhatial, Goh, et al., 2019). Through XRF is concluded that WSA is a pozzolanic material as the sum of the percentage of SiO2, Fe2O3, and Al2O3 is greater than 70% and has the potential to be used as a partial replacement of cement in the production of sustainable concrete (Khan et al., 2019)

From the above result, the combined oxide components ($SiO_2 + Al_2O_3 + Fe_2O_3$) for wheat straw ash is more than 70% of the minimum requirement for class F and N pozzolanic material for partial cement replacement as per ASTM C 618-08(2008). As per ASTM C 618-08 wheat straw ash is categorized under class F pozzolanic materials. Wheat straw ash shows a greater concentration of ferric which contributes resistance to acid attack. From the above value, eggshells have a higher percentage of CaO, and the presence of calcium oxide in eggshell powder can participate in this reaction, potentially influencing the formation of CSH while silica in wheat straw ash reacts with leftover CaOH to form CSH that contribute to strength of concrete.

4.2.1.2. Fines of cement, eggshell powder, and wheat straw ash

Finess of materials is an important parameter of cementitious materials that highly contributes to the strength of concrete materials, hydration rate, and durability. Finess of material can be measured by various methods, such as sieving, air permeability, image analysis, and laser diffraction. As per ASTM C 618, the fines of pozzolanic material like wheat straw ash of 70% should be passed 45 μm (No. 325) sieve and not more than the maximum of 34% should retained on the sieve.

4.2.1.3. Specific gravity of cement, eggshell powder, and wheat straw ash

The cement utilized was OPC 43 grade with a consistency (P) of 28%. With a specific gravity of 3.15(Shar et al., 2019) When wheat straw, the dried stalks of the wheat plant, is burnt and the ash is obtained, its specific gravity is found to be 2.31g/cm^3 (Biricik et al., 2018). According to the study, the specific gravity (Gs) range of wheat straw ash falls between 0.34 and 0.38. This range indicates that wheat straw ash is relatively lightweight compared to water. Understanding this specific gravity range is crucial for assessing the density and physical characteristics of wheat straw ash in various applications (Muhammad & Marri, 2018) The specific gravity of the eggshell powder in the study was determined to be 1.89. This value signifies that the eggshell powder is denser than water (Mishra & Pathak, 2017)

Table 4.2: Specific gravity of replacement materials.

Particulars	Denotations	Samples in gram	
		ESP	WSA
Weight of empty pycnometer (g)	W1	50	50
Weight of pycnometer with ESP or WSA (g)	B	81.75	153.89
Weight of pycnometer with ESP or WSA and kerosene (g)	C	156.02	228.64
Weight of pycnometer with kerosene (g)	W2	124.75	124.75
Weight of kerosene (g)	Wk.=W2-W1	74.75	74.75
Density of kerosene (g/cm3)		0.82	0.82
Weight of displaced kerosine (g)	Wdk=W2-B	31.76	103.89
Specific gravity=Wk*0.82/(W displaced)	SG	1.93	0.59

4.2.2. Water

The PH of water was tested at Adama Science and Technology Laboratory using a Ph meter and was found 7.45 which falls within the acceptable range for use in concrete. Typically, the ideal pH range for water used in concrete is between 6 to 8.5 as per ASTM standards. As of this test value, it is slightly basic but within the acceptable range of mixing.

4.2.3. Fine aggregate

4.2.3.1. Sieve analysis of fine aggregate

Sieve analysis as per ASTM standard, is a fundamental test to determine the particle size distribution of fine aggregate. This analysis is crucial in ensuring the appropriate grading and quality of fine aggregate, which directly impacts the performance and behavior of concrete results. The process involves taking 500g of SSD sample of fine aggregate and sieve for 10 to 15 minutes using ASTM standard sieve series. The weight of material retained on each sieve is measured and the cumulative percentage of passing through each sieve is measured and compared with ASTM standard value. The result data is then used to create a gradation curve of the particle size distribution. The ASTM standard such as ASTM C136 and C177, outline the procedure and requirements for conducting the sieve analysis of fine aggregate. The result is shown below table.

Table 4.3: Results of sieve analysis and its respective ASTM standard.

sieve size	weight of sample retained(g)	% of the sample retained	% sample cumulative	% cumulative pass	% ASTM min	% ASTM max
9.5	0	0	0	100	100	100
4.75	9.5	1.9	1.9	98.1	95	100
2.36	60.3	12.06	13.96	86.04	80	100
1.18	101.4	20.28	34.24	65.76	50	85
0.6	115	23	57.24	42.76	25	60
0.3	135	27	84.24	15.76	5	30
0.15	64.5	12.9	97.14	2.86	0	10
pan	13.2	2.64	99.78	0.22		
Total sum	498.9		288.72			

From the obtained value above of the percentage of sample cumulative result, the sand fines modulus is calculated is 2.887.

From the result obtained above here, it is typically in between the range value of 2.3 to 3.1 which fulfils the requirement of ASTM C33 that indicates the fine aggregate used for concrete mix fulfils the requirement of standard value.

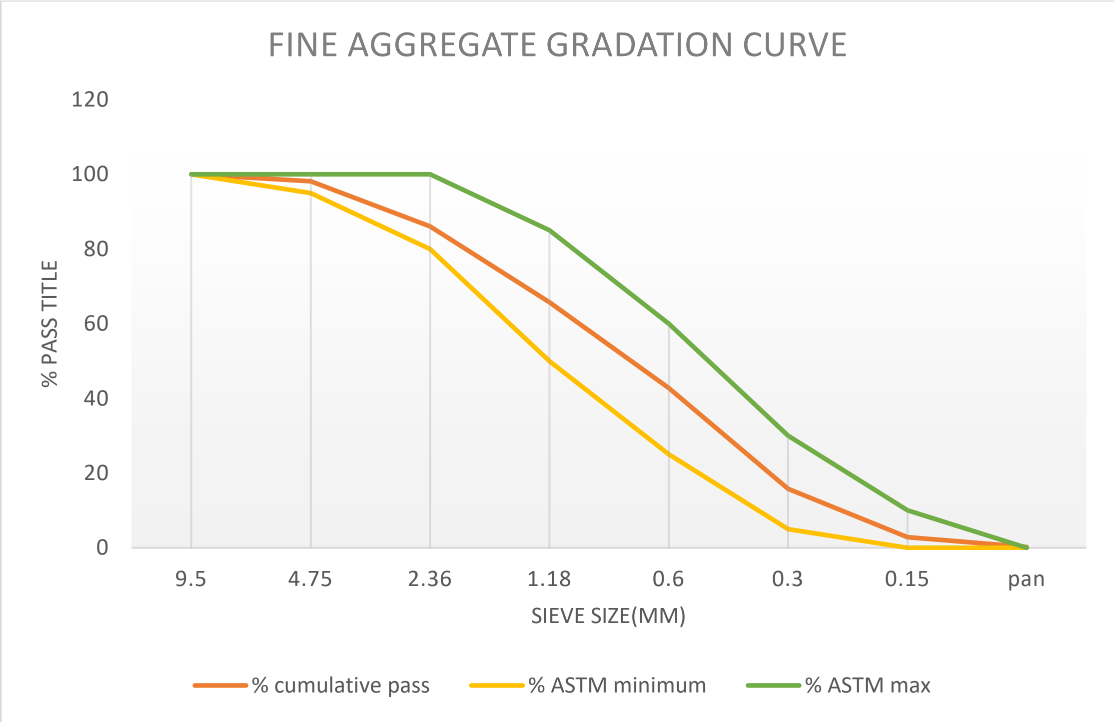

Figure 4.1: Fine aggregate gradation curve.

From the graph shown above, the value obtained falls the upper and lower limit value of the ASTM C136 standard. In general, the result obtained indicates the fine aggregate used for this study fulfills general standard requirements and specifications.

4.2.3.2. Silt content of fine aggregate

The primary standard for determining the silt content of fine aggregate is ASTM C117-standard and the particle finer than 75µm in fine aggregate used in concrete is considered as silt.

Total sand taken(A)=250ml

Silt deposit above the sand after 24 hrs. (B)=4ml

silt content (%) = 1.6%

4.2.3.3. Water absorption and specific gravity of fine aggregate

It is used to know the absolute volume and weight of fine aggregate used in a concrete mix design to ensure consistent aggregate properties, which is important for maintaining uniform concrete performance and it is very important for acceptance of aggregate material for use in concrete production. The water absorption is accounted for when determining the effective water-cement ratio, as the absorbed water does not contribute to the workability of the fresh concrete and later on hardened concrete.

Weight of Saturated surface dry sample in air(W1) = 505.5g

Weight of oven-dry sample(W2) = 496

Weight of the pycnometer filled with water to the calibration mark(W3) = 1505.9

Weight of pycnometer filled with sample and water to calibration mark(W4) = 1828.3

A) Bulk Specific Gravity (BSG): is referred to as the oven-dry specific gravity and it represents the ratio of the mass of aggregate including the impermeable and permeable void to the normal material (including the pore space within individual particle), to the mass of an equal volume of gas-free distilled volume water at the stated temperature and obtained value is 2.708.

B) Saturated surface dry specific gravity (SSD-SG): It represents the ratio of the mass of the aggregate, with its pore filled with water to the mass of an equal volume. It's typically higher than oven-dry(bulk) specific gravity as it accounts for water absorbed in the pore of the aggregate particle.

$$BSG = \frac{505.5}{(496+1505.9-1828.3)} = 2.912$$

C) Apparent specific gravity (ASG): represents the ratio of the mass of the solid material in the aggregate particle, excluding the pore space, to the mass of an equal volume of water. It is typically higher than both the oven-dry(bulk), as it only accounts for the solid material in aggregate particles.

$$BSG = \frac{496}{(496+1505.9-1828.3)} = 2.857$$

C) Water absorption test: it is determined through the ASTM C128 test method and it represents the amount of water that the aggregate particle can absorb when fully saturated.

$$\text{Absorbtion} = \frac{505.5 - 496}{(496)} * 100 = 1.91\%$$

In general, the result obtained above for bulk specific gravity is 2.776 and it is acceptable as it's within the typical range value which is 2.6 to 2.8, and the most acceptable value as it accounts for the mass of aggregate including pore spaces within the individual particle. Also, the result obtained for water absorption is equal to 1.41% and the typical water absorption value for natural sand ranges from 0.2% to 2.0%, however, for aggregate such as recycled, crushed stone requires adjustment to maintain desired workability as it may exceed the above result.

4.2.3.4. Unit weight of fine aggregate

Unit weight known as the bulk density of fine aggregate, is the mass of the aggregate per unit volume, including the volume of the void between the particles.

Table 4.4: Unit weight value obtained as per ASTM C 29.

S.no	Sample trail	Weight of sample plus weight container (kg) (A)	Weight of container (kg) (B)	Weight sample obtained (kg) (A-B)	The volume of the container (m^3)
1	Trail-1	8.27	5.5	2.75	Volume(V)= 1.82×10^{-3}
2	Trail-2	8.3	5.5	2.8	
3	Trail-3	8.26	5.5	2.76	
Total sum				2.77	

$$\text{UWFA} = \frac{2.77}{0.00182} = 1521.9 \text{ kg/m}^3$$

Therefore, as the result is within the range value of 1400-1600 kg/m^3 it is considered as suitable for use in concrete for the mix.

4.2.3.5. Moisture content of fine aggregate

It is necessary to measure and account for the actual moisture content of fine aggregate when proportioning concrete mixes to ensure the proper water-cement ratio and workability are achieved. According to ASTM C33 moisture content of fine aggregate should not exceed 8% by weight. Then from the obtained value the moisture content is 0.8%.

4.2.4. Coarse aggregate

4.2.4.1. Sieve analysis of Coarse aggregate

As coarse aggregate accounts for most of the concrete volume, testing as per the requirement of ASTM accordingly is necessary. The aggregate used for this study was crushed stone with a maximum size of 20mm and in the same way, fine aggregate primary test was conducted in the laboratory. Gradation of coarse aggregate is one of the primary tests to be conducted and this study was conducted as per the standard of ASTM C 136 using sieve analysis according to this standard. The result is shown in the below table and the figure for the gradation curve.

Table 4.5: Sieve analysis and Standard for Coarse aggregate.

sieve size	weight of sample retained(g)	% of individual samples retained	% sample cumulative	% cumulative pass	% ASTM minimum	% ASTM max
20		0	0	100	100	100
19	289	4.82	4.82	95.18	95	100
12.5	2310	38.5	43.32	56.68	40	80
9.5	2111	35.18	78.5	21.5	20	55
4.75	1290	21.5	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	_	_	_	_	_	_
sum	6000		726.64			

From the obtained value above of the percentage of sample cumulative result, the sand fines modulus is calculated is 7.26.

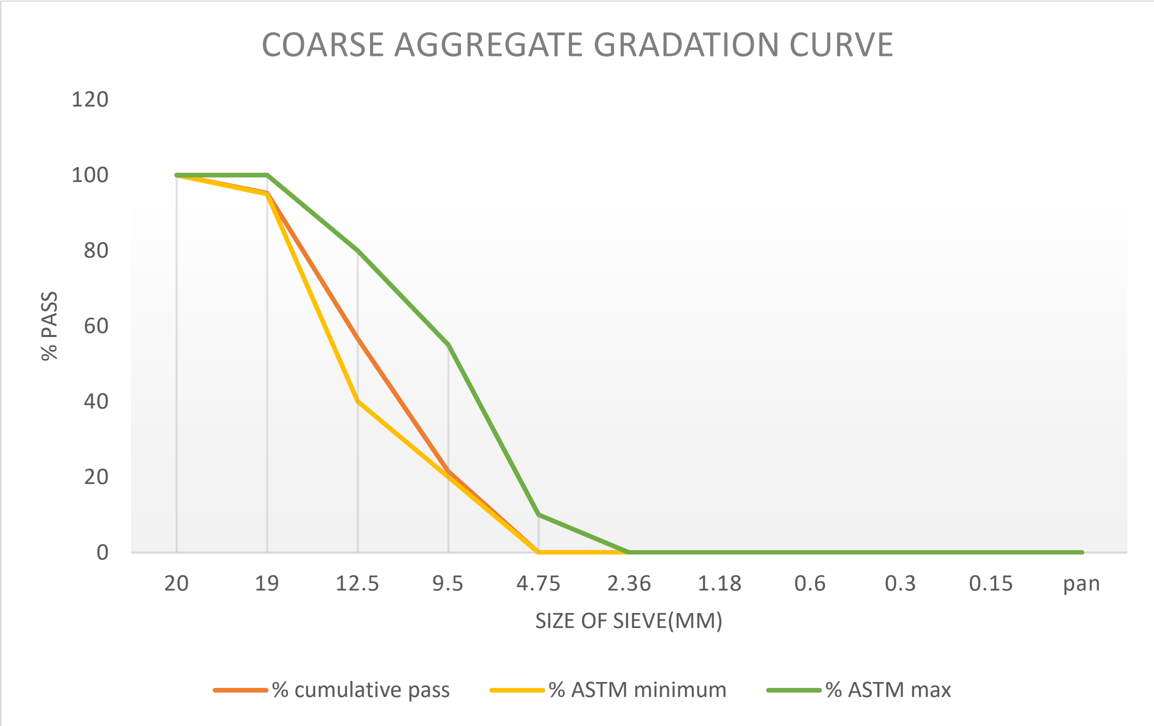

Figure 4.2: Coarse aggregate gradation Curve.

4.2.4.2. Specific gravity and water absorption of coarse aggregate

The specific gravity of aggregate is considered a measure of the strength or quality of the material and helps identify stone. Water absorption gives an idea of the strength of aggregate and it is percent by weight of water absorbed in terms of oven-dried weight of aggregate. The result obtained from the laboratory test is as below.

Weight of oven-dry sample (W1) = 4970gm

Weight of saturated surface dry sample in air (W2) = 5099 gm

Weight of saturated sample in water (W3) = 3340 gm

Based on above, obtained results for Bulk specific gravity, Apparent specific gravity and water absorption is 2.74, 2.87 and 2.5% respectively.

4.2.4.3. Unit weight of coarse aggregate

Unit weight known as bulk density of Coarse aggregate, is the mass of the aggregate per unit volume, including the volume of the void between the particles.

Table 4.6: Unit weight value obtained as per ASTM C 29.

S.no	Sample trail	Weight of sample plus weight container (kg) (A)	Weight of container (kg) (B)	Weight sample obtained (kg) (A-B)	The volume (m^3)
1	Trail-1	8.60	5.5	3.10	Volume(V)= $1.82x10^{-3}$
2	Trail-2	8.55	5.5	3.05	
3	Trail-3	8.51	5.5	3.01	
Total sum				3.533	

$$\text{UWFA} = \frac{3.713}{0.00182} = 1677.64\ \text{kg/m}^3$$

4.2.4.4. Moisture content of coarse aggregate

This test method provides a standardized way to determine the total evaporable moisture content of coarse aggregate, which is an important parameter in concrete mix design. Knowing the moisture content allows the concrete procedure to adjust the mixing water accordingly. It is tested according to the ASTM C566 standard test method.

$$\text{Moisture content of CA} = \frac{5000 - 4970}{5000} * 5000 = 0.6\%$$

As per the ASTM C33, the value falls between 0.5% to 2%, and as for the above result, it is acceptable as it is within the range value.

4.2.5 Blended paste of cement, Eggshell powder, and Wheat straw ash

4.2.5.1. Cement, Eggshell powder, and Wheat straw ash Consistency test.

The consistency test is a crucial parameter to determine the amount of water required to produce a cement paste of standard workability. The standard consistency of cement paste refers to the quantity of water needed for the Vicat plunger to penetrate from the bottom and the test was performed to determine the water needed to achieve a standard cement paste with a normal consistency. The purpose of this test is to find the precise water content at which the cement paste reaches the desired consistency and the consistency of cement varies from 26-

33% (Surshuwlhv et al., 2016)The standard. To conduct the consistency test, the cement paste was poured into the Vicat mould, ensuring the surface was levelled with the top of the mould. The filled mold was then cantered under the rod-bearing plunger. The plunger was gently lowered until it contacted the paste surface, and then swiftly released to allow it to sink into the paste. This action should occur within 30 seconds of completing the mixing process. Normal paste consistency is reached when the rod settles to a point where it is 5-7 mm above the bottom surface, as depicted in Figure 3. The test was repeated with varying percentages of water until the desired normal consistency was achieved (Surshuwlhv et al., 2016).

This study investigated the influence of eggshell powder and wheat straw ash on the normal consistency of cement paste. Normal consistency refers to the amount of water required to achieve a standard fluidity level in the paste. It is determined by measuring the depth to which a plunger penetrates the paste, specifically 10 +1 mm from its initial surface. This factor is essential as it affects both the workability and strength of the resulting concrete. The obtained results are presented in the table below.

Table 4.7: Normal Consistency Value.

Mix	% Replacement			Normal consistency (%)
	Cement	Eggshell	Wheat straw	
Mix-1	100	0	0	33
Mix-2	90	5	5	35
Mix-3	85	5	10	39
Mix-4	80	10	5	38
Mix-5	85	10	10	38
Mix-6	80	15	5	37
Mix-7	75	15	10	41

The standard consistency test was evaluated as per ASTM C-187 standard using Vicat apparatus on a mixture of the mix-1 (normal mix,0,0), mix-2 (5% ESP, 5 % WSA), mix-3 (5% ESP, 10% WSA), mix-4 (10% ESP, 5% WSA), mix-5 (10% ESP, 10 % WSA), mix-6 (15% ESP, 5% WSA) and mix-7(15% ESP, 10% WSA). The normal consistency is presented in the form of a percentage and the obtained value for mix-1 is 33% and for mix-2, mix-3, mix-4, mix-5, mix-6, and mix-7 is 35%, 38% 37%, 39%, 38%, and 40% respectively. The result presented above demonstrates that as the percentage of eggshell powder and wheat straw ash increases standard consistency value also increases due to the natural fibrous, and porous structure of wheat straw ash and eggshell powder allowing them to absorb and hold onto significantly more water compared to the dense inorganic matrix of hardened cement. As the percentage of WSA increases, there is a proportional increase in water absorption.

The relationship between these two variables shows that higher WSA percentages result in higher levels of water absorption. (Khan et al., 2019). When cement is partially replaced with eggshells, the consistency of the cement tends to increase gradually over time(Sharma & Netula, 2019).

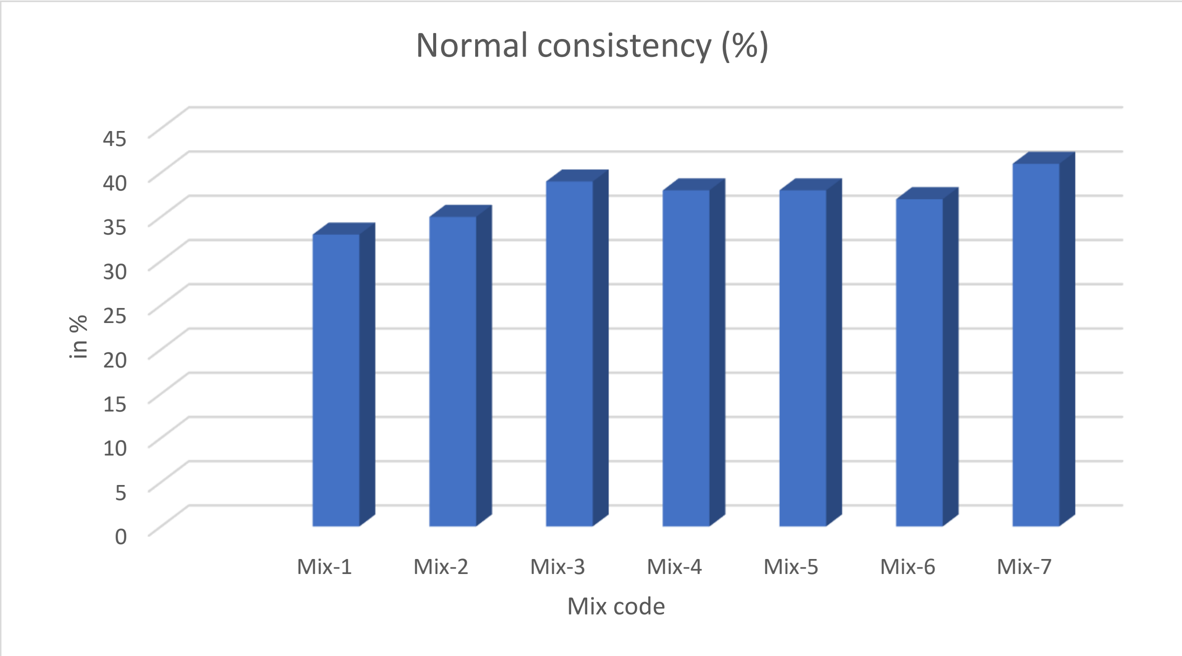

Figure 4.3: Normal consistency result graph.

The above graph shows that the consistency test for partial replacement of cement at different percentages with eggshell powder and wheat straw ash

4.3. Fresh Concrete Properties

4.3.1. Workability of fresh concrete

Workability refers to the ease and ability of fresh concrete to be mixed, transported, placed, and compacted effectively without segregation or excessive bleeding. The following table presents the workability results of fresh concrete using the slum test method. It shows the number of tests conducted for each mixing ratio and at different proportions of ESP and WSA.

Table 4.8: Slump test value.

Mix	% Replacement			Slump in (mm)	% Reduction
	Cement	Eggshell	Wheat straw		
Mix-1	100	0	0	43	0
Mix-2	90	5	5	40	6.9767
Mix-3	85	5	10	36	16.279
Mix-4	80	10	5	37	13.953
Mix-5	85	10	10	35	18.605
Mix-6	80	15	5	34	20.93
Mix-7	75	15	10	33	23.256

The workability test was carried out as per ASTM standard using slum con on a fresh concrete mixture of the mix-1 (normal mix,0,0), mix-2 (5% ESP, 5 % WSA), mix-3 (5% ESP, 10% WSA), mix-4 (10% ESP, 5% WSA), mix-5 (10% ESP, 10 % WSA), mix-6 (15% ESP, 5% WSA) and mix-7(15% ESP, 10% WSA). The obtained value of workability is presented in mm and the value for mix-1 is 43 and for mix-2, mix-3, mix-4, mix-5, mix-6, and mix-7 is 40, 37, 34, 36, 35, and 33 respectively. The result presented above demonstrates that as the percentage of eggshell powder and wheat straw ash increases workability value decreases due to that ESP and WSA consume or absorb more water than cement comparatively.

For eggshell powder and rice husk ash replaced from 0- 40% by cement weight, the slump decreased from 135mm to 81 mm. (Sivakumar & Mahendran, 2014). Based on the findings, it was concluded that an increase in the amount of WSA in concrete requires a higher water content to enhance workability. Consequently, the slump value decreases as the percentage of WSA increases (Shar et al., 2019).

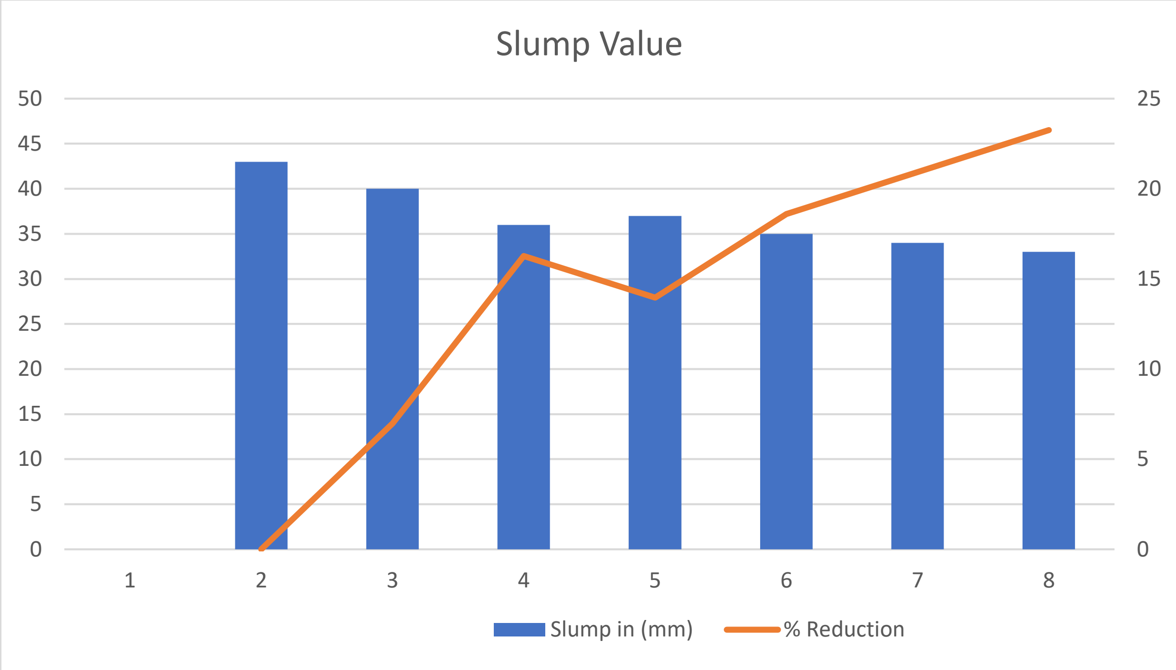

Figure 4.4: Slump test result graph.

4.4. Hardened concrete properties (Compressive and flexural strength of concrete)

4.4.1. Compressive strength of eggshell and wheat straw ash cement concrete

The table below displays the compressive strength test outcomes for concrete cubes containing a blend of eggshell powder and wheat straw ash, alongside the curing durations and replacement percentages. It presents the compressive strengths of three replicated samples of blended cement concrete cubes, mean compressive strength values, and the percentage achievement of the desired strength (33.5 N/mm²) after a 28-day curing period in a water tank.

Table 4.9: Compressive strength of concrete with different partial replacements at 28 days.

Curing days	Compressive strength for 28 days in N/mm^2						
	Mix code	Parameter	1	2	3	Target mean strength 33.5 (N/mm^2)	Percentage Target mean strength (N/mm2)
28 days	Mix 1(0-0)	Load (KN)	730	743	726	35.73	106.66
		stress	35.6	36.2	35.4		
	Mix 2(5-5)	Load (KN)	597	595	572	25.82	77.1

		stress	26.53	25.53	25.42		
	Mix 3(5-10)	Load (KN)	591	595	588	26.27	78.42
		stress	26.26	26.44	26.13		
	Mix 4(10-5)	Load (KN)	554	589	568	25.33	75.61
		stress	24.6	26.2	25.21		
	Mix 5(10-10)	Load (KN)	679	617	666.17	29.09	86.84
		stress	30.17	27.51	29.6		
	Mix 6(15-5)	Load (KN)	687	673	711	33.66	100.48
		stress	33.5	32.8	34.7		
	Mix 7(15-10)	Load (KN)	530	554	567	24.45	72.99
		stress	23.55	24.6	25.2		

Replacement level (cement, ESP, WSA in %) at 28 days

mix-1(100,0,0), mix-2(90,5,5), mix-3(85,5,10) mix-4(85,10,5), mix-5(80,10,10), mix-6(80,15,5), and mix-7(75,15,10).

Table 4.10: Compressive strength of concrete with different partial replacements at 56 days.

Curing days	Compressive strength for 56 days in N/mm^2						
	Mix code	Compressive strength (n/mm2)			Target mean strength 33.5 (N/mm^2)	Percentage Target mean strength (N/mm2)	% gain in 28 days after 56 in water
56 days	Mix 1(0-0)	36.8	36.5	37.4	36.9	106.66	3.270
	Mix 2(5-5)	27.83	26.53	27.42	27.26	77.10	5.580
	Mix 3(5-10)	28.46	28.44	27.13	28.01	78.42	6.620
	Mix 4(10-5)	26.64	27.42	26.52	26.86	75.61	8.685
	Mix 5(10-10)	30.42	31.12	31.76	31.10	86.84	6.910
	Mix 6(15-5)	36.44	34.24	35.28	35.32	100.48	4.930

	Mix 7(15-10)	25.68	26.56	27.42	26.55	72.99	8.590

Replacement level (cement, ESP, WSA in %) at 56 days

mix-1(100,0,0), mix-2(90,5,5), mix-3(85,5,10) mix-4(85,10,5), mix-5(80,10,10), mix-6(80,15,5), and mix-7(75,15,10)

Graphically, the compressive strength of control and excremental value of eggshell powder and wheat straw ash are presented below.

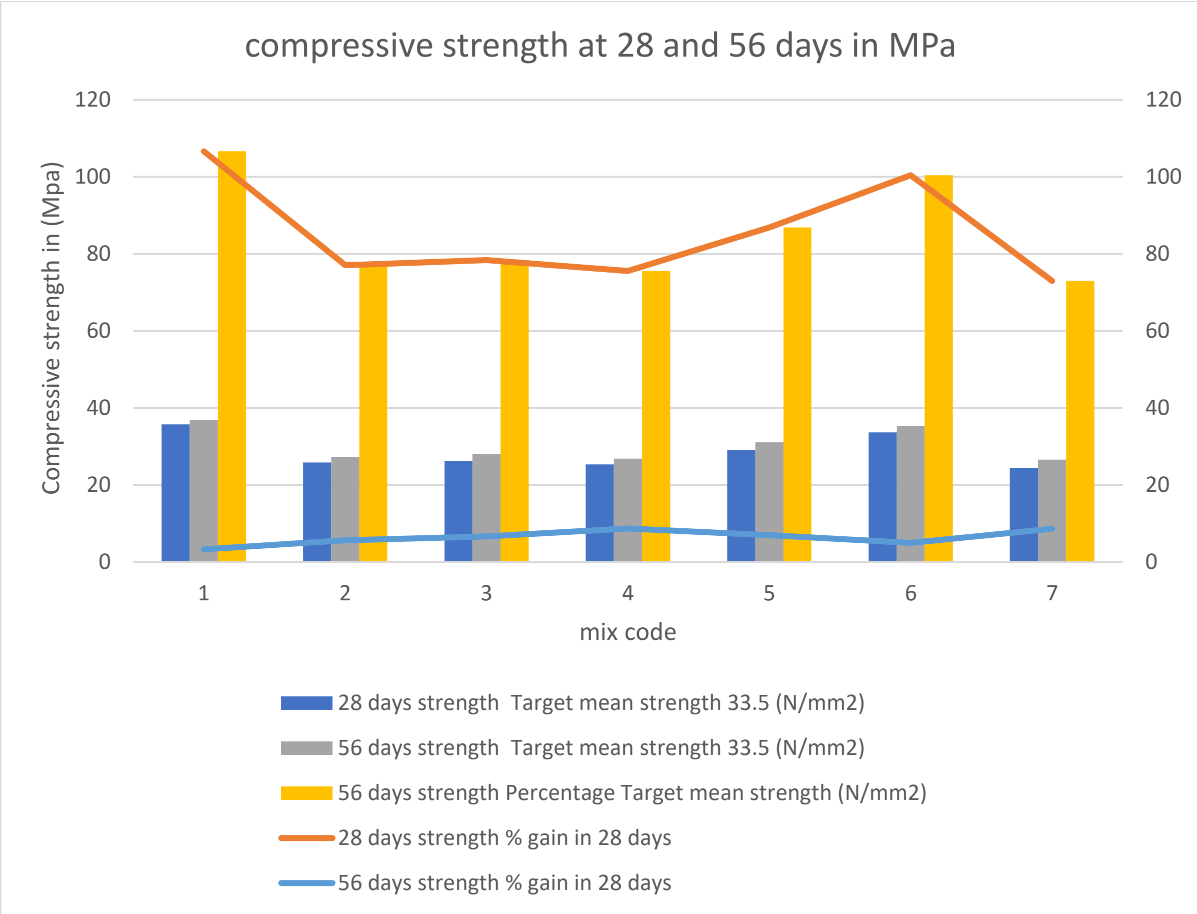

Figure 4.5: Compressive strength graphic result.

Eggshell powder improved the microstructure of mortar reduced pores, and provided extra calcium hydroxide for strength gain (Beng Wei et al., 2020).. a highly reactive pozzolan material with a lower calcium/silica ratio, when substituted with a calcium-rich material, can enhance the properties of concrete while also reducing the amount of cement used (Jhatial, Goh, et al., 2019).

Based on the compressive strength values, mix 1 and Mix 6 (15% eggshell powder and 5% wheat straw ash) have met or exceeded the target mean strength, while the other mixes fall below the target mean strength of 33.5 N/mm². This research demonstrated that incorporating up to 15% eggshell and an additional 5% wheat straw ash can serve as an effective substitute for cement in concrete. However, the introduction of more wheat straw ash leads to a notable decline in compressive strength. Hence, a blend of 15% eggshell powder and 5% wheat straw ash emerges as an ideal partial replacement choice, and any further increase in wheat straw ash content result in decreased strength.

4.4.1.1. Statical analysis of compressive strength

This study was conducted to explore the specific correlations between chosen mixes through an analysis of compressive strength values using a two-way ANOVA on experimental data, with the findings detailed in the discussion section.

Table 4.11: Data table.

	Sample-1	Sample-2	Sample-3
Mix 1	36.8	36.6	37.4
Mix 6	34.24	35.28	36.44
Mix 1	36.8	36.6	37.4
Mix 5	30.42	31.12	31.75

Table 4.12: Summary and ANOVA table for mix-1 and mix-6.

SUMMARY	*Count*	*Sum*	*Average*	*Variance*
mix 1	3	110.8	36.93333	0.173333
mix 6	3	105.96	35.32	1.2112
Sample-1	2	71.04	35.52	3.2768
Sample-2	2	71.88	35.94	0.8712
Sample-3	2	73.84	36.92	0.4608

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	3.904267	1	3.904267	11.08327	0.079602	18.51282
Columns	2.064533	2	1.032267	2.930356	0.25443	19
Error	0.704533	2	0.352267			

Total	6.673333	5				

During data analysis, comparisons based on p-values, F-critical values, and F-values determine the statistical significance of the mixes. The F-value signifies the ratio of variance between groups to variance within groups, while the p-value indicates the likelihood of the observed difference happening by chance. In the comparison between mix-1 and mix-6 from the provided table, the F-critical value exceeds the F-value, and the p-value (0.0796) is greater than 0.005. Hence, at the alpha level of 0.05, this disparity is not statistically significant. Therefore, mix-6, comprising 15% ESP and 5% WSA, can be considered a viable alternative to mix-1 based on the statistical analysis results.

Table 4.13: Summary and ANOVA value for Mix-1 and Mix-5.

SUMMARY	*Count*	*Sum*	*Average*	*Variance*		
mix 1	3	110.8	36.93333	0.173333		
mix 5	3	93.29	31.09667	0.442633		
Sample-1	2	67.22	33.61	20.3522		
Sample-2	2	67.72	33.86	15.0152		
Sample-3	2	69.15	34.575	15.96125		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	51.10002	1	51.10002	447.0041	0.00223	18.51282
Columns	1.0033	2	0.50165	4.388249	0.185589	19
Error	0.228633	2	0.114317			
Total	52.33195	5				

In comparing mix-1 and mix-5, the F-critical value for mix-5 was 18.51282, the F-value was 447.0041, and the p-value was 0.00223. The F-critical value is less than the F-value, and the p-value (0.00223) is less than 0.005. Therefore, this difference is statistically significant at the predetermined alpha level 0.05. Consequently, mix-5, characterized by 18.51282 for the F-critical value, 447.0041 for the F-value, and a p-value of 0.00223, demonstrates statistical significance over mix-1. Therefore, mix-5 which exhibits 31.9 N/mm2 in compressive strength cannot be considered a viable alternative to mix-1

4.4.1.2. Validity of compressive strength result

A validity test outcome is determined by averaging the test results from three samples extracted from a single concrete batch produced and cured under standard conditions for 28 and 56 days. According to the Indian Standard IS 516, "The average of three values shall be taken as the representative of the batch provided the Individual variation is not more than ± 15 percent of the average". However, the concrete standards in Ethiopia do not contain comparable specifications.

Table 4.14: Validity analysis for compressive strength at 28 and 56 days.

Mix	28 days				56 days			
	Mean	Standard deviation	Variance	Coefficient of variation	Mean	Standard deviation	Variance	Coefficient of variation
Mix -1	35.73	0.42	0.173333	1.17%	36.9	0.456	0.21	1.24%
Mix 2	25.82	0.61	0.374033	2.37%	27.26	0.66	0.4417	2.44%
Mix -3	26.27	0.16	0.024233	0.59%	28.01	0.76	0.5809	2.72%
Mix -4	25.33	0.81	0.652033	3.19%	26.86	0.49	0.2388	1.82%
Mix -5	29.09	1.40	1.961433	4.81%	31.1	0.67	0.4492	2.16%
Mix -6	33.67	0.96	0.923333	2.85%	35.32	1.10	1.2112	3.12%
Mix -7	24.45	0.834	0.6975	3.42%	26.55	0.87	0.7569	3.28%

Replacement level (cement, ESP, WSA in %)

mix-1(100,0,0), mix-2(90,5,5), mix-3(85,5,10) mix-4(85,10,5), mix-5(80,10,10), mix-6(80,15,5), and mix-7(75,15,10)

When a test produces an invalid outcome or a series of such results, it indicates potential problems with the testing process. In quality control, discarding invalid results and thoroughly investigating the reasons behind their inaccuracy is essential. Common causes of invalid results include insufficient sampling and cube preparation, mislabelling of cubes, cube molds that do not meet tolerance standards, errors made by operators, and malfunctions in compression machines. The result obtained proved that the obtained value from the experimental analysis of Cube is valid as it is below ± 15 percent of the average.

4.4.2. Flexural strength of eggshell and wheat straw ash cement concrete

The following table presents data on the flexural strength observed at two distinct time points, specifically at 28 days and 58 days of curing within a water tank. Additionally, the table includes the percentage increment associated with these strength values. This data offers insights into how the flexural strength of the concrete containing pozzolanic material evolves underwater tank curing conditions, highlighting any improvements or changes in strength between the two-time intervals.

Flexural strength of 42 concrete beams tested at 28 and 56 days using a two-point load machine. Three 100mm x 100mm x 500mm specimens per replacement level were tested. The mean of three same-batch specimens at a specific age is considered a valid result in MPa.

Table 4.15: Flexural strength of concrete with different partial replacements at 28 days.

Curing days	Mix code	28 days (N/mm^2)	Mean value (N/mm^2)	56 days (N/mm^2)	Mean value (N/mm^2)	% Increment
Flexural strength in 28 and 56 days	Mix- 1	4.192	4.204	4.221	4.250	
		4.255		4.312		1.094
		4.165		4.231		
	Mix-2	3.760	3.688	3.860	3.833	
		3.650		3.840		
		3.655		3.798		3.932
	Mix-3	3.681	3.663	3.840	3.867	
		3.540		3.890		
		3.769		3.870		5.569

	Mix-4	3.769	3.739	3.870	3.889	
		3.694		3.910		4.012
		3.755		3.888		
	Mix-5	3.520	3.648	3.860	3.878	
		3.654		3.890		
		3.769		3.885		6.305
	Mix-6	3.801	3.865	3.950	4.070	
		3.912		4.123		
		3.882		4.137		5.304
	Mix-7	3.192	2.949	3.345	3.232	
		2.812		3.142		
		2.842		3.210		9.596

Replacement level (cement, ESP, WSA in %)

mix-1(100,0,0), mix-2(90,5,5), mix-3(85,5,10) mix-4(85,10,5), mix-5(80,10,10), mix-6(80,15,5), and mix-7(75,15,10)

This analysis highlights the varying trends in flexural strength for different concrete mixes over time and emphasizes the need for careful consideration of curing methods and material compositions in concrete design. Mix-1 show higher flexural strength whereas mix 7 shows low flexural strength when compared to the other mixes. Mix 6 has high flexural strength when compared to all other experimental specimens.

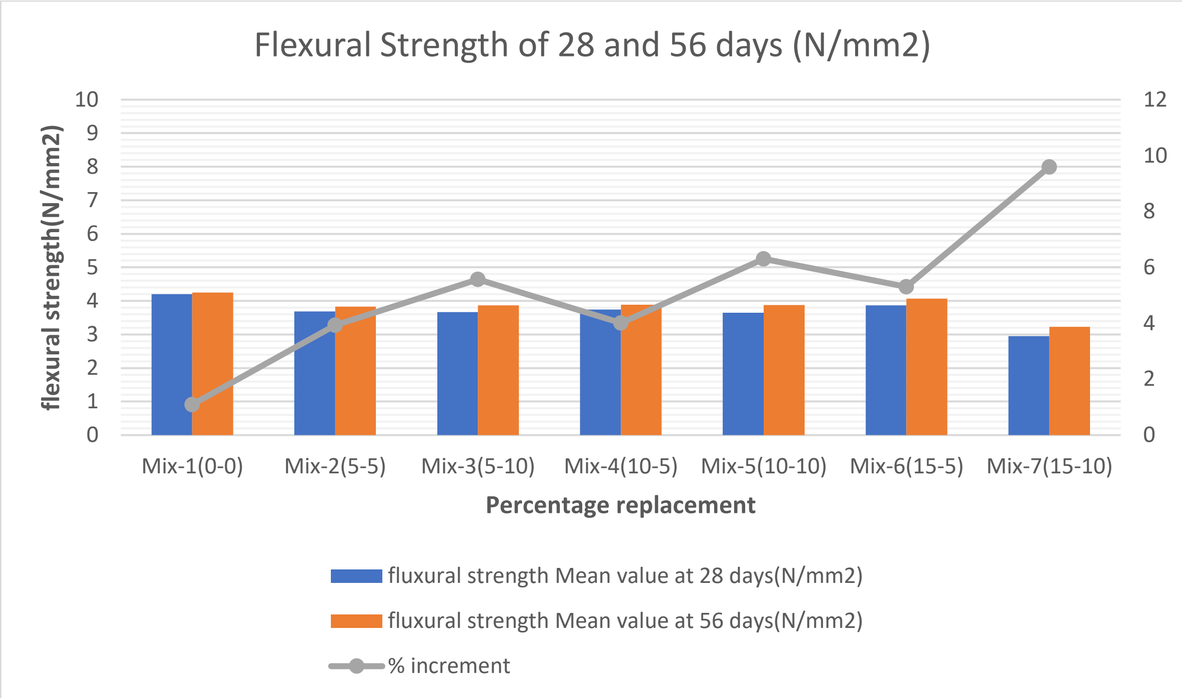

Figure 4.6: Flexural strength results and it is incremental.

From the graph above, mixes 2, 3, and 4 show a slightly close value, whereas mix 6 shows a slightly higher value comparatively. Therefore, mix 6 can be an ideal cement replacement with wheat straw ash and eggshell powder composite.

As per IS 456 2000 the flexural strength of concrete is computed as 0.7sqrt(fck) which is 3.5N/mm^2. Therefore, except mix-7 all attain the requirement for flexural strength.

4.4.2.1. Validity of Flexural Strength Result

Table 4.16 below analyzes the validity of the obtained flexural test results of concrete partially replaced with eggshell powder and wheat straw ash.

Table 4.16: Validity analysis of flexural strength.

28 flexural strengths				56 flexural strengths			
Mean	Standard deviation	Variance	Coefficient of variation	Mean	Standard deviation	Variance	Coefficient of variation
4.204	0.046	0.002	1.10%	4.255	0.05	0.002	1.17%
3.688	0.062	0.004	1.68%	3.833	0.032	0.001	0.83%
3.663	0.116	0.013	3.15%	3.867	0.025	6E-04	0.65%

3.739	0.04	0.002	1.07%	3.889	0.02	4E-04	0.52%
3.648	0.125	0.016	3.42%	3.878	0.016	3E-04	0.41%
3.865	0.057	0.003	1.49%	4.07	0.104	0.011	2.56%
2.949	0.211	0.045	7.16%	3.232	0.103	0.011	3.20%

Replacement level (cement, ESP, WSA in %)

mix-1(100,0,0), mix-2(90,5,5), mix-3(85,5,10) mix-4(85,10,5), mix-5(80,10,10), mix-6(80,15,5), and mix-7(75,15,10).

The statistical analysis table reveals that the derived value is robust and reliable, as it falls within a narrow margin of deviation from the average, not exceeding ±15 percent. This narrow range signifies a high level of precision and confidence in the obtained result, bolstering its credibility and trustworthiness.

4.5. Durability test of eggshell powder and wheat straw ash concrete

4.5.1. Acidic test

The results displayed the percentage loss in weight and compressive strength of mortar cube specimens following 28 days of immersion in 5% acidic solution. It was evident that all eggshell mortar samples exhibited greater susceptibility to damage in comparison to the control specimens. This increased vulnerability can be attributed to the additional calcium hydroxide provided by the eggshell, leading to higher mass loss in the eggshell mortar compared to the control. Despite this, the incorporation of eggshell powder enhanced the microstructure of the mortar by reducing pores and supplying extra calcium hydroxide, contributing to strength improvement. Nevertheless, when exposed to acidic environments, eggshell mortar proved to be less suitable than the control specimens (Beng Wei et al., 2020). The compressive strength of the eggshell concrete decreased gradually when the amount of eggshell powder increased, during immersion in acid and alkali solutions, because eggshell contains a high amount of calcium, which reacts readily with acid and alkali solutions. As the eggshell content increases, the solution reacts with the paste so the bonding of the paste reduces, and therefore the strength also reduces (Tan et al., 2018). Concrete cube specimens that were cured for 56 days underwent immersion in 0.5% dilute sulphuric acid for 30 days. It was observed that the control specimens exhibited the highest mass and strength loss, whereas the concrete cubes with 10% optimal partial cement replacement with rice straw ash showed the least loss in both mass and strength. In the control samples, the reaction of $Ca(OH)_2$ with sulphuric acid resulted in the formation of gypsum. Conversely, in the cubes with 10% partial cement replacement with rice straw ash, the $Ca(OH)_2$ produced during hydration was utilized in pozzolanic reactions with the silica present in the rice straw ash, leading to the generation of additional calcium silicate hydrates. This process diminished the chances of the reaction that typically gives rise to gypsum formation, thereby reducing mass loss (Oliko et al., 2020). Therefore, additional pozzolanic material with eggshell powder could improve both the strength and durability of concrete.

The table below presents the cube immersed in 5% sulphuric acid solution to analyze loss in strength of control and partially substituted with eggshell powder and wheat straw ash composite after keeping in the solution for 28 days.

Table 4.17: Compressive strength of cube in an acid solution of 28 days.

Curing days	Mix code	Average Weight before acid immersion (kg)	Average Weight after acid immersion(kg)	% reduction in weight	Mean value before acid immersion (N/mm2)	Mean value after acid immersion (N/mm2)	% decreased
compressive strength of 28 days in sulphuric acid solution	Mix- 1	7.755	6.740	14.378	35.73	31.42	12.06269
	Mix- 2	7.575	6.980	7.8548	25.82	23.22	10.06971
	Mix- 3	7.591	7.005	7.7197	26.47	24.78	6.384586
	Mix- 4	7.583	6.874	9.3499	25.33	23.46	7.38255
	Mix- 5	7.668	7.020	8.4507	29.09	27.02	7.115847
	Mix- 6	7.690	7.100	7.0221	33.66	32.04	4.812834
	Mix- 7	7.501	6.987	6.8524	24.45	23.35	4.498978

Replacement level (cement, ESP, WSA in %)

mix-1(100,0,0), mix-2(90,5,5), mix-3(85,5,10) mix-4(85,10,5), mix-5(80,10,10), mix-6(80,15,5), and mix-7(75,15,10).

Eggshell concrete exhibits increased susceptibility to weight loss and reduced compressive strength when exposed to sulfate and chloride environments, primarily because the calcium compounds within it are prone to degradation in aggressive solutions. (Chong et al. 2020).

Based on the value obtained it is shown that the compressive strength of control decreased by 12% which showed a higher percentage, whereas Mix-7(15 eggshell-10 wheat straw ash) showed 4.5% which is the lowest strength loss. Mix=6 decreased by 4.8%, indicating less susceptibility to acidic solution when compared to conventional concrete making it an ideal replacement to withstand acidic solution. This is due to the introduction of pozzolanic material which consumes CaOH and decreases crystal ettringite to formed likely.

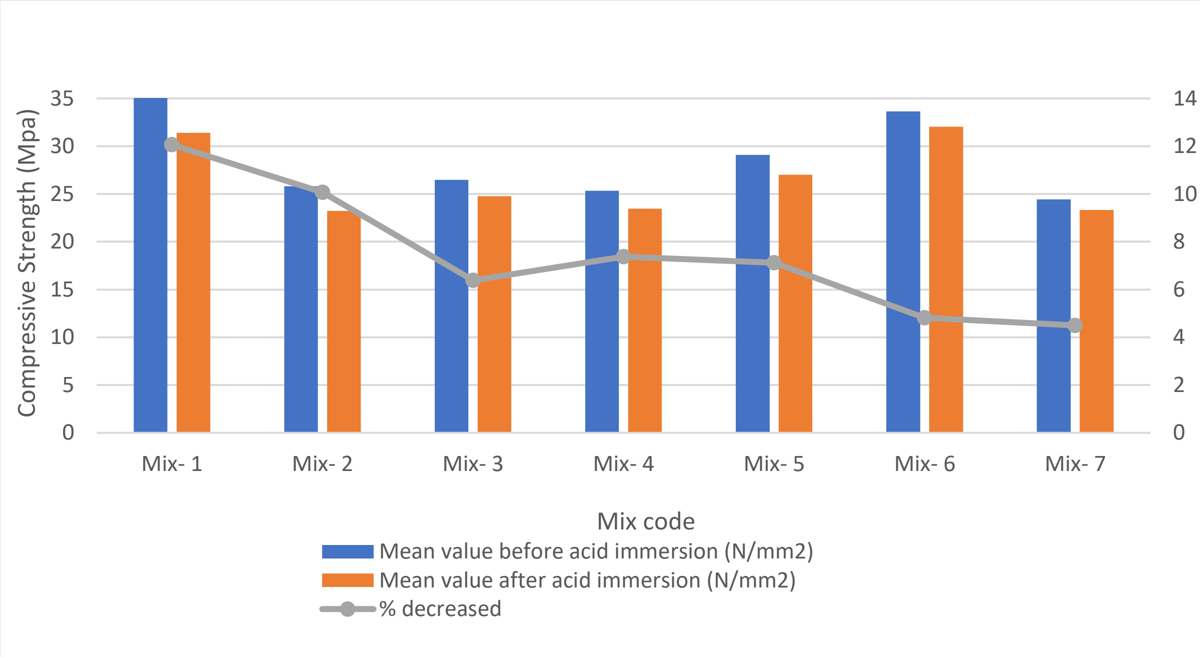

Figure 4.7: Compressive strength loss in acidic solutions.

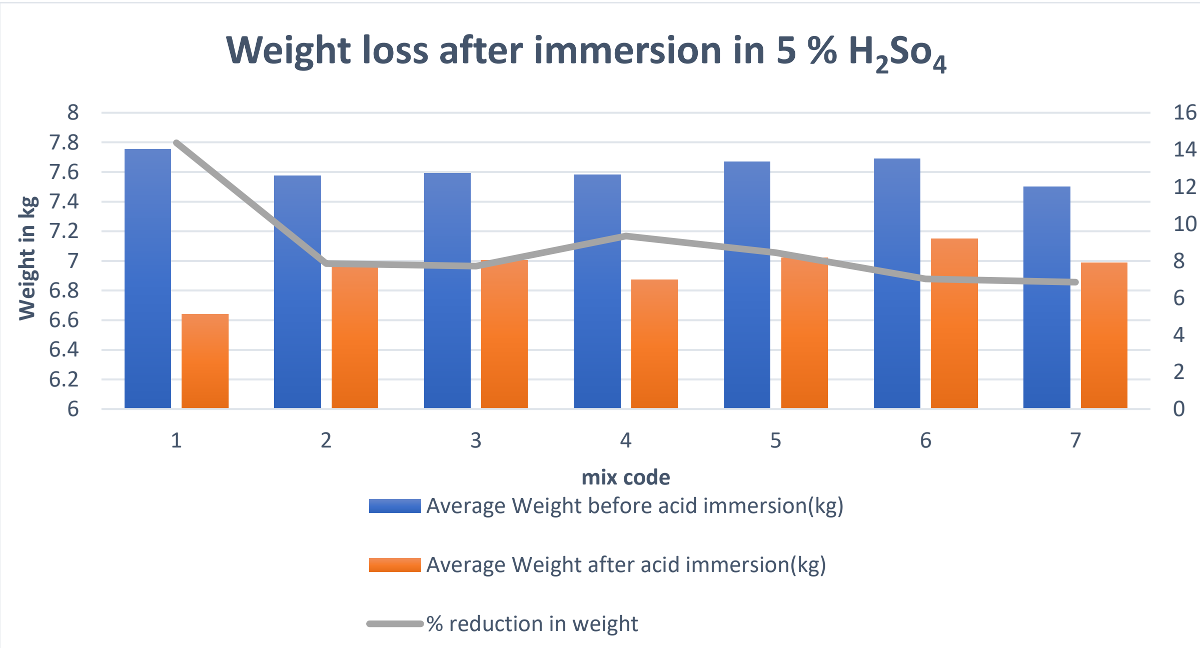

Figure 4.8: Weight loss after immersion in 5 % H2SO4.

The initial sharp decline in both strength and weight, followed by a stabilization over time as depicted in the durability analysis graphs, indicates a significant improvement attributed to the introduction of pozzolanic materials. This trend underscores the positive impact of incorporating such materials in enhancing the overall performance and longevity of the concrete composite.

4.6. Microstructural analysis

4.6.1. Scanning Electron Microscope (SEM)

(SEM) tests were performed to characterize the carbonation reaction products of the calcium silicate phases(Ashraf & Olek, 2016). As the result of SEM, in both ordinary Portland cement (OPC) and the eggshell powder-containing sample, the primary hydration products are portlandite (plate-like) and CSH (sheet-like). OPC displays a needle-like structure, suggesting the existence of ettringite. However, in the eggshell powder-containing sample, ettringite is absent due to the presence of calcium carbonate. Instead, a crystalline structure known as mono-carbo aluminate is visible, which is a crystalline structure.(Shiferaw et al., 2019). The existence of calcium carbonate in the cement pastes hinders the transformation of ettringite into sulfoaluminate and promotes the substitution of sulfoaluminate with carbo aluminate (Kakali et al., 2000). The inclusion of WSA densified the microstructure of the mortars. This improvement was caused due to the pozzolanic and filler effects of WSA particles. In particular, the inclusion of fine-sized ash particles demonstrated enhanced densification as compared to coarse-sized ash particles (Qudoos et al., 2020). The use of WSA-based concrete was examined through SEM imaging during the hydration process for up to 28 days. Needle-like crystals of the ettringite phase were observed. Long and sharp CSH and/or CAH crystals were identified, alongside well-crystallized larger masses of CSH and/or CAH. Additionally, varying levels of spots and pits of portlandite (free lime) were observed but eventually disappeared. This disappearance indicated that the inclusion of WSA reduced the free lime content resulting from the pozzolanic reactions between CSA and the formed Ca(OH)2 during regular cement hydration (Darweesh, 2020).

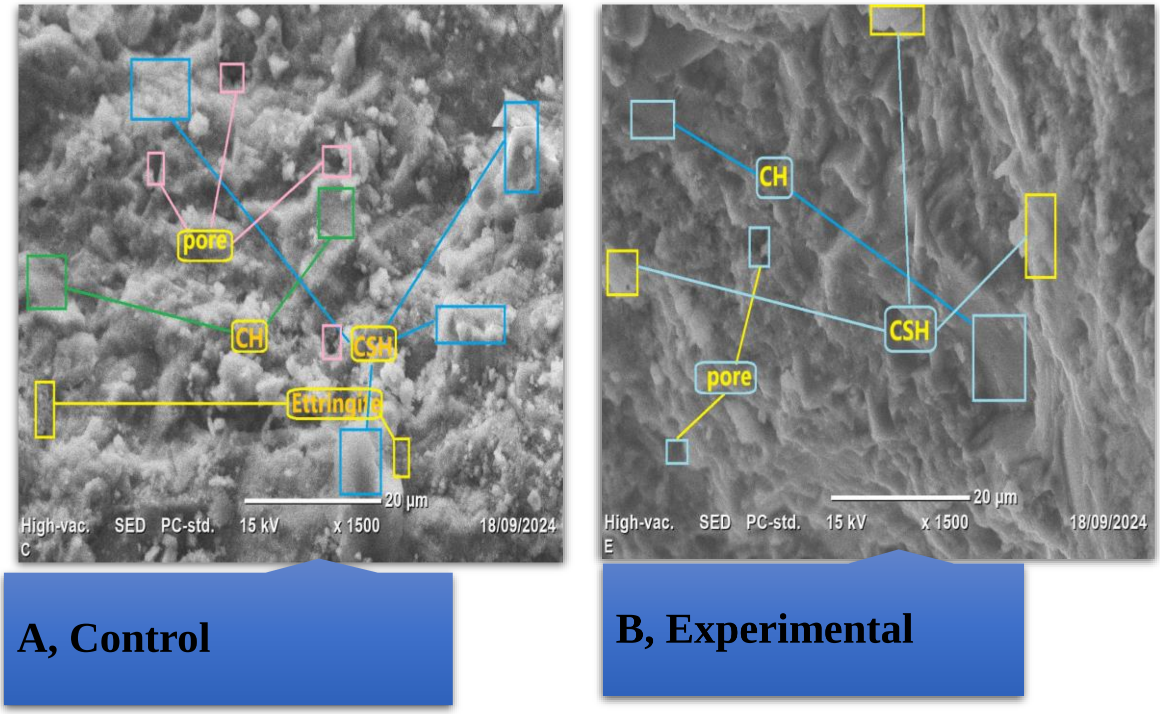

Figure 4.9: SEM Images. A) Control mix and B) Mix-6 (20, 15, 5).

The SEM image analysis reveals that the experimental concrete displays a dense structure, which can be attributed to the presence of pozzolanic material. The pore structure in the experimental concrete is reduced, along with a decrease in ettringite content and free lime which is consumed by up addition of pozzolanic material. These findings suggest that the incorporation of pozzolanic material enhances the performance of the concrete durability and decreases porous structures.

4.6.2. X-ray Diffraction (XRD)

The x-ray diffraction of 28 days is shown below figure with the measuring condition being θ-2θ drive axis, scanning range of 10-80, and 3 deg/minute of speed by applying 40kV X-ray tube voltage.

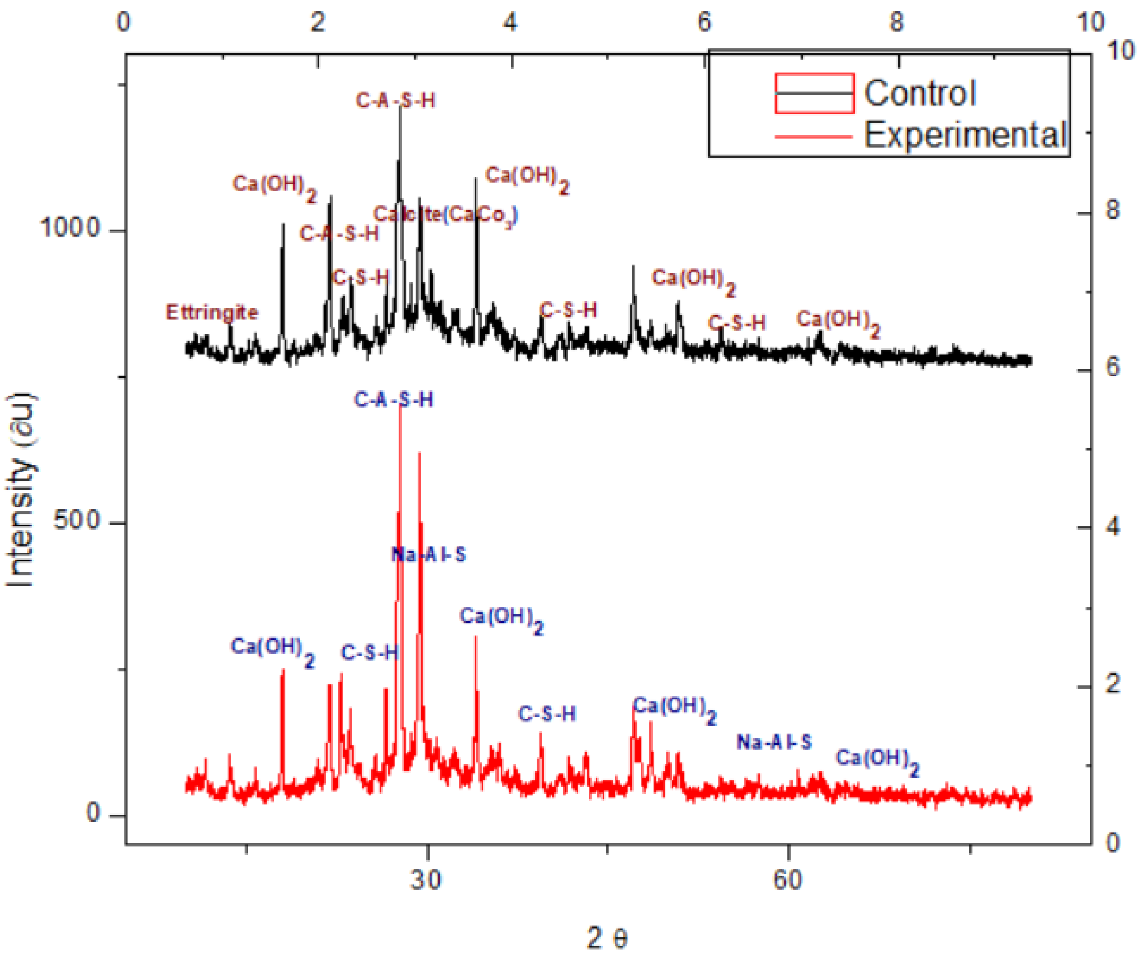

Figure 4.10: X-ray diffraction pattern of conventional concrete and mix-6 blended concrete.

Portlandite (CH) and calcium silicate hydrate (C-S-H) are produced as the primary hydration products when tricalcium silicate (C3S) and dicalcium silicate (C2S) undergo hydration with water. These compounds are essential components of all cement pastes and play a significant role in the hydration process (Shiferaw et al., 2019). The primary phases include ettringite, portlandite, and C-S-H. After 28 days, the intensity of the peaks corresponding to portlandite is higher as shown in the equation below (Costa et al., 2017).

$2C_3S + 6H_2O \rightarrow 3C\text{-}S\text{-}H\ (gel) + 3Ca(OH)_2$ (1)

$2C_2S + 4H_2O \rightarrow 3C\text{-}S\text{-}H\ (gel) + Ca(OH)_2$ (2)

sodium aluminate (Na[Al(OH)4]) leads to an increase in the water demand of cement and a decrease in its strength, however, polycarboxylate ether (PCE) admixtures ensure the production of higher strength (Bian-li et al., 2019).

X-ray diffraction is a valuable analytical technique used in concrete research to analyze and identify crystalline in required specimens to evaluate the phase of composition of anhydrous and hydrated cementitious materials. By irradiating the sample with x-ray diffraction measuring the angle and intensity of the diffracted ray at 2θ. Portlandite, C-A-S-H, C-S-H, calcite, and are major hydration products of OPC that appear at the peak. It is often observed as a distinct peak in XRD patterns of OPC concrete and contributes to the hydration processes and by-product of cement hydration. Portlandite (CH) exhibits a hexagonal structure, displaying a prominent peak at 34.060 degrees 2θ in X-ray diffraction analysis. On the other hand, C-A-S-H generates a significant peak at 27.70 degrees 2θ, while C-S-H displays a strong peak at 21.880 degrees 2θ in XRD patterns for control. For experimental Na-Al-S shown at 29.76-degree 2θ that may decrease concrete strength. The XRD analysis has unveiled two noteworthy phenomena in the experimental concrete, a reduction in ettringite content and the emergence of Na-Al-S. These newly observed occurrences highlight significant changes in the concrete composition, indicating potential alterations in its properties and characteristics.

CHAPTER FIVE

5. CONCLUSION, AND RECOMMENDATIONS

5.1. Conclusion

Eggshell and Wheat straw ash are suitable materials for partial replacement as eggshell powder contains a high percentage of CaO, which is a major cement oxide, whereas wheat straw ash meets minimum requirements as per ASTM C-618 and based on chemical characterization falls under Class-F pozzolanas.

Eggshell and Wheat straw ash are proven to be suitable materials for partial replacement based on chemical characterization.

As the percentage of eggshell powder and wheat straw ash increases standard consistency value increases and workability decreases.

On 28 days and 56 days, the compressive strength of concrete of normal concrete and a mix-6 blends of 15% eggshell powder and 5% wheat straw attained the target mean strength(33.5Mpa). Whereas, statical significance analysis of mix-6 has no statistically significance variation with mix 1(Control mix).

From the acidic test result, the introduction of wheat straw ash, increased the durability of concrete and mix-6 exhibits high compressive strength exceeding control mix, also control mix decreased significantly.

In addition, SEM results showed that the inclusion of WSA results in the formation of dense concrete and a reduction of pores and free lime. Moreover, the XRD analysis has unveiled two noteworthy phenomena in the experimental concrete, a reduction in ettringite content and the emergence of Na-Al-S

Therefore, incorporation of 15% eggshell and 5% wheat straw ash as replacements in concrete has yielded favorable outcomes, as evidenced by comprehensive statistical and durability analysis. These findings suggest that this composite blend could serve as a practical alternative to traditional concrete.

5.2. Future Recommendation

The addition of superplasticizer and ether-like polycarboxylate (PCE) admixtures ensures the production of higher strength and the introduction of those chemicals could be greatly beneficial.

As workability diminished due to the introduction of eggshell powder and wheat straw ash composite Workability should be investigated for further improvement.

The calcination temperature of eggshell powder and wheat straw ash should be highly considered long with grinding ashes to the minimum size required as per standard.

Other durability parameters and strength properties such as tensile and shear can be studied for the ternary combination of ESP and WSA in concrete

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APPENDIX

APPENDIX A1: Oxide composite of eggshell powder and wheat straw ash

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

Customer Name:-Abdulsemed Jemal

Issue Date:-04/07/2024

Sample type :- Egg Shell power

Sample Preparation:-200 Mesh

Date Submitted:-30/05/2024

Request No:- GLD/RQ/1382/24

Report No:- GLD/RN/3535/24

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	H_2O	LOI	Weight of Sample
A-S-J-02	6.54	1.40	0.70	55.50	0.50	<0.01	0.10	0.04	0.20	0.12	0.16	35.20	400gm

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

- LOI = Loss on Ignition

Analysts	Checked By	Approved By	Quality Control
Haimanot Bayeh			
Kindie Kasahun	Nigist Fikadu	Lidet Endeshaw	Gosa Haile
Melkamu Debalka			
Shashe Haile			

Geochemical Laboratory Desk Page 1

	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:-Abdulsemed Jemal

Issue Date:-09/07/2024

Sample type :- Wheat straw Ash

Sample Preparation:-200 Mesh

Date Submitted:-30/05/2024

Request No:- GLD/RQ/1381/24

Report No:- GLD/RN/3534/24

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	H_2O	LOI	Weight of Sample
A-S-J-01	78.01	8.6	0.36	2.7	1.6	0.3	0.8	0.4	1.46	0.06	2.4	3.31	300gm

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

- LOI = Loss on Ignition

Analysts	Checked By	Approved By	Quality Control
Haimanot Bayeh			
Kindie Kasahun	Nigist Fikadu	Lidet Endeshaw	Gosa Haile
Melkamu Debalka			
Shashe Haile			

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APPENDIX A2: Test procedure for specific gravity test

1. Thoroughly dry a flask and fill it with kerosene or naphtha up to a level between 0 and 1 ml on the stem.

2. Record the initial liquid level in the flask.

3. Add about 60 g of cement to the flask, ensuring the cement does not stick to the sides above the liquid. This should raise the liquid level to around 22 ml.

4. Roll the flask on an incline to remove any air bubbles.

5. Record the new, final liquid level.

APPENDIX A3: Test procedure for normal consistency test for cement, ESP, WSA

1. measure 400 grams of cement.

2. Water was added to the cement in an amount equal to 22-30% of the cement's weight, and the mixture was combined.

3. After 3-5 minutes, the cement paste was properly mixed.

4. The cement paste was filled into a Vicat Mold and any excess was removed with a trowel.

5. The Vicat mold was placed on a glass plate, with the plunger lightly touching the surface of the mold.

6. The plunger was released and allowed to sink into the test mold.

7. The depth of the plunger's penetration from the bottom of the mold was recorded using the scale.

8. repeat the experimental procedure with varied percentages of water until the reading of the visit apparatus reaches between 5-7 mm

9. then the result is recorded.

APPENDIX A4: Test procedure for silt content

1. Use a 1000 ml graduated cylinder.

2. Pour 300 ml of sand into the cylinder.

3. Fill about 3/4 of the cylinder with water.

4. Shake the cylinder vigorously for about a minute.

5. Let the cylinder sit for an hour to allow the silt to settle on top of the sand layer.

6. Measure the amount of fine material forming a separate layer on top.

7. Calculate the silt content using the provided equation.

APPENDIX A5: Test procedure for grading fine aggregate

1. Took a 2 kg sample of fine aggregates.

2. The sample was quartered to obtain a smaller representative sample.

3. From the quartered sample, a 500 g portion was taken.

4. The empty sieves were weighed and the data was recorded.

5. The pan was placed at the bottom, and the sieves were arranged in order of increasing opening size, with the largest on top.

6. The 500 g sample was placed on the top sieve.

7. The sieves were shaken mechanically for about 10 minutes.

8. Each sieve, along with the aggregate retained on it, was weighed, and the weight retained on each sieve was calculated.

9. The gradation chart was filled out, and the fineness modulus was computed using the formula:

Fineness Modulus = Cumulative percent retained / 100

APPENDIX A6: Test procedure for unit weight of fine aggregate (UWFA)

1. Preparation of the Sample:

- Obtain a representative sample of the fine aggregate and dry it to a constant mass.
- The sample size should be at least three times the volume of the measure used.

2. Place the measure on a level, rigid surface in three equal layers, rodding each layer 25 times with a rounded metal tamping rod ensuring any projections are balanced by voids.

3. Weigh the filled measure to the nearest 0.1% of the total weight and record the weight of the filled measure.

4. Calculation of the Unit Weight using below formula:

Unit Weight = (Mass of Filled Measure - Mass of Empty Measure) / Volume of Measure

5. Repeat the procedure at least three times for the same sample and calculate the average unit weight from the three measurements.

APPENDIX A7: Test procedure for specific gravity and water absorption of fine aggregate

1. Obtain a representative sample of the fine aggregate and dry it to a constant mass.

2. Weigh out 500 g of the saturated surface-dry (SSD) sample.

3. Partially fill a calibrated pycnometer with water and add the 500 g SSD sample.

4. Fill the pycnometer to about 90% of its capacity with additional water.

5. Roll and invert the pycnometer to remove any air bubbles.

6. Place the pycnometer in a water bath at 23°C (73.4°F) for 1 hour.

7. Adjust the water level in the pycnometer to its calibrated volume.

8. Weigh the pycnometer containing the sample, water, and any remaining air.

9. Remove the sample from the pycnometer, dry it to constant mass at 105°C (221°F), cool it for 1 hour, and weigh it.

10. Weigh the pycnometer filled to its calibrated capacity with water at 23°C (73.4°F).

11. Use the recorded data to calculate the specific gravity and water absorption of the fine aggregate.

APPENDIX B Mix design for C-25 concrete strength

Obtained data from primary tests on materials

Parameter	cement	Fine aggregate	Coarse aggregate
Specific gravity	3.15	2.708	2.74
Water absorption	_	1.91%	2.5%

Moisture content	_	0.8%	0.6%
Finess modules	_	2.887	7.26
Unit weight	_	1521.9kg/m3	1677.4kg/m3

Step 1: Calculating required mean compressive strength based on characteristics strength of 25 Mpa.

Characteristic strength (f’ck, Mpa)	Mean strength (fck, Mpa)
<25	F’ck + 7
25-35	F’ck + 8.5
>35	1.1F’ck + 5

From the above table mean strength of 25 Mpa is obtained below

$$Fck = f'ck + 8.5 \quad = 25 + 8.5 = 33.5 \text{ Mpa}$$

Step 2: minimum cement content determination

As per ACI standard, the minimum cement content of cement is equal to 300 kg/m3

Step 3: choosing slump value

As per ACI 211.1-91 recommended slump is from 25-100mm

Step 4: Choosing the maximum Coarse aggregate size

For higher strength purposes reduced size of aggregate was selected in this case the maximum size of Coarse aggregate is 20mm, and the nominal size of aggregate is 19mm.

Slump (cm)	Water (kg/m3) of concrete for indicated maximum size of aggregate in mm

	10	12.5	20	25	40	50	70	150
	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 air Entrapped (%)	3	2.5	2	1.5	1	0.5	0.3	0.2

From the above table, with a slum of 2-10 cm and a maximum size of aggregate of 20 mm the water content becomes 185kg/m3 and 2 % of air or 20 liters and entrapped air.

Step 6: determine water-cement ratio

In mix design of concrete, water to cement ratio is the ratio of the weight of water to the weight of cement

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 mean value obtained above for 25 Mpa strength is 33.3 Mpa, as the value was not stated clearly above the ACI table, it was obtained by using linear interpolation methods as calculated below.

35	33.5	30
0.47	x	0.54

By linear interpolation $\frac{35-33.5}{0.47-x} = \frac{33.5-30}{x-0.54} = \frac{1.5}{0.47-x} = \frac{3.5}{x-0.54} = 1.5(x-0.54) = 3.5(0.47-x)$

X=0.491

Step 7: Determination of cement content

From the above obtained w/c ratio is 0.491, therefore

Water/cement=0.491

Cement $=\frac{185}{0.491} = 376.78kg/m3$

Step 8: estimate the bulk volume per unit volume of concrete

Maximum size of aggregate(mm)	The volume of coarse aggregate per volume of concrete for different fine modules		
	2.6	2.8	3.0
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	0.70
50	0.78	0.74	0.72
70	0.81	0.77	0.75
150	0.87	0.83	0.81

As the above table does not state clearly the value of the bulk volume of dry aggregate, the linear interpolation method is used to find the value, and the fines module value of 2.887 falls between 2.8 and 3.0 for the 20mm maximum size of aggregate. Therefore, the required value is obtained as below.

2.8	2.887	3.0
0.62	x	0.60

By linear interpolation $\frac{3.0-2.887}{0.60-x} = \frac{2.887-2.8}{x-0.62} = \frac{0.113}{0.60-x} = \frac{0.087}{x-0.62}$

$$= 0.113(x - 0.62) = 0.087(0.60 - x)$$

$$= x - 0.62 = 0.7699(0.60 - x)$$

$$= 1.7699x = 1.08194$$

$$x = 0.6113$$

Step 9: calculate the weight of coarse aggregate (WCA) per m3 of concrete

WCA=bulk Volume x bulk density of coarse aggregate

0.6113 x 1677.4kg/m^3

=1025.4kg/m^3

Step 10: Calculate the solid volume of coarse aggregate

The solid volume of coarse aggregate = WCA/specific gravity of Coarse aggregate

=1025.4/2.74

374.233kg/m^3

Step 11: calculate the solid volume of cement, water, and air.

Volume of Cement (VC) = weight of cement/ specific gravity of cement

$= \frac{376.78kg/m3}{3.15} = 119.612$

Volume of water (VW) = 185kg/m3

Volume of air (VA) = 20kg/m3

Step 12: Calculate the volume of sand (VS)

VS=1000-(VCA+VC+VW+VA)

1000-(119.612+374.233+185+20)

=301.155kg/m3

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

= 301.155 x 2.708

=815.5277kg/m3

Step 13: adjustment for moisture in aggregate

Actual moisture content of fine aggregate (Am) = 0.8%

Fine aggregate water absorption value (Aw) = 1.91%

Water absorbed by fine aggregate = $\frac{815.5277\ x\ 1.91}{100} = 15.577$kg/m^3

The water content of fine aggregate = $\frac{815.5277\ x\ 0.008}{100} = 6.524$kg/m^3

Amount of water required to be added = 15.577 – 6.524 = 9. 053

Actual moisture content of coarse aggregate (Am)= 0.6%

Coarse aggregate water absorption (WA)= 2.5%

Water absorbed by fine aggregate = $\frac{1025.4\ x\ 2.5}{100} = 25.635$kg/m^3

The water content of fine aggregate = $\frac{1025.4\ x\ 0.6}{100} = 6.1524$kg/m^3

Amount of water required to be added = 25.635 – 6.1524 = 19.481 kg/m3

Total water required = 185 + 9.053 + 19.481 = 213.534 kg/m^3

material	amount in kg/m3
Cement	376.78
Fine aggregate	815.5277
Coarse aggregate	1025.4
water	213

The above result is shown below in ratio form

Ingredient	cement	Fine aggregate	Coarse aggregate
Amount/ m^3	376.78/376.78	815.5277/376.78	1025.4/376.78
	1	2.164	2.721

Based above results concrete ingredients calculated for one cube standard as below

Wet volume of one cube =length*width*height $=0.15*0.15*0.15=0.003375\ m^3$	Dry volume = wet volume * 1.55 $0.003375*1.55=0.00523\ m^3$

The sum of ratio= 1+2.164+2.721=5.885

Weight of cement=$\frac{1}{\text{sum ratio}}$ x dry volume x unit weight of the cement

$= \frac{1}{5.885}\ x\ 0.00523 \text{ x } 1440 = 1.28$

Weight of FA = $\frac{1}{\text{sum ratio}}$ x dry volume x unit weight of the FA

$= \frac{2.164}{5.885}\ x\ 0.00523 \text{ x } 1521.9 = 2.9268$

Weight of CA = $\frac{1}{\text{sum ratio}}$ x dry volume x unit weight of the CA

$= = \frac{2.721}{5.885}\ x\ 0.00523 \text{ x } 1677.4 = 4.0562$

The quantity of concrete ingredients for beam standard mold is calculated as follows

Wet volume of one = 0.5 x 0.1 x 0.1= 0.005

Dry volume = wet volume X 1.55 = 0.55 m^3 x 1.55 = 0.00775

Weight of cement=$\frac{1}{\text{sum ratio}}$ x dry volume x unit weight of the cement

$= \frac{1}{5.885}\ x\ 0.00775 \text{ x } 1440 = 1.896$

Weight of FA = $\frac{1}{\text{sum ratio}}$ x dry volume x unit weight of the FA

$= \frac{2.164}{5.885}\ x\ 0.00775 \text{ x } 1521.9 = 4.337$

Weight of CA = $\frac{1}{\text{sum ratio}}$ x dry volume x unit weight of the CA

$= = \frac{2.721}{5.885}\ x\ 0.00775 \text{ x } 1677.4 = 6.01$

Ingredient in kg	1 cube	1 beam	9 cubes	6 beams
cement	1.28	1.896	11.52	11.376
Fine aggregate	2.968	4.337	26.712	26.022
Coarse aggregate	4.0562	6.01	36.5058	36.06

Ingredients in Kg	9 cubes	6 beams	Total sum
Cement in kg	11.52	11.376	22.896
Fine aggregate in Kg	26.712	26.022	52.734
Coarse aggregate in Kg	36.5058	36.06	72.5658

Mix code	Cement in kg	Fine aggregate in kg	Coarse aggregate in kg	% reduction in cement
mix 1	22.896	52.734	72.5658	0
mix 2	20.6064	52.734	72.5658	10
mix 3	19.4616	52.734	72.5658	15
mix 4	19.4616	52.734	72.5658	15
mix 5	18.3168	52.734	72.5658	20
mix 6	18.3168	52.734	72.5658	20
mix 7	17.172	52.734	72.5658	25
sum	136.231	369.138	507.961	