Experimental Investigation on Physio-Mechanical and Micro-Structural Properties of Concrete as Partial Replacement of Cement with Eggshell Powder and Wastepaper Ash

Yalew Yibeltal Ademasu

A Thesis Submitted to Department of Civil Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfilment of The Requirements for The Degree of Master's Science in Civil Engineering (Specialization in Construction Engineering and Management)

Office of Graduate Studies

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Advisor: Lemma Beressa (PhD)

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DECLARATION

I declare that this master thesis entitled "Experimental Investigation on Physio-Mechanical and Micro-Structural Properties of Concrete as partial replacement of cement with eggshell powder and wastepaper ash"is my original work, prepared under the guidance of Lemma Beressa (PhD). All sources of material used for organizing this research have been dually acknowledged by proper citation. Moreover, this work has not been submitted by any other person in any university or Higher Educational Institute for an award of a degree.

Yalew Yibeltal Ademasu ____________________ ____________________

Signature Date

RECOMANDATION OF ADVISOR

I, the major advisor/supervisor of this Thesis work, hereby certify that I have closely advised/supervised the student while developing this thesis and read the draft thesis paper entitled "Experimental Investigation on Physio Mechanical and Micro-Structural Properties of Concrete as partial replacement of cement with eggshell powder and wastepaper ash "prepared under my guidance by Yalew Yibeltal. Therefore, I recommend the submission of the thesis.

Lemma Beressa (PhD)	___________________	____________________
Major advisor	Signature	Date

APPROVAL PAGE OF ADVISOR

I hereby certify that the recommendation and suggestion given by the thesis review Committee are appropriately incorporated into the final thesis entitled "Experimental Investigation on Physio Mechanical and Micro-Structural Properties of Concrete as partial replacement of cement with eggshell powder and wastepaper ash" by Yalew Yibeltal.

Lemma Beressa (PhD)	__________________	__________________
(Major Advisor)	Signature	Date

APPROVAL OF BOARD OF EXAMINERS

We, the undersigned, members of the Board of examiners of the master's thesis open defense by Yalew Yibeltal Ademasu have read and evaluated the thesis entitled "Experimental Investigation on Physio Mechanical and Micro-Structural Properties of Concrete as partial replacement of cement with eggshell powder and wastepaper ash" and assessed the understanding of the candidate about the thesis work. This is, therefore, to certify that this thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Civil Engineering (Specialization in Construction Engineering and Management).

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LIST OF ABBREVIATION

ACI	American concrete Institute
ASTM	American standard for testing materials
ASTU	Adama science and technology university
CA	Coarse Aggregate
CCA	Corncob ash
CHA	Coffee husk ash
ESP	Eggshell powder
FA	fly ash
FA	Fine Aggregate
FM	Fineness Modulus
GGBFS	ground granulated blast furnace slag
LOI	loss of ignition
LSF	lime saturation factor
MJ	Mega Joule
OPC	Ordinary Portland cement
SCM	Supplementary cementitious materials
SF	silica fume
SEM	Scanning Electron Microscope
WPA	wastepaper ash
XRD	x-ray diffraction

LIST OF CHEMICAL FORMULAS

Al_2O_3	Aluminium Oxide
CaO	Calcium Oxide
$CaCO_3$	Calcium carbonate
$Ca\ (OH)_2$	Calcium hydroxide
C-A-H	Calcium aluminate hydrate
CO_2	Carbon Dioxide
C_3A	Tri-calcium aluminate
C_4AF	Tetra-calcium alumina ferrite
C-H	Calcium hydroxide
C-S-H	Calcium Silicate Hydrate
C_2S	Tri-calcium silicate
C_3S	Tri-Calcium silicate
Fe_2O_3	Iron Oxide
H_2O	Water
K_2O	Potassium dioxide
MgO	Magnesium Oxide
NO_2	Nitrogen dioxide
Na_2O	Sodium oxide
SiO_2	Silicon dioxide
SO_3	Sulphur tri oxide
TiO_2	Titanium dioxide

ABSTRACT

Concrete is the most preferred building material in the world and its production has increased exponentially with the rapid construction of infrastructures. The generation of waste materials has also increased due to rapid urbanization. Eggshell and wastepaper is one such solid waste material which is being generated in huge quantity due to it being a cheap source in the Environment. Cement, the vital ingredient of concrete has been reported to contribute approximately 5% of total global Carbon Dioxide (CO_2) gas emissions. Therefore, the current study aimed to investigate incorporation the combined use of ESP and WPA as supplementary cementitious material along with its effect on workability, compressive strength,split tensile strength and microstructure of concrete with its environmental and economic implications. The control mix was made from a mixture of cement, water, fine and coarse aggregate to attain 25 MPa according to ACI standard, whereas the other trail mix was made with a blend of 6% 8% 10% and, 12% ESP and 4% 6% 8% and, 10% WPA by the weight of cement. Maximum compressive strength was obtained at 6%WPA and 8%ESP replacement which improved the compressive strength by 1.93%, while the improvement in tensile strength was noted to be 15% at 28 days of curing. Therefor a blend of 6%WPA and 8%ESP is taken as the better replacement ratio which had shown a better hardened property as compared to the control mix. The SEM shows compacted dense and less cracked with high C-H and C-S-H amount in the same blend motioned above. As conclusion, a blend of 6%WPA and 8%ESP replacement that is of cement can enhance the strength of concrete while reducing the environmental impact, i.e., carbon dioxide emission and energy consumption by 10.2% and 12.5% as compared to the control sample. In addition, the cost performance of the above blend decreased the of cost of control Sample by 10.35 % at 14% replacement of cement by eggshell powder and wastepaper ash.

Key words: - Eggshell powder, wastepaper ash, Compressive strength, Tensile strength, environmental impact, cost performance…………………..

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Concrete is the most preferred building material in the world and its production has increased exponentially with the rapid construction of dams, buildings, roads, storage tanks, tunnels, seaports, bridges, subways, and other infrastructures (Jhatial, Sohu et al., 2019a). Now a day for variety of reasons, the concrete industry is not sustainable. Firstly, it consumes huge amount of natural resource due to which no virgin material will be left for future generation. Secondly, the major component of concrete is cement and a lot amount of greenhouse gas will be emitted in the manufacturing process of cement, lastly concrete is consume high amount of cement than the other ingredients and then current price of cement is more expensive (Dhanalakshmi, Sowmya et al., 2015).

Cement is the most popular material consume daily in human life in construction next to water.it is mandatory for countries development and growth. The production of cement is immensely energy intensive. It is also a major cause of environmental problems and accounts for around 5-8%of global carbon dioxide emissions (Shiferaw, Habte et al., 2019).

To minimize the high amount of co_2 emission and environmental pollution it should be use industrial and agricultural waste material. The improper management of solid waste leads to public health and environmental problem (Shiferaw et al., 2019). The utilization of industrial waste or secondary materials has encouraged the production of cement and concrete in construction field. By product and waste material are being generated by various industries. Therefore, recycling of waste material like eggshell powder and waste paper ash is a great potential in concrete industry and key advantage such as cost reduction of cement- based materials, cost reduction for landfill, saving energy, and protecting the environment form pollution effects (Rashid, Javed et al., 2017).

Eggshell is the wastage material and cement replacement material because it has a very high content of calcium. Dry eggshell is used as a source of calcium in animal feeds (Chong, Othman et al., 2020). The overall chemical composition of eggshell is said to be similar with limestone (Chandrasekaran, Vasanth et al., 2018). Interestingly, $CaCO_3$ is one of the four primary raw materials that produce cement. The other main compounds of cement being dicalcium silicates, (C_2S), tri-calcium silicate, (C_3S), tri-calcium aluminate, (C_3A), and tetra-calcium alumina ferrite, (C_4AF). Hence, eggshell has potential to serve as a cement replacement in concrete (Ujin, Ali et al., 2017)

When mixed with concrete, ESP is known to have good strength properties (Marinamarican, 2015).Most of the eggshell waste is commonly disposed in landfills without any pre-treatment because it is traditionally useless (Rathnam & SomBabu).The use of eggshell powder in concrete production reduced the cost of raw material and contributes to the construction industry. Eggshell also contribute to construction industry which is it can be reduce in construction budget with sustain concrete property. Thus, eggshells can be applicable to reduced cost of construction material and produced a new raw material for development in the construction industry (Hut, 2014). The other wastage material is WPA. Paper is an available material and valuable material that can be recycled (Okeyinka & Idowu, 2014). Disposable paper available in abundance throughout the world is composed mainly of short, natural, cellulose fibers and is already used in many local raw materials. Waste paper arises from several sources such as newspaper, office, and printing paper (Kejela, 2020). The demand of paper was increasing from year to year because of education expansion polices and overall economic development of the country (Asmare, 2015). In Ethiopia there are more than 15 formal and informal paper recyclers and collectively recycle only around 5% of paper. More than 200,000 tonnes of paper and cartons are lost wastage which is dumped, burned or left in the streets as a garbage (Teshome, 2021). To reduce disposal and pollution problems form these industrial waste it is most important to develop profitable building materials from them keeping this in view, investigation were carried out to minimise the cost of production of concrete by adding paper waste ash with concrete mix and investigate basic characteristics of concrete (chandran, appril 2016).

1.2 Statement of the Problem

Concrete is a construction material composed of cement, fine aggregates (sand) and coarse aggregates mixed with water which hardens with time. And the most-used material in the construction industry today. Global cement production has reached 4 billion tonnes with about half of which being consumed to produce concrete for construction needs (Benhelal, Zahedi et al., 2013). Cement is the most-used building material due to its myriads of strength, such as economical, durable, fire and water resistance, and more (Chong et al., 2020).

However, the negative environmental impact of concrete is increasingly being highlighted across the world. The cement industry is the among the largest contributors of greenhouse gas. About high amount of global CO_2 emission comes from the industry, with 900 kg CO_2 emitted to the atmosphere for producing one ton of cement(Naqi & Jang, 2019).

Recently, it was discovered that inclusion of hybrid different supplementary Cementous material enhance behaviour of concrete. Most researchers have conducted studies concerning eggshell powder and wastepaper ash separately and hybrid with other supplementary Cementous materials to attain both economic and strength advantage of concrete because cement production and raw material extraction pose to the pre-existing ecosystem in extraction and manufacturing sites. There are two major hag-ridden situations with respect to sustainability. The first one is about 1.5 tons of raw materials are needed in the production of every ton of cement which is non-renewable (Mohamad, Muthusamy et al., 2022). At the same time a high amount of carbon dioxide about one tone of CO_2 is released into the environments to produce one ton of cement (Wang, 2004). It accounts approximately 5-7% of the world’s CO_2 emissions annually (Amran, Makul et al., 2022). To make it cost-efficient and environmentally friendly, it is mandatory to use other materials as partial replacement of cement (Jaramillo-Murcia, Abellán-García et al., 2022), like silica fume, fly ash ,eggshell and wastepaper. large quantities of eggshell and wastepaper resources are available worldwide also in Ethiopia. This study was done to fill the gap in knowledge of the effect of using hybrid eggshell powder and wastepaper ash as a cement. The morphological behaviour, mechanical property, and hydration process of concrete containing eggshell powder and wastepaper ash is not studied at all. In this experimental study, eggshell powder and wastepaper ash was used as a cement substitute to minimize cost of cement; Cement replacement material is not only minimizing cost of cement, to minimize environmental pollution and health problem.

1.3 Research Objectives

1.3.1 General objective

Study on physio-mechanical and microstructural properties of concrete, and environmental as well as economic performances of C-25 concrete produced by partial replacement of cement with eggshell ash and wastepaper ash:

1.3.2 Specific objectives

1) To assess physical and chemical Characteristics of material.
2) To Determine the optimal replacement amount of cement by a blend of WPA and ESP
3) To conduct the effect of ESP and WPA on microstructural properties of concrete
4) Comparison between economic and environmental performance of concrete per unit volume with ESP+WPA and control mix.

1.4 Significance of the research

The study is believed to contribute a new knowledge area on the effect of using waste eggshell ash and paper ash in concrete as cement. In doing so, it contributes its part in the sustainable use of waste eggshells and wastepaper products from the wastage. Therefore, this research deals with waste eggshell ash and wastepaper as partial replacements for cement in concrete production to reduce the environmental pollution created in cement industries by the emission of carbon dioxide and to minimize environmental pollution as well as cost of cement by reducing the amount of cement. Moreover, give information on how to incorporate eggshell powder and wastepaper ash in concrete works. On another stage, it paves the way for new researchers to investigate more, and for cement manufacturers, it indicates new sources of material for cement compounds.

1.5 Scope of the study

The scope of this research work is limited to the following structural considerations: investigating mechanical properties like compressive, Split tensile strength and morphological behaviour, including XRD and SEM image tests of C-25 concrete grade. At the first stage, a preliminary test of the ingredient is performed to determine the concrete, which blended with ESP and WPA. The ESP and WPA is added to the concrete in percentage of 6% 8% 10% and, 12% ESP and 4% 6% 8% and, 10% WPA percent of the cement weight. To get the optimum amount of ESP and WPA Based on Compressive strength and Split Tensile strength tests. The main experiment process includes collecting, preparing, proportioning, mixing, casting, curing, and investigating the effect on concrete. The tests that are conducted here are workability, compressive strength, split tensile strength, morphology, and mineralogical analysis. ,

1.6 Study Limitations

The WPA and its incineration process are the study's primary limitations. WPA was not studied according to data gathered from various previous works. As the result, obtaining some references for the current work is main challenge. In other hand, due to limitation of the furnace at Adama, incineration took place at the Ethiopian Defiance University Laboratory in Bishoftu. The furnace has the capacity of burning temperature up to 500 oC only. This the main reason for incineration of WPA at 500 ^{o}C only. In addition, due to this reason incineration at different temperature to obtain the optimum burning temperature for WPA is not possible for current study. High LOI values which reflects the presence of unburned substance in ash is due low incineration temperature. Because of limitations in availability of furnace, it was not possible to incinerate more than 15 kg of wastepaper ash during the development of this study.

1.7 Organisation of the thesis

The presentation of this thesis work is organized in five parts. The first part gives a brief description of thesis background, statement of the problem, objective of the research, significance of the study and scope of the study adopted. In the second section presents literature review on supplementary cementitious material and concrete reinforcing material as general. Moreover, focus on ESP and WPA as a cement replacement as a reinforcing ingredient also its effects on mechanical properties of fresh and hardened concrete and on morphology of concrete assessed on a previous work. The third section discuss the general experimental methodology that followed to conduct tests in ASTU construction material laboratory, biology laboratory, material engineering laboratory and at Addis Ababa geological survey institute. Detail procedures of the material preparation, mix proportions, mixing process, and workability tests, casting process and curing process of various concrete mixes used in this investigation is presented. The fourth section consists of the test result and discussion. The last section presents conclusions and recommendations depending on this research finding.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Introduction

This chapter contains a brief discussion of different approach that researchers have taken to address eggshell and wastepaper replacement of concrete. The general purpose of this chapter is to provide an extensive review on recent papers towards partial replacement of cement by eggshell ash and wastepaper ash.

2.1.1. General concept of concrete

Concrete is one of the versatile and widely used building materials in the world construction industry. Cement being the main binder in concrete, its production process is both uneconomical and environmental unfriendly (Kejela, 2020).

Concrete is one of the most frequently used building materials and plays an essential role in many areas. It is widely used in the construction of buildings, underground structures, dams, storage tanks, ports, roads, bridges, tunnels, subways and other infrastructure (Seifan, 2018) Concrete is one of the building materials that is commonly utilized as a construction material throughout the world. The gradual development in concrete research has led towards the production of high strength concrete, which is technically applicable for construction work where durability and strength is critical such as high-rise buildings (A. Neville & Aitcin, 1998).

Concrete is the proportional mix of cement, water, fine aggregate, and coarse aggregate. Among the concrete forming materials, cement is the most important component that binds aggregates, when cement is reacted with water, and fills the tiny voids between coarse and fine particles (Lee, Cody et al., 2005). Sustainability in concrete industry is achieved by reducing the production of cement. As 1 ton of cement production release equal amount of CO_2 in atmosphere. Such adverse environmental effects demand means in which cement production can be reduced (Shabbir, Ejaz et al., 2015).

2.1.2 Ingredients of concrete

Aggregates

Aggregate are the filler component of concrete, accounts for a sizable amount of the concrete volume roughly 70–75 percent. Aggregate can be found in both natural and manmade sources. Natural aggregate taken from quarries without changing their nature except for crushing, size, or grading during production (John, Damineli et al., 2018),Aggregates are often described using words like

1. Fine aggregate- aggregate particles passing 4.75mm sieve and retained on 75- μ m sieve.
2. Coarse aggregate- aggregate predominantly retained on the No.4 (4.75mm) sieve.

Water

Water has two purposes in production of concrete. First it makes the mixture fluid and workable then triggers cement to hydrate. It's critical to use clean water since contaminants weaken the bond between the paste and aggregate. Concrete should be produced using water that is safe to drink(Kucche, Jamkar et al., 2015) Water with a noticeable taste or odor should not be used until it is tasted for organic impurities. Impurities in mixing water cause any one or all the following: - abnormal setting time, decreased strength, volume changes, efflorescence, corrosion of reinforcement.

Cement

Cement has a property of setting and hardening when coming in to contact with water by a means of chemical reaction. These types of cements are generally known as hydraulic cements which are of a great interest in making concrete. Hydraulic cements are mainly made up of silicates and aluminates of lime, and can be classified broadly as natural cements, Portland cements, and high-alumina cements (A. M. Neville, 1995). Portland cement is the most common type which is produced by crushing clinker which consists primarily of hydraulic calcium silicates. There are different types of Portland cement that are manufactured to meet various requirements for specific purposes. Type I Portland cement is a versatile cement type suitable for all uses where special requirements are not needed (S. H. Kosmatka, Panarese et al., 2002). Type II cement is for general use especially when moderate sulphate resistance is needed. Whereas Type III cement type is used when high early strength is desired. Type IV is used when low heat of hydration is needed and Type V cement is used when high sulphate resistance is desired (D. ASTM, 2011).

Cement being the most expensive ingredient of concrete mixes, its optimization not only results in overall project cost reductions but also in reduced cement consumption, in the long run, leading to reduced CO_2 emission, raw material depletion, and energy consumption (eshetu, 2020).

Manufacturing process of Portland cement

Portland cement is produced by grinding cement clinker in association with gypsum to specified fineness depending on the requirements of the cement consumers. Cement clinker is produced on large scale by heating finely ground raw materials (calcareous and argillaceous materials at very high temperature up to 1450 ^{0}C in rotary kilns.

The fundamental stage for Portland cement production are raw mixture preparation and mix blending, formation and grinding of clinker are the necessary stages in the Portland cement production (en.wikipedia.org/wiki/Portland-cement).

1. Raw mix preparation and blending

The raw materials for Portland cement production are a mixture (as slurry in the 'wet processes of in the form of fine powder 'dry processes) of materials containing calcium oxide, silicon oxide, aluminium oxide, ferric oxide and magnesium oxide. The raw materials are usually quarried from local rock, which in some places has already practically the desired composition and in the other places requires the addition of clay and limestone, as well as iron ore, bauxite or recycled materials. The individual raw materials are first crushed typically to below 50mm, in many plants; some or all of the raw materials are then roughly blended in a "pre-homogenization pile". The raw materials are next ground together in a raw mill. Silos of individual raw materials are arranged over the feed conveyor belt. Accurately controlled proportions of each material are delivered onto the belt by weigh feeders. Passing into the raw mill, the mixture is ground to raw mix. The fineness of raw mix is specified in terms of the size of largest particles and is usually controlled so that there are less than 5%-15% by mass of particles exceeding 90μm in diameter. It is important that the raw mix contains no large particles in order to complete the chemical reactions in the kiln, and to ensure the mix is chemically homogenous. In the case of a dry process, the raw mill also dries the raw materials, usually by-passing hot exhaust gases from kiln through the mill, so that the raw mix emerges as a fine powder. This is conveyed to the blending system by conveyor belt or by a powder pump. In the case of wet process, water is added to the raw mill feed, and the mill product is slurry with moisture content of 25%-45% by mass. This slurry is conveyed to the blending system by conventional liquid pumps(Bedaso, 2022).

The raw mix is formulated to a very tight chemical specification. Typically, the content of individual components of in the raw mix must be controlled within 0.1% or better. Calcium and silicon are present in order to produce liquid ("flux") in the kiln burning zone. The liquid act as a solvent for the silicate forming reactions and allows these to occur at an economically low temperature.

Insufficient aluminium and iron lead to difficult burning of the clinker, while excessive amounts lead to low strength due to dilution of the silicates by aluminates and ferrites, very small changes in calcium lead to large changes in the ratio of alite to belite in the clinker, and to corresponding changes in the cement's strength growth characteristics.

The relative amounts of each oxide are therefore kept constant in order to maintain steady conditions in kiln, and to maintain constant product properties. In practice, the raw mix is controlled by frequent chemical analysis (hourly by X-ray fluorescence, or every three minutes by prompt gamma neutron activation analysis). The analysis data is used to make automatic adjustments to raw material feed rates. Remaining chemical variation is minimized by passing the raw mix through a blending system that homogenizes up to a day's supply of raw mix(Environment, Scrivener et al., 2018).

2. Formation and grinding of clinker

The raw mixture is heated in a cement kiln, with temperatures increasing over the length of the cylinder up to a peak temperature of 1400-1450^{0}C. a complex succession of chemical reactions take place as the temperature rises. The peak temperature is regulated so that the product contains sintered but not fused lumps. Sintering consists of the melting of 25-30% of the mass of the material. The resulting liquid draws the remaining solid particles together by surface tension, and act as a solvent for the final chemical reaction in which alite is formed. Too low a temperature causes insufficient sintering and incomplete reaction, but too high a temperature results in a molten mass or glass, destruction of the kiln lining, and waste of fuel. When all goes to plan, the resulting material is clinker. On cooling, it is conveyed to storage. Some effort is usually made to blend the clinker, because although the chemistry of the raw mix may have been tightly controlled, the kiln process potentially introduces new sources of chemical variability. The clinker can be stored for a number of years before use. Prolonged exposure to water decrease the activity of cement produced from weathered clinker(Aldieb & Ibrahim, 2010).

In order to achieve the desired setting qualities in the finished product, a quantity (2-8%, but typically 5%) of calcium sulfate (usually gypsum or anhydrite) is added to the clinker and the mixture is finely ground to form the finished cement powder. This is achieved in a cement mill. The grinding process is controlled to obtain a powder with a broad particle size range, in which typically 15% by mass consists of particles below 5 μm diameter, and 5% of particles above 45 μm.

The measure of fineness usually used is the "specific surface", which is the total particle surface area of a unit mass of cement. The rate of initial reaction (up to 24 hours) of the cement on addition of water is directly proportional to the specific surface. Typical values are 320-380m^2/kg for general-purpose cements, and 450-650 m^2/kg for "rapid hardening" cement(Black, 2016)

Normal Consistency of Cement

A normal consistency of cement paste is defined as a percentage of water by weight of cement that allows a standard plunger of 10 mm diameter to penetrate up to a depth of 5 to 7 mm above the bottom of Vicat's mold. The Higher values of normal consistency of cement paste are observed when cement is old and when the cement is too fine that has a high specific surface area(Dinku, 2002). According to ASTM C187(2004), normal consistency is expressed as a percentage of dry cement weight and ranges from 22 to 30.

Setting Time of Cement

The cement paste setting time is the length of time it takes for the cement paste to lose its plasticity after it has been combined with water. Cement setting time is classified into two types: initial and final setting time. The time elapsed between adding water to the cement and the paste losing its flexibility and hardening is referred to as the initial setting time. While, final setting time is the time interval between when water is added to the cement and when the paste has completely lost its plasticity(J. Zhang, Weissinger et al., 2010). According to ASTM C150(2010) the initial setting time should be no less than 45 minutes, and the final setting time should be no more than 375 minutes. According to Ethiopian standards, the initial setting time for cement should not be less than 45 minutes, and the final setting time should not be more than 600 minutes(Dinku, 2002).

Chemical Properties of the Cement

Lime, silica, alumina, and iron oxide are the main source of raw materials for PC production. These oxides carry out complex reactions in the kiln at high temperatures to form complex compounds. The chemical components of PC are reported in terms of oxides. The Chemical properties of cement are determined from the chemical analysis of these raw materials(Nawy, 2008) As demonstrated in Table 2.1, Cao accounted for 60 to 70% of cement oxide, while SiO2 accounted for 17 to 25%. When compared to lime, alumina and ferric oxide contribute very little.

Table 2.1 Chemical composition of OPC cement (Andersson, Allard et al., 1989).

Oxide name	Percent composition	Oxide name	Percent composition
CaO	60-70	MgO	0.1-4
SiO_2	17-25	Fe2O3	0.5-6
Al_2O_3	3-8	K_2O & Na_2O	0.5-1.3

The rate of cooling of clinker, fineness of the particle, and the proportions of the oxide composition of cement mainly influence the properties of cement. The foremost compounds in PC are C_3S, C_2S, C_3A, and C_4AF. The compounds chargeable for the development of strength are C_2S and C_3S. These compounds represent approximately 70-80% of cement. C_3S are hydrates and harden very fast. In addition, it miles liable for the early strength of cement even as C_2S hardens slowly and is responsible for later strength improvement of concrete. Cement with excessive C_3S is better for cold climate concreting since it allows early strength improvement of concrete (Shetty, 2005).C3A hydrates very fast but contributes a little to the early strength development of concrete. Due to C3A, reacting with water very fast water affects flash setting; however, with the aid of using which includes gypsum to the clinker at the time of grinding it may be prevented. The presence of C3A can result in sturdiness problems of concretes, which are uncovered to sulfates. C4AF hydrates rapidly but contributes little to the strength development of concrete. Comparatively, C3A shows lower sulfate attack resistance than hydrated C4AF (Dunuweera & Rajapakse, 2018).

2.2 Environmental effect of cement production

Many of the aspects of cement making process are potentially environmentally damaging, although these risk can be minimized (M. Ali, Saidur et al., 2011). Cement manufacturing is an energy intensive process. The enthalpy of formation of clinker from calcium carbonate and clay minerals is about 1500 up-to 1700 kJ/kg. However, because of heat loss during production, actual values can be much higher, the high-energy requirements and the release of significant amounts of carbon dioxide make cement production a concern for global warming(S. Kosmatka, Kerkhoff et al., 2003). Carbon dioxide is produced during the calcination phase of the manufacturing process and because of burning fossil fuels. Opportunity to reduce emission through increased energy efficiency is only possible on the latter of the CO_2 emissions (Beall, 2001).approximately 1 ton CO_2 is generated for making 1 ton of clinker (Van Oss & Padovani, 2003).

2.3 Physical properties of cement concrete

2.3.1 Fresh concrete properties

Workability

ASTM C 125 defines workability as the property determining the effort required to manipulate freshly mixed quantity of concrete with minimum loss of homogeneity. The term "manipulate" includes the early age operations of placing, compacting and finishing (C. Astm, 2003).

A workable concrete allows full compaction using a reasonable amount of work. This helps in achieving maximum possible density (i.e. minimum possible voids) of concrete, which Results in more strength and durability of concrete (A. M. Neville, 1995).Water content is the most important factor affecting the workability of concrete. Increasing the amount of water will increase the workability of concrete. However, the increase in water content of the mix will decrease the strength and result in segregation and bleeding (A, June 1987.).

The amount of aggregate, the proportion and fine aggregate, shape, and texture of the aggregate particles affect the workability of concrete. Keeping the water content and cement content constant increasing the amount of aggregate reduces the workability of concrete (A, June 1987.). Freshly mixed concrete stiffens with time. The change in workability with time depends on the moisture condition of aggregate, evaporation, and hydration reaction. The loss of workability is greater with dry aggregate due to the absorption of water by aggregate. The workability of a concrete is also affected by the temperature of the concrete itself (A. M. Neville, 1995).

Setting time of concrete

ASTM C125 defines time of setting as the elapsed time from addition of mixing water to a cementitious mixture until reaches a specified degree of rigidity as measured by a specific Procedure. The development of rigidity in cementitious mixture is a gradual and continuous Process. For cementitious mixture, development of rigidity is measured as the elapsed time to attain a specified level of resistance penetration by a probe (Kamal, 2019).

ASTM C403.A mortar portion is extracted by wet sieving using a 5 mm (No.4 ASTM) sieve from the concrete sample measures the setting time of concrete. A spring reaction- type probe known as Proctor probe, is used to determine the times when the resistance to Penetration is 3.5MPa (500 psi) (A. C. C.-o. Concrete & Aggregates, 2008).

The initial setting time and indicates that the concrete has become too stiff to be made mobile by vibration. These setting times are distinct from the setting times of cement (A. M. Neville, 1995).

The stiffening of concrete can be recognized by a loss of workability that usually occurs during placing but is dependent upon the composition and fineness of the cement, any admixtures used, mixture proportions, and temperature conditions. Subsequently, the concrete sets and becomes hard. In addition to this, Organic impurities may also delay setting of concrete (S. H. Kosmatka et al., 2002).

2.3.2 Hardened concrete properties.

Compressive strength of concrete

The strength development characteristics of cement are determined by measuring the compressive strength of 50-mm (2-in.) mortar cubes tested in accordance with ASTM C109 (AASHTO T 106), Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens (Figure 3-32). Compressive strength is influenced by the cement type, specifically: the phase composition, sulfate content, and fineness of the cement. Minimum strength requirements in cement specifications are typically exceeded comfortably.

Split Tensile strength of concrete.

Concrete possesses a very low tensile strength, limited ductility and little resistance to cracking Concrete naturally contains internal micro-cracks, and as a result of these micro-cracks spreading, the material has inadequate tensile strength, which can eventually cause brittle fracture(Wakchaure, Shaikh et al., 2012).

2.3.3 Micro structural properties of concrete

Concrete has a heterogenous microstructure, and consist of three components, could be, cement paste, pore structure, and interfacial transition zone between the cement paste and aggregates. Enhancing these three elements leads to strengthening mechanical strength and durability of concrete(Mehta & Monteiro, 2014a).

Cementitious binder

Cementitious binder Cement mainly consists of lime (Cao), silica (SiO_2), alumina (AL_2O_3) and iron oxide (Fe_2O_3). the basic compounds of ordinary Portland cement are tri-calcium silicate (C3S), di- calcium silicate (C_2S), tri-calcium aluminate (C_3A), and tetra-calcium alumino-ferrite (C_4A).

During cement hydration the following phases present: (i) calcium silicate hydrate (C-S-H); (ii) calcium hydroxide (CH); (iii) ettringite; (iv) monosulfate; (v) unhydrated (UH) cement particles; and (vi) air voids(Mehta & Monteiro, 2014b).

pore structure

Pore structure of cementitious material is critical characteristics of concrete, because it affects strength and durable properties due to their dependence on material permeability, porosity and pore size distribution(Ramamurthy, Nambiar et al., 2009).

Interfacial transition zone (ITZ)

Concrete is made of three phases: cement paste, aggregate, and the interfacial transition zone (ITZ) between them. The ITZ has a different structure from the bulk paste in terms of density composition and morphology. It has less un-hydrated cement, less C-S-H, big calcium hydroxide crystals, more ettringite, and more porosity. The dissolution of calcium sulfate and calcium aluminate compounds results in the formation of calcium, sulfate, hydroxyl, and aluminate ions, which combine to form ettringite and calcium hydroxide. These compounds become larger in the vicinity of the aggregate, because of the high water-to-cement ratio, creating a more porous structure than in the bulk cement paste(Mehta & Monteiro, 2014a).

2.4 Alternative raw materials for partial replacement of cement

Several alternative raw materials were studied to replacement. For example, use of the alternative waste product from agricultural waste like rice husk ash, eggshell ash, cow dung, bagasse ash, coffee husk ash, and from by product like silica fume, fly ash, slag, waste paper used as a partial replacement for cement (Al Robayie, Al-Azzawy et al., 2015). Those are can reduce environmental and health problem during cement production, lower the cost of cement, and improved the performance of concrete (Duan, Liao et al., 2018)**.**

Industrial waste materials

I. Fly ash (FA): is pozzolanic materials obtained from coal-burning electric generation powder plants. Fly ash is one of the most widely used composites to cement due to its' higher amount of reactive amorphous silica and cost-effectiveness. When fly ash is reacted with calcium hydroxide $Ca(OH)_2$ in cement, formed additional calcium silicates hydrated (C-S-H), which can improve the mechanical strength of the cement up to a certain replacement level (Dembovska, Bajare et al., 2017). Fly ash also improves the workability, compressive strength, and durability of concrete as well as reduces drying shrinkage and creep in the concrete (M. R. Ahmad, Chen et al., 2019). Recently some studies are used the superfine particles of fly ash as a partial replacement for cement to obtained superior mechanical strength than normal concrete because finer particles have higher surface area (Duan et al., 2018). Coal fly ash (CFA) also becomes a key alternative for producing high-performance concrete. However, many countries have shortages of CFA because enlarges the demand for CFA (P. Zhang, Liao et al., 2020). It is less available in our country, and it is not recommended for early strength of Concrete.

II. Ground granulated blast furnace slag: (GGBFS) is a by-product of iron or steel production (Sandhu, Rind et al., 2019). GGBFS is used as a partial replacement for cement to lower the emission of CO_2 (Suresh & Nagaraju, 2015). Furthermore, concrete containing GGBFS resists environmental conditions such as chloride penetration, sulfate attack. The optimum compressive strength was achieved with 5% and 10% GGBFS replacement of cement, Further replacement can decrease strength (Sandhu et al., 2019; Suresh & Nagaraju, 2015). Additionally GGBFS improves the workability of concrete and reduces the risk of cracking at an early age (Pane & Hansen, 2008). However, GGBFS needs higher energy to ground into small particles and it is less available in our country.

III. Silica fume (SF): is a by-product of the manufacture of silicon or Ferrosilicon alloy, known as micro silica. It is used as an artificial pozzolanic admixture because it contains more than 90 percent silicon dioxide, carbon, Sulphur, and oxides of aluminium (Selvapriya, 2019). 20% replacement of silica fume with cement improved compressive strength and durability of concrete at 24 hours, 7, and 28 days (Güneyisi, Gesoğlu et al., 2004). In the other research, silica fume reduces the workability or consistency of concrete but no change is observed in the tensile and flexural strength of the concrete as compared to the conventional concrete (Srivastava, Kumar et al., 2012). Moreover, silica fume also influences the high-performance concrete due to its ultra-fine particles and the ability to reduce the porosity of concrete with the formation of calcium silicate hydrate (C-S-H)gel (Sabir, 1995). However, it has negative effects on workability due to its high specific surface area (Imam, Kumar et al., 2018; Kumar & Dhaka, 2016). And it is less available in our country.

2.5 Wastepaper ash (WPA)

Wastepaper is the major source of waste that will affect the environment. In Ethiopia, a sufficient amount of waste papers goes unused, end up in a landfill or dumpsites, and incinerated rather than recycled, thus causing environmental problems by polluting the air, water, and land. Waste paper is available in the environment from different sources, such as office, newspaper, higher educational institutions, and markets (Mitikie & Waldtsadik, 2022).

Efficient wastepaper recycling has a significant role in the sustainable environment. Recyclable waste paper as a fundamental ingredient of municipal solid wastes is indeed an "urban ore" (Rahman, Hussain et al., 2014)

The use of waste materials in place of natural resources is one of the best approaches to make concrete industry sustainable. Wastepaper is a major economic and environmental problem for the paper and board industry. An enormous quantity of waste paper sludge is generated all around the world (S. Ahmad, Malik et al., 2013). Waste paper ash (WPA) was found to be one of the most mature cement substitute materials (Zewdie, Zewdie et al., 2020).

2.4.1 Availability of wastepaper

In fact, the global consumption of pulp and paper is expected to double. The same will the amount of paper waste. From our newspapers to our paper wrappings, paper is still everywhere and most of them are ending up in our landfills creating a staggering amount of paper waste(Ozola, Vesere et al., 2019).

Fact about paper and paper waste, As we speak, more than 199 tons of paper has already been produced (paper production in 15 seconds), U.S offices use 12.1 trillion sheets of paper a year, Paper accounts for around 26% of landfill waste and 33% of municipal waste, With all the paper we waste each year, we can build a 12-foot-high wall of paper from New York to California, Lessening of paper usage was predicted due to the electronic revolution and It didn't happen. Demand for paper is expected to double before 2030(Mirel, 2007; Stang & Hawthorne, 2005).

2.4.2 Wastepaper properties

Wastepaper Sludge Ash (WPSA) contain lime (CaO) and silica (SiO_2). Except MgO the number of other elements were less than 2%. Therefore it contains also Aluminium trioxide(Al_2O_3), Ferric trioxide(Fe_2O_3) ,Magnesium oxide(MgO), Sulphate(SO_3), Potassium oxide(K_2O) (Amit & Islam).

Table 2.2 chemical properties of wastepaper sludge ash

Oxide (%)	Cao	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	SO_3	LOI
(Bui, Satomi et al., 2019)	44.55	27.8	13.79	4.94	0.28	3.92		
(Segui, Aubert et al., 2012)	45.5	28	13.2	1.3	4	0.7	1.3	5.7
(Bai, Chaipanich et al., 2003)	43.51	25.7	18.86	.87	5.15	1.31	1.05	1.2
(Bai et al., 2003)	40.21	22.32	14.55	.56	2.35	.37	0.32	18.5
(Vegas, Frías et al., 2006)	36.5	21.6	14.4	0.5	2.4	0.4	0.1	23.2
(Banfill & Frias, 2007)	31.4	30.20	18	0.7	2.7	0.32	0.27	14.5

According to the above researcher the amount of Cao and SiO2 is 31.4-45.5 % and 16.58 30.2% respectively the other oxide amount below 5% except aluminium.

Table 2.3 physical properties of wastepaper sludge ash

Author	Specific gravity(gm/cm^3)	Moisture content	Water absorption
(Chandra, July 2022)	3.1		1.5-2.36
(Kaur & Talwar)	2.09		
(Yusuf, Noor et al., 2012)	2.39–2.99	0.28	1.6-2.61
(Yusuf et al., 2012)	1.67	0.16	

(Mitikie & Waldtsadik, 2022)	2.36		

2.4.3 Properties of concrete containing wastepaper

Fresh concrete

The slump value of concrete decreases, as the amount of wastepaper is increase. Accordingly, when a higher amount of paper was included in the mix, it required more amount of water to attain a given slump; shortly the slump value decreased with the amount wastepaper mix increase(Kejela, 2020).

In a comparison with cement, wastepaper particles absorbed more water and thus reducing the workability of the concrete mix. Up to 5% cement substitution, the slump increased; above 5%, the slump decreased as the amount of paper pulp in the concrete mixtures increased(S. Ahmad et al., 2013; Kejela, 2020; Seyyedalipour, Kebria et al., 2014).

Hardened concrete

The paper pulp content in the concrete mixtures played a great role in the mechanical properties. Compressive strength and splitting tensile strength increases initially on of the paper waste, but it is decreased significantly on further addition of the paper waste(Zaki, Gorgis et al., 2018). The compressive and splitting tensile increased up to 10% addition of waste paper pulp and further increased in waste paper pulp reduces the strengths gradually(Singh, Saleem et al., 2015). An increase in compressive strength and splitting tensile strength was observed at 5% replacement of cement by waste paper sludge ash and there after decreased with increasing waste paper sludge ash content(Seyyedalipour et al., 2014).

AGRICULTURAL WASTE MATERIALS

Agricultural wastes are optional materials for partial replacement of cement for minimizing the cost of concrete. They are not preferable to the above industrial waste products because of less availability in a developing country. Researches on the replacement for cement-containing agricultural wastes shows great potential in concrete production and it reduces the amount of waste and costs of cement (Espíndola-Gonzalez, Martínez-Hernández et al., 2010).

I. Coffee husk ash (CHA): coffee husk ash is used as pozzolanic material because it contains silica (SiO2) and aluminates. Which reacts with free lime released during hydration of the cement forms extra calcium silicate hydrate as a new hydration product. In addition to this, it is eco-friendly and reduces the emission of CO_2. However, the addition of CHA affects the workability and lowers the compressive strength of cement. Similarly on the other research, (CH) burned at 400, 500, 600, 700, and 800 ^{O}C. Those higher temperatures give a higher amount of silica content, but the silica is not reactive (crystalline silica)which affects the strength of concrete (Lin, Kuo et al., 2016).

II. Corn cob ash (CCA): Some researchers use Corn cob ash as a pozzolanic material because it contains more than 70% of the combination of SiO_2, Al_2O_3, and Fe_2O_3 (Adesanya & Raheem, 2009a). It is important to lower the chemical attack and permeability of corrosive chemicals of mortar up to 15% replacement ratio by cement (Adesanya & Raheem, 2010). However, CCA reduces Concrete strengths, workability, and compacting factor in all replacement ratios and ages (up to 28 days) but it is expected to improved compressive strength at later ages after 120 days of curing (Adesanya & Raheem, 2009b; Olafusi & Olutoge, 2012).

2.5 Eggshell ash (ESP)

Eggshell is waste material produced from poultry farms, hotels, bakeries etc. (Pillai & Mathew, 2021). In huge. Eggshell powder is made by crushing the eggshells and made up of 50-55% of CaO. Also, silicon dioxide, aluminium, magnesium, phosphorous, sodium etc. are occurred which is very similar to cement properties so it can be used as partial replacement of cement (Vaidya & Bastwadkar, 2019).

2.5.1 Preparation of eggshell ash

Eggshell powder prepared by four steps. First is washing in which eggshells are clean 2-3 time by normal water. Second step is eggshells were dry for 4-5days at a temperature range of $25^{0}c$ to $30^{0}c$. After drying, third step is grinding is which dried eggshells were ground in mixer. And fourth steps is sieving in which eggshell powder were sieve through 90micron sieve (Vaidya & Bastwadkar, 2019).

2.5.2 Properties of eggshell powder

Table 2.4 chemical properties of waste eggshell powder

Oxides	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	SO_3
(Sivakumar & Mahendran, 2014)	32.5	0.09	0.44	0.34		0.37	0.14
(Afolayan, Oriola et al., 2017)	46.69	0.12	0.49	0.32	0.18	0.21	0.57

(Pathan, Nagalkar et al., 2021)	50.7	0.11	0.05	2.6		0.43	
(Parthasarathi, Prakash et al., 2017)	50.7	0.09	0.03	0.02	0.01		0.57
(Shiferaw et al., 2019)	52.75	0.01	0.01	0.01	0.51	0.04	
(Hama, Hamdullah et al., 2019)	52.8	0.08	0.04	0.01	0.01		0.44
(Zaini, Hasan et al., 2022)	62.5	0.02	0.01	0.02	0.71	0.05	

The main component of ESP is Cao, which constitutes between 32.5% (Sivakumar & Mahendran, 2014) and 62.5% (Abdulabbas, 2016) of own chemical composition. However, silica oxide (SiO_2) is only found in very low percentages. ESP is therefore not a pozzolanic substance. Additionally, the composites made from ESP particles have around 3% organic content (Baláž, 2018).

Table 2.5 physical properties of waste eggshell powder

Author	Specific gravity	Bulk Density kg/m^3	Surface area	Moisture
(Sivakumar & Mahendran, 2014)	1.89	1081	290	
(Afolayan et al., 2017)	2.14	1500		
(Parkash & Singh, 2017a)	0.85	800	21.2	1.18
(Adogla, Yalley et al., 2019)	2.58	2088		5.1
(Raji & Samuel, 2015)	0.85	800	21.2	
(Olorunnisola & Okanlawon, 2017)	0.85	700		0.99

The specific gravity ranges between 0.85 (Olorunnisola & Okanlawon, 2017) and 2.58 (Adogla et al., 2019). The results for bulk density range from 700 to 2088 kg/m3, while those for cement range from 1000 to 1300 kg/m3.

2.5.3 Properties of concrete containing Eggshell powder

Fresh concrete properties

Eggshell concrete (ESC) has lower workability compared to normal Portland cement concrete (PC). The workability of ESC decreases with an increase in the percentage of eggshell powder as cement replacement(Parkash & Singh, 2017b). The workability of concrete is obtained by slump test in compliance with ASTM C 143 (Jhatial, Sohu et al., 2019b)stated that this trend was attributed to the high-water absorption of eggshell powder ESC which absorbs the water needed to provide a high workability. In addition, the eggshell powder's particle size affects workability. Since eggshell powder has a larger surface area when it is ground more finely, it absorbs more water and reduces workability of the mix more adversely. This had been tested in an experiment integrating eggshell powder pulverized to 50µm and 100µm. The reduction becomes more prominent the more eggshell is used to replace cement. Similar to the way concrete mix influences workability, eggshell has an influence on mortar mix(Sharma & Netula, 2018). Percentage powder replacement increase workability of mortar decrease(Ramamurthy et al., 2009).

Hardened concrete properties.

Compressive strength: ESC has been shown to have higher compressive strength than normal concrete up to a certain percentage of eggshell powder in the mix, usually around 10%. However, beyond this point, the strength decreases due to increased water demand. The exact compressive strength of ESC depends on the percentage of eggshell powder used and other factors such as curing conditions(Chong et al., 2020). Split tensile test is an important parameter in concrete to understand its resistance to tensile crack. In the experiment of (Bandhavya, Sandeep et al., 2017), the maximum split tensile strength was achieved at 5% ESC. For 10% ESC, the split tensile strength was roughly equal to that of the control, but a significant loss of strength was observed at higher eggshell content. However, it is worth nothing that the optimal eggshell in the experiment is 10% as it produces the highest compressive strength. (Chong et al., 2020) conducted a feasibility study of ESC with M20 grade concrete specimens. The maximum splitting strength was achieved at 10% ESC of 28 days. The optimal content for both compressive strength and flexural strength was 5%. 5% ESC had slightly higher value on both parameters, while at a higher percentage eggshell, the performance reduced. The optimal content of eggshell for maximum split tensile strength is similar in experiments involving two or more replacement materials. 5 to 10% eggshell replacement generally has a positive effect on the split tensile strength of ESC.

2.6 Environment effect of cement production

2.6.1 Air pollution

Dust emissions are a major source of environmental pollution during cement manufacturing, for example, dust is generated during transportation, loading, and unloading of the clinker to be deposited outside the silo (Gregg & Andres, 2008).CO2 is indeed one of the major greenhouse gas emissions which also a major contributor to global warming (NASA). During the formation of CaO through cement production, CO2 will be released with water vapour at high temperatures. It is responsible for 5% to 7% of global CO2 emissions from total industrial energy utilization, and CO_2 is also accounts for 65% of greenhouse gases (Change, 2014). The Fifth Assessment Report of the Intergovernmental Panel on Climate Change confirmed that industrial CO_2 emissions derived mainly from material production. Sectors namely industry, electricity, and heat, and transport account for 84% of global CO_2 emissions (Outlook, 2014). Production of cement refers to the method of energy and resource used, which absorbs almost 12% to 15% of total industrial energy utilization (Madlool, Saidur et al., 2011). It also actually reported for 5% to 8% of CO_2 emissions from cement production (Shen, Cao et al., 2015). On the other side, the output of one tonne of Portland cement produces around one tonne of GHG and, for each tonne of Portland cement clinker, 1.5 to 10 kg of NO_x is emitted into the environment (Altwair & Kabir, 2010). NO_x is a potent greenhouse gas created by fossil fuel combustion, nitric acid production and biomass combustion (NASA). In addition, the emission of dust and other pollutant gasses reduces the quality of air which affects the healthy lifestyle of world population.

2.6.2 Water and noise pollution

The manufacturing process of cement also causes dust pollution which may reduce visibility and quality of air. When the dust has been drained, it can contaminate the water and cause adverse effects on human wellbeing or even to animal as clearly stated by the Centres for Disease Control and Prevention. Wastewater runoff to the atmosphere is responsible for contaminating water supplies from rivers or groundwater supplies. In areas with a grow g population, building and urbanization, also land human activities lead to soil degradation problem (Ding, Chen et al., 2015). In addition, noise emissions are produced mostly during the cement manufacturing process. The preparation of raw materials, clinker burning, storage of materials, the heavy machines used in the process contributed to noise pollution (Jadoon, Amin et al., 2016). According to the noise processing process, industrial noise is classified into complex gas noise, electrical magnetic noise, and mechanical noise (Hongwu, 2003). The key sources of noise in cement plants are gas dynamic noise which generated from blower activity, mechanical noise created by milling machines and crushers, electromagnetic noise caused by electric engines (Canfeng, Shujie et al., 2012). Noise pollution not only affected human hearing, but it’s severely affected the anatomy and physiology of human body system such as nervous, digestive, and cardiovascular (Hongwu, 2003). Individual that has long-term exposure to high-noise cement plant settings increase tendency to experience neurasthenia syndrome such as loss of memory, hypertension, insomnia, dizziness, headache, and fatigue. Currently, people believe that high levels of industrial noise and road noise are one of the risk factors associated to cardiovascular disease. Furthermore, the employees work in the cement plant has difficulty to detect any danger signal due to the noise pollution during their working period thus affected the safety for the work.

2.7 Summary and gap

The literature review in the previous sections on eggshell powder and wastepaper ash as a cement substitute reveals that several researchers have carried out studies in this area independently. However, there are still some gaps to collaborate both the economic and morphological properties of concrete. But There is no researcher hybrid eggshell and wastepaper ash .In the area of eggshell powder and wastepaper ash is hydride with different cementitious material to minimize the cost of cement and environmental impact like eggshell with rice husk ash (Asman, Dullah et al., 2017), eggshell powder with cow dung (Deshpande, Nanjunda et al., 2018), eggshell powder with glass powder (Chandrasekaran et al., 2018)wastepaper ash with silica fume (Azar, Najarchi et al., 2019) , wastepaper ash with fly ash (Owaid, Al-Rubaye et al., 2021)Etc. Although the overall review shows that both eggshell and wastepaper ash have the creditability to be used as cement replacement in concrete up to some extent those results show partial substitution of cement from 5-10% independently have some positive effect on properties of concrete. And most of researchers report a failure in mechanical properties due to substitution of cement by eggshell powder and wastepaper ash above 5% independently. However still there is a limited knowledge on behaviour of concrete using hybrid eggshell powder and wastepaper ash as a cementitious material. This study was done to fill the gap on the experiences and knowledge on the effect of using hybrid effect of eggshell powder and wastepaper ash as a cement. So, from the review the researcher understands that there is a significant result variation on previous works both on eggshell powder and wastepaper ash concrete as well morphological behaviour mechanical property and hydration process of concrete containing eggshell powder and wastepaper ash is not studied at all. And this taken as research gaps that enabled to set objective for this research.

The next chapter discusses the research methodology adopted to achieve the objectives of the study.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Introduction

The main aim of this research is to Study on physio-mechanical and microstructural properties of concrete, and environmental as well as economic performances of C-25 concrete produced by partial replacement of cement with eggshell ash and wastepaper ash. The replacement is planned by replacing cement with 0%,10%,14%,18%,22% of a blend of WPA and ESP.

The experiment consists of material characterization, mix proportioning, concrete specimens' preparation, and laboratory tests on fresh and hardened concrete as well as environmental and cost performance of C-25 concrete using 42.5 OPC cements.

3.2 Materials

The materials are used for this experimental investigation will be tested to check their physio-mechanical and micro structural properties that confirms to the requirements based on the standard available. This section will detail the materials that may be used for the experimental research of the physio-mechanical and microstructural characteristics of concrete in relation to those characteristics.

3.2.1 Cement

A finely powdered powder known as cement is prepared when calcareous, siliceous, and argillaceous ingredients are chemically mixed with gypsum, iron oxide, and a tiny quantity of other components. The chemical composition of cement are presented in the table 3.1 Fineness, soundness (retains its volume after setting), consistency (ability of cement paste to flow), setting time (cement hardens when water is added; not too low initial setting time (30-45 minutes); not too high final setting time below 10 hours); heat of hydration; loss on ignition; bulk density; And specific gravity are the physical properties of good cement. For this study locally available ordinary Portland cement (OPC) will be used throughout the experiment which holds the aggregate together when it reacts with water. OPC is used because of its optimum mechanical properties, early stripping, and high-grade cement. After all, it must adhere to ASTMC150/C150M standards.

Table 3.1 Chemical composition of national cement (AZARIA, 2005).

Cao	SiO_2	Al_2O_3	Fe_2O_3	MgO	So_3
65.81	22.31	4.95	4.03	1.84	0.70

3.2.2 Fine Aggregate

Fine aggregates are basically natural sand particles from the land through the mining process, the fine aggregates consist of natural sand or any crushed stone particles. Sand is a by-product of the man-made and natural disintegration of rock and minerals, and it can be found in deposits along rivers, lakes, in the ocean, on land, and in wind-blown or residual deposits. River sand it passes through a 4.75mm sieve and is retained on 150 microns in accordance with ASTM C33/C33M will be used for this experimental investigation. There shouldn't be any silt, clay, or other organic contaminants in the sand. If the standard silt concentration is greater than 6%, the sand must be cleaned or replaced.

3.2.3 Coarse aggregate

The aggregates retained on the 4.75 mm sieve are basically classified as coarse aggregates. It is an irregular and granular material made of crushed stone, obtained from quarries by crushing by hand or using a crusher. The coarse aggregate must be free from impurities like clay, silt, dirt, and organic matter. Soft, porous rock can limit the strength and wear resistance; it may also disintegrate during concrete mixing, which affects the workability of fresh concrete by increasing the number of fines adversely. The coarse aggregate used to make up the concrete samples in this work consists of crushed gravel, which was collected from a local quarry that confirms the requirements of ASTM C33. Generally, the coarse aggregate used for the experiment should be strong, durable, free from vegetable matter, with less than 5% water absorption, and not sharp and angular as per ASTM C33.

3.2.4 Water

Water is one of the most important elements in construction and is required for the preparation of mortar, mixing of cement concrete and for curing work etc. Oil, alkalis, and acids should not be present in the mixing water. In general, water that is safe to drink can be used. Water impurities may affect cement's ability to cure and negatively impact concrete's strength and durability. A concrete that has too much water will have unequal strength because the water will segregate. For concrete mixing and curing the pH value should be between 6 and 8.5. The pH value of less than 6 causes corrosion and if the pH is too high it loses its binding properties causes cracking.

3.2.5 Hen's Eggshell

The ES were gathered through domestic sources. The ES was physically cleaned before being let to air dry. ES was ground to a fineness that would pass through a sieve with a particle size of 75 μm in order to meet the physical requirements for fineness. The eggshells are manually crushed and ground, and the ground ESP is then sieved to the necessary particle size. According to a previous study, eggshells are composed of 95% calcium carbonate and 5% each of silica, magnesium, phosphorus, sodium, and potassium. The preparation of Eggshells is collected and wash with tap water and boiled with distilled water for 2 hours at 100°C to remove the white film inside the eggshells and dry it at 100°C for 2 hours to remove all moistures.

3.2.5.1 Preparation of eggshell powder

Eggshell collected from adama science and technology university cafeteria. Then Eggshell powder prepared by four steps. First was washed in which eggshells were clean 2-3 time by normal portable water. Second step was eggshells were dry for 4-5 days at a temperature range of 25^0c to 30^0c. After collecting, drying and clearing, the samples were placed in a box for manual crushing up to some extent. Then samples were crushed in powder form by using some electronic equipment like coffee grinder machine.

The grinded eggshells were sieved though the 75µm size and then packed to use it in the cement replacement.

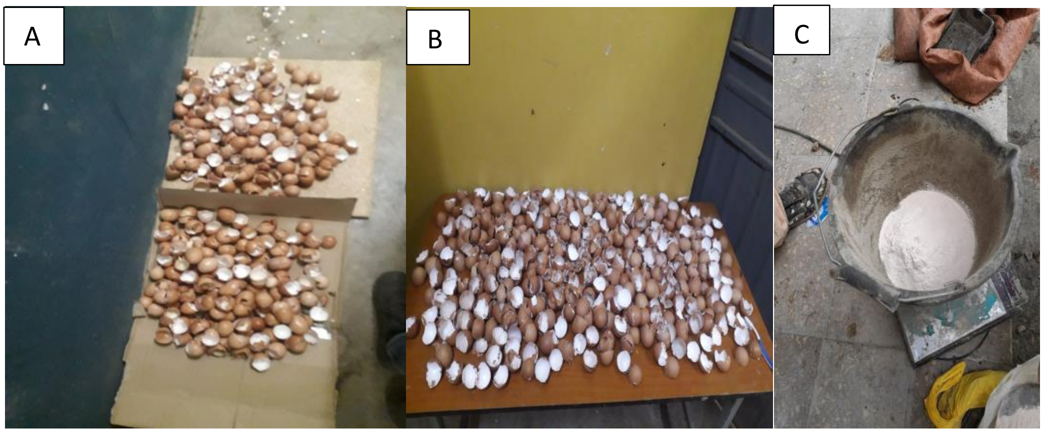


Figure 3.1 Shows the eggshell samples A, before wash, B, after washing, C, dried eggshell and eggshell powder respectively.

3.2.6 Wastepaper Ash

Wastepaper is to collect from different school, office, and libraries. According to the previous study wastepaper to prevent the production of crystalline ash, wastepaper burnt using an incinerator at a temperature of 500°C, which is less reactive to lime. Then after burning, the wastepaper pass through sieve No .75µm to obtain the used wastepaper ash.

3.2.6.1 Preparation of wastepaper ash

The wastepaper process in sequence steps were shredded manually into small pieces and the soaked in tap water at room temperature for 3 days. The soaked papers were mixed by hand and using an asphalt mixer machine until paper slurry was obtained, and then, the slurry was dewatered until excess water was drained. A wastepaper pulp in wet state is obtained after these processes. The wet pulps were dried in an oven at 105^0c for 24 hrs. And the formation of waste paper ash is a process of thermal activation provides waste paper mill sludge ash with pozzolanic properties in the range of temperatures between 500°C and 1000°C, with retention times in the furnace between 2 and 5 hours(Tappi, 2002). The paper mill sludge calcined at 500°C for 2 hours is composed of talc, kaolinite, illite, dolomite, calcite, and quartz(Mitikie & Waldtsadik, 2022). In this research, the wastepaper pulp was calcined in a furnace at 500°C for 2 hrs by cleaning carefully the empty crucibles. After calcination, it is cooled slightly and then placed in a metal plate. When cooled to room temperature, the ash is weighed on the balance. The calcination temperature was checked by preparation of a pre-test for properties of wastepaper ash concrete.

Figure 3.2 Shows the wet wastepaper, A, dried wastepaper, B, and wastepaper ash, C respectively.

3.3 METHODS

3.3.1 Experimental and analytical Frameworks.

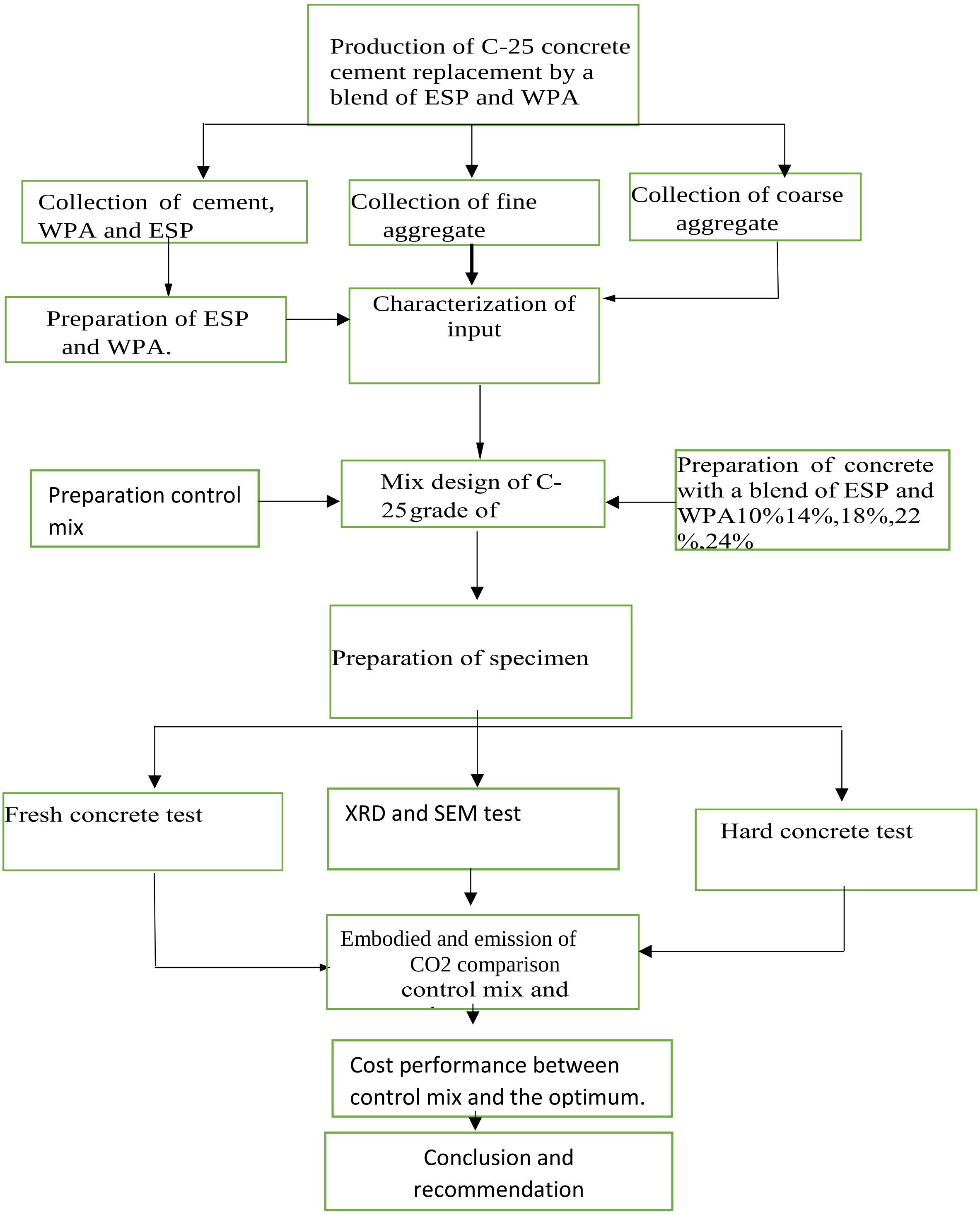


Figure 3.3 Experimental Design of the research.

3.3.2 Mix design and preparation

Concrete mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. In this study, ACI method was used to design mix proportion for C-25 grade of concrete. The mix designs were done as per ACI 318 building code requirement for structural concrete, the detail procedure is provided in the Appendix-A. Five mix categories for concrete grades of C-25 were produced. A control mix with eggshell and wastepaper ash is done and replacement was casted to make a comparative analysis. The step followed to calculate the mix design is.

Step 1 Computing required average compressive strength from the given characteristic strength of 25MPa. Calculating the required mean compressive strength based on characteristic strength of 25 MPa which gives; fck = f'ck + 8.5 = 25 + 8.5 = 33.5 MPa

Step 2 Specifying minimum cement content. Minimum cement content = 300 kg/m^3

Step 3 Choice of slump, the slump chosen ranges from 2-10 cm.

Step 4 Selecting maximum size of Aggregate, maximum aggregate size taken is 20 mm.

Step 5 Estimate mixing water and air content with a slump of 2-10 cm and a maximum size aggregate of 20 mm, the water content becomes 185 Kg/m^3 and 2%, or 20 liters.

Step 6 Computing water cement ratio (W/C) the minimum water cement ratio is 0.491.

Step 7 Determining the mix cement content, which becomes 377 kg/$m^{3.}$

Step 8 Estimating the bulk volume of dry rodded as per unit volume of concrete Hence, the dry volume of aggregate per volume of concrete is 0.602.

Step 9 Calculating the weight of coarse aggregate per m^3 of concrete = 1014 kg

Step 10 Determining the solid volume of the coarse aggregate =358.3 kg/m3

Step 11 Calculating the solid volume of cement, water, and air where Volume of Water (VW) = 185 Kg/m^3, Volume of Air (VA) = 20 Kg/$m^{3,}$ solid volume of cement=120 Kg/m^3

Step 12 Determining solid volume of sand (Solid volume of sand is then calculated by subtracting from the data volume of concrete).

Table 3.2 Solid volume and weight of concrete ingredients.

Ingredient	Volume	Wt. (kg/m3)
Air	20	-
Cement	120	377
Water	185	185
Coarse aggregate	359.49	1017.38
Fine aggregate	315.5	867.62
Total	1000	2,447 kg/m^3

Step 13 Summary of mix design ratio after water adjustment

Table 3.3 Summary of mix design ratio.

	Cement	Fine aggregate	Coarse aggregate
Quantity in m^3	377	877	1044
Ratio	1	2.32	2.77

To see the effect of wastepaper ash and eggshell powder on the properties of concrete, the trail mix designs were prepared for concretes made with wastepaper ash and eggshell powder of 0%,10%, 14%, 18%, and 22% percentages. In this research normal strength concrete C-25 was selected and prepared as ACI standard.

Four concrete mixes containing Portland cement, wastepaper ash, eggshell powder, river sand maximum size of 4.75mm, coarse aggregate with 19mm maximum size and drinkable water were prepared and compare with control mix. Various proportions of the replacement were investigated by batching each by weight. The water to cement ratio for the mixes containing the wastepaper ash and eggshell powder were based on preliminary testing to obtain a workable mix.

Table 3.4 Sample preparation.

S/no	Mix code	Cement quantity in kg	Wastepaper ash in kg	Eggshell powder in kg	Water in kg	FA in kg	CA in ka	W/C
1	OPC	34.22			19.8	83	108	0.58
2	OPC+4%WPA+6ESP	31.065	1.24	1.92	19.8	83	108	0.58
3	OPC+6%WPA+8ESP	29.75	2.07	2.62	19.8	83	108	0.58
4	OPC+8%WPA+10ESP	28.63	2.74	3.2	19.8	83	108	0.58
5	OPC+10%WPA+12ESP	28.6	3.4	3.72	0.58	83	108	0.58

3.4 Specimen preparation

Specimen Preparation Mixings were done using a hand mix and the materials were batched by weight. First, the cement, eggshell powder and Wastepaper pulp ash blended. Then, coarse aggregate, sand, and the blended paste (cement and wastepaper pulp ash) were mixed a few minutes and stopped. Next, some of the mixing water was added and then mixing was started and stopped again. Finally, the rest of the mixing water added. After all of the ingredients were added, the fresh concrete was mixed for between 3-5 minute of final mixing and until the concrete appears to be homogeneous (S. F. Concrete). After the mix was done, the fresh concrete was then poured into moulds. The cube moulds with internal dimensions of 150x150x150mm were used, cleaned, and oiled before casting and compacted using a hand compaction technique.

Total of 45 cubes specimens of 150mm×150mm×150mm for compressive strength, 30 cube cube specimens of 150mm diameter and 300mm height for split tensile strength were casted. Therefore, overall, 105 cube specimens were casted to obtain the engineering properties of concrete containing various percentage of wastepaper ash and eggshell powder.

3.4.1 Batching

Batching of concrete is the process of measuring concrete ingredients to get concrete mixtures. For this specific experiment, batching by weight was preferred over volume batching to get a proper mix of concrete ingredients since it is difficult to find the exact volume of granular materials because of their voids.

3.4.2 Mixing

The dry mix was carried out by mixing aggregate, cement, ESP and WPA were mixed for one minute. After that, water was added to the mix and punched for three minutes. then the slump is checked to assure the workability.

3.4.3 Casting

Castings of all specimens were carried out under same ambient conditions of average room temperature. The specimens were then placed on a firm and level surface of prepared cubic molds (150 x 150 x 150 mm) for compressive strength,for tensile strength teste cylindrical molds with cross section of (300cm height and 150 mm diameter) used for casting of concrete.

Usually, sufficient vibration has been applied as soon as the surface of the concrete has become relatively smooth and large air bubbles cease to break through the top surface. until full compaction achieved without segregation was achieved. After compaction of the final layer, the top surface was finished using a trowel. Placing, compaction and finishing were completed within 15minutes.The specimens were de-molded after 24 hours and the hardened cubes were transferred into a curing tank for 7, 14 and 28 days at room temperature(Dinku, 2002) .

3. 5 Testing program

The test program was considered the casted concrete specimen of cube. For testing, before placing the test specimens centrally in the testing machine, any excess moisture from the surface of the specimen was air dried for between 2 to 20 hours; according to ASTM C-39 2hrs for 3 day curing, 6hrs for 7 days curing, and 20hrs for 28 days curing(C. ASTM, 2001). Then, three specimens were tested for the compressive strength and split tensile strength of concrete containing wastepaper pulp ash, eggshell powder and control mix in Adama science and technology University laboratory.

3.6 Test on Concrete Ingredients

3.6.1 Test for Fine Aggregate

3.6.1.1 Silt content of sand

The material in fine aggregate which is finer than 75μm is generally regarded as silt. The amount of silt content greater than 6 % in the sand for concrete has a severe effect on the quality of concrete strength and workability.

From the silt content test performed on the sand, it was found that the original silt content was 3.4%. the Ethiopia standard of sand silt content does not exceed 6%. If it exceeds it recommend the sand properly wash or reject. According to (Dinku, 2002)construction materials laboratory manual, the average silt content of the sand used for the mix was determined using equation 3.1

$$\text{Silt content} \ = \frac{\text{A}}{\text{B}} \text{ x } 100\%$$

Whereas A = silt content layer height

B = sand +silt content layer height

3.6.1.2 Gradation test/ sieve analysis of fine aggregates.

The sieve analysis, commonly known as the gradation test, is a basic essential test for all aggregate technicians. The sieve analysis determines the gradation (the distribution of aggregate particles, by size, within a given sample) in order to determine compliance with design, production control requirements, and verification specifications. Therefore, the objective of this test is to ascertain the fineness modulus of fine aggregate using the following equipment: a balance, 500g of fine aggregate, a series of IS sieves with sizes of (4.75 mm, 2.36 mm, 1.18 mm, 0.6mm, 0.3mm, 0.15, and pan) from top to bottom, respectively. All test procedures and results must adhere to ASTM C136/c136M standards.

Take 500g of fine aggregate and empty sieves were weighted. After that, the pan was placed at the bottom of the sieve shaker and the other sieves were arranged according ascending of opening size of the sieves. Following that, 500 gm of fine aggregate was put on the top of sieve and shaken for 10 minutes in a sieve shaker. Lastly, the retained weight on each sieve was calculated and fineness modules was computed.

The fineness modulus is calculated using the formula:

$$\text{F M of fine aggregate} \ = \frac{\text{cumulative \% of retained weight}}{100\%} \text{ ----Equation 3.2}$$

3.6.1.3 Specific gravity, and water absorption capacity of aggregate.

Specific Gravity and Water Absorption Tests The specific gravity test of fine aggregate is the ratio of a given volume of fine aggregate to the weight of an equal volume of water. The difference between the weight of the surface-dried saturated fine aggregate and the weight of the oven-dried aggregate at a given temperature is used to calculate the aggregate's water absorption. ASTM C128(2012) standard was followed to undertake specific gravity, and water absorption tests for fine aggregate. These experiments were carried out using a balance, pycnometer, pan, shovel, spoon, oven, cone, tamper, and 1000 g of fine aggregate sample. Before the test, the specimen had to be prepared. At first, 1000 g of fine aggregate was obtained through a sample splitter and dried at 110°C for 24 hours before being allowed to cool. Then the sample was decanted with water to reduce fine loss, and the specimen was spread out on a flat non-absorbent surface. Following that, the sample was swirled repeatedly to ensure homogenous drying until it reached the saturated surface dry condition, and the surface moisture was measured using a cone test. The mold was held firmly on a smooth non-absorbent surface with a large diameter down, a portion of partially dried fine aggregate was placed loosely in the mold by filling it over and heaping additional materials above the top of the mold. Then the sand was lightly tamped into the mold with 25 light drops of tamper. Lastly, the surface was adjusted, loose sand was removed from the base, and the mold was lifted vertically. To conduct the test, initially, 500 g of S.S.D sample was taken once the specimen was processed. The pycnometer was then half-filled with water and instantly filled with 500 g of S.S.D fine aggregate. After that, the pycnometer was filled with additional water to 90% capacity and rolled to eliminate all air bubbles. Following the removal of air bubbles, the water level was transmitted to the pycnometer calibrated capacity, and the total weight of the pycnometer, specimen, and water was calculated. The fine aggregate was then removed from the pycnometer, dried to constant weight at 110°C, cooled for one hour in the air at room temperature, and then weighed. Finally, the weight of filled pycnometer to its capacity was determined.

- $Bulk\ specific\ gravity\ =\ A/\ (A+S-C)$ ………………... Equation 3.3
- $Apparent\ specific\ gravity\ =\ A/\ (B+A-C)$ …………...Equation 3.4
- $Absorption\ capacity\ =\ ((S-A)/A)\ *\ 100$ ...……………Equation 3.5

Whereas,

- Weight of oven dry specimen in oven (A)
- Weight of pycnometer filled with water (B)
- Weight of saturated surface dry specimen (C)
- Weight of pycnometer with specimen and water to calibration mark(S)

3.6.1.4 Unit weight test

The unit weight of fine aggregate is the weight of the sand that is required to fill a container of a specified unit volume. It depends on a variety of factors, including wet, dry, and loose conditions. The test was conducted by using a metal cylinder with a diameter of 100 mm and a height of 17 5 mm, a tamping rod, and balance. An empty cylinder was weighed and recorded to conduct this test. The cylinder was then filled with fine aggregate in three layers, each of which was tamped with 25 strokes by a tamping rod. The weight of the fine aggregate-filled cylinder was then measured and recorded. Finally, the unit weight of fine aggregate was calculated through the following formula:

$$Unit\ weight\ =\ (C-A)/\ V$$

Whereas

- Weight of empty cylinder (A)
- Volume of the cylinder was (V)
- Weight of the fine aggregate plus the cylinder (C)

3.6.2 Coarse Aggregate

3.6.2.1 Gradation test/ sieve analysis of coarse aggregates

Concrete is made of many components but is mostly made up of materials known as coarse aggregates. Coarse aggregates have a wide variety of construction applications because they resemble standard rock particles, as opposed to fine aggregate, which more closely resembles sand. Coarse aggregates are an integral part of many construction applications, sometimes used on their own, such as a granular base placed under a slab or pavement, or as a component in a mixture, such as asphalt or concrete mixtures. Coarse aggregates are generally categorized as rock larger than a standard No. 4 sieve (3/16 inches) and less than 2 inches. Crushed gravel that adheres with ASTM C33/C33M standards will be obtained from a nearby quarry and utilized as the coarse aggregate in the concrete samples. The coarse aggregate used for the experiment should generally be durable, chemically inert, and durable, devoid of plant materials, absorb less than 5% water, and not be sharp or angular. From top to bottom, the IS sieves are 20 mm, 19 mm, 12.5 mm, 9.5 mm, 4.75 mm, and pan, respectively. Because the material that passed through the sieve opening 4.75mm was initially excluded, aggregates than 4.75 mm were not used. Sieve analysis apparatus used for the current study includes a set of IS sieves, a pan, shovel, balance, a mechanical sieve shaker, and a sample splitter. The test was undertaken according to ASTM C13 (2006) standard. This test began with a 10 kg sample of coarse aggregate. Quartering was used to select the representative sample, and 1.5 kg of coarse aggregate was extracted from the quartered sample The weights of empty sieves were then recorded. After that, the pan was placed at the bottom of the sieve shaker, and the additional sieves were placed on the pan in order of increasing the sieve opening size. Then 1.5 kg of sample was placed on top of the sieve and shaken for 10 minutes. Lastly, the retained weight on each sieve were calculated and fineness modules was computed.

The fineness modulus is calculated using the formula:

$\text{Fineness modulus of coarse aggregate} = \frac{\text{cumulative \% of retained}}{100\%}$ ----Equation 3.3

3.6.2.2 Unit weight, specific gravity, and water absorption capacity of aggregate

Specific gravity is the ratio of a given volume of aggregate to the weight of an equal volume of water. The water absorption test determines the water holding capacity of the coarse aggregates. It gives an idea of the internal structure of the aggregate and the strength of the aggregate. Apparatus used for sieve analysis is a series of the pan, shovel, balance, sample splitter, wire basket (20 cm diameter and 20 cm in height), absorbent cloth, and oven. Density, specific gravity, and water absorption tests were done according to ASTM C127(2007) standard. To carry out this test, sample was taken by using a sample splitter and sieved with 20- and 4.75-mm sieves to ignore materials retained on sieve opening 20 mm and passed through a sieve opening 4.75 mm. Then the sample was washed to remove dust particles and put in the oven at 110oC for 24 hours. After that, the sample was allowed to cool after being removed from the oven and its weight was measured. The sample was submerged in the water for 24 hours. After the sample was removed from the water, it was rolled in a large absorbent cloth until all visible films of water were removed, and the required weight of the saturated surface dry sample was taken. After being weighted, immediately S.S.D sample was placed in the wire basket, and its weight in the water was determined. Finally, the sample dried to constant weight at a temperature of 110^{o}C, and cooled in the air for 2 hours:

- $Bulk\ specific\ gravity\ = A/\,(A + S - C)$ ----------------------------Equation 3.7
- $Apparent\ specific\ gravity\ = A/\,(B + A - C)$ ----------------------Equation 3.8
- $Absorption\ capacity\ = ((S - A)/A)\ *\ 100$-------------------------Equation 3.9

Whereas:

- A=Weight of oven dry specimen in oven (A).
- B=Weight of pycnometer filled with water (B).
- C=Weight of saturated surface dry specimen (C).
- S=Weight of pycnometer with specimen and water to calibration mark(S).

3.6.3 Tests on cement

3.6.3.1 Normal consistency test for cement

When cement mixed with water cement set and harden into a solid mass up on hydration. The normal consistency refers the amount of water require to make a neat paste of satisfactory workability. The normal consistency test of cement is measured based on the ASTM C 187 standard method. As a result, a vicat apparatus was used to determine the typical consistency.

Test Procedures for normal consistency test of cement 500 grams of cement were measured and taken water added to cement and mixed thoroughly for 3 min. Water amounting to a percentage of cement was 26% for the first trial. cement paste in approximate shaped like a ball with gloved hand by tossing 6 times from one hand to another hand. Then Vicat mold filled with the paste in appropriately and removed any surplus paste. Then, set the Vicat mold on the glass plate, making sure the plunger lightly touches the surface of the Vicat mold. Allow the plunger to sink into the test mold after it has been released. Thirty second after releasing the plunger record its penetration. The paste said to be of normal consistency when the rod settles 10$\pm$1 mm below the original surface within 30 seconds. Repeat the experiment with varied percentages of water until the Vicat apparatus scale reading is between 10$\pm$1 mm. and water amount is calculated by the formula specified on equation .13.

$$percent\ of\ water = \frac{weight\ of\ water\ in\ g}{weight\ of\ cement\ in\ g}\ x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 3.13}$$

3.7 Fresh concrete test.

Fresh concrete is the concrete is referred to as fresh when the setting and hardening process has not yet started. Fresh concrete tests measure factors such as strength, consistency, unit weight, air content, and temperature.

3.7.1 Workability test.

Workability of fresh concrete was measuring slump test. Slump test is the simplest for workability and is most widely used on construction sites. In this study, the workability of the concrete was assessed by using (ASTM-C143) slump test. Three about equal layers were put into a cone – shaped mold with a bottom diameter of 200mm, a top diameter of 100mm, and a height of 300mm. three layer was then tempered with a standard tempering rod using 25 strokes. After the surface was filled and leveled, the mold was removed by lifting vertically. Slump in millimeters, which is the height difference between the mould and the highest point of the subsiding concrete mass, was used to express the workability testing results.

Figure 3.4 slump test

3.7.2 Setting time test.

Setting time is the time required for stiffening of cement paste to a defined consistency. Indirectly related to the initial chemical reaction of cement with water to form aluminium-silicate compound. There are initial and final setting time of concrete. Initial setting time of concrete the time when cement paste starts hardening while the final setting time is time when cement paste has hardened sufficiently. The apparatus and materials used for this study are fresh concrete, vicat's apparatus, balance, measuring cylinder, stopwatch, glass plate, enamel tray, trowel. All procedures must be done based on ASTM C 191.

3.7.3 Density of concrete.

Density of is the required for the indication of weight of structure and properties of concrete. the higher the density of concrete, the strength of the concrete. at the end of the required curing days, 3 concrete cubes specimen were taken out for each mix from curing tank to measure the density of concrete before conducting compressive strength.

The density of concrete was calculated by: -

$$density\ of\ concrete = \frac{\text{mass of concrete in (kg)}}{\text{Volume of concrete in (m3)}} \text{---------------------equation 3.10}$$

3.8 Hardened concrete test.

3.8.1 Compressive strength of concrete.

Compressive strength is regarded as the most important property of hardened concrete. This test was done as per ASTM standard, according to ASTMC-39/C39M. Compressive strength of concrete was evaluated at age of 7 days, 14 days and 28 days using standard cube specimens of 150mmx150mmx150mm. Compressive testing machine of 140kg/cm^2 capacity was used for testing of compressive strength of concrete. Concrete specimens were demoulded 24 hours after the casting and placed in the curing tank to ensure sufficient curing. At each specified age, specimen was, placed centrally between the bearing plates of compression testing machines and load was applied continuously and uniformly at specific loading rate of 140kg/cm^2 per minute till the specimens fail, record the maximum load and calculated using equation 3.3.

$Compressive\ strength\ = F/A$ …………………… Equation 3.11

where F = Force

A= area

3.8.2 Tensile strength of concrete

The 14 days and 28 days tensile strength test for the control and replacement mixes was conducted as BS EN 12390-5:2009, "tensile strength of test specimen." for each mix the tensile strength was done on three concrete cylinder specimen having 150mm diameter and 300mm height. A loading rate of 1.2 kN/s was applied for the tensile test and calculated by:

$T\ =\ 2000P/\ \pi LD$ ---Equation 3.12

Whereas

T = Indirect tensile strength, in MPa

P = Maximum indirect tensile force indicated by the testing machine, in KN

L = Length, in mm

D = Diameter, in mm

3.9 Microstructural properties of concrete

3.9.1 Scanning electron microscopy (SEM)

The scanning microscopy was carried out to find the shape and size of ESP and WPA particles in dry form. The scanning electron microscopy (SEM) is performed on the ash and powder passing through the 90 μm sieve. Samples are taken to the Adama science and Technology University, school of applied science department of biology to perform SEM analysis of the replacement concrete.

3.9.2 X-ray diffraction (XRD)

X-ray diffraction test was conducted to study and examine elemental chemical composition of the replacement material, beside this X-ray diffraction test was to examine amorphous and crystalline structure of eggshell powder and wastepaper ash particles in dry form XRD test is performed on the ash and powder passing through the 90 μm sieve. Samples are taken to the ASTU, school of Mechanical, chemical, and material engineering, department of material engineering to perform XRD analysis of the replacement concrete.

3.10 Environmental and economic implication exploration

The environmental and economic implications of using ESP and WPA as partial cement replacement in concrete were explored in terms of raw materials usage, energy usage, CO_2 emissions, and economic implications. To investigate raw material usage, raw material consumption to produce one cubic meter of concrete without and with ESP and WPA was calculated and compared. The difference in incineration temperatures of cement clinker and ESP and WPA was employed as a parameter to investigate the energy usage and coal consumption of concrete without and with ESP and WPA. To determine CO_2 emissions during the manufacturing of 1 kg of ESP and WPA and compare them to cement CO_2 emissions, coal consumption and the difference in incineration temperature were used as a parameter due to the CO_2 emission of cement highly depends on coal consumption. Lastly, the cost of one cubic meter of concrete without and with 14% of ESP and WPA was computed to explore cost implications.

CHAPTER FOUR

4. RESULT AND DISCUSSION

In this section, the results of the laboratory tests are discussed. The results presented include the properties of material characterization fresh and hardened concrete, microstructural property produced by partial replacement of cement with eggshell powder and wastepaper ash. Slump test for the fresh property was tested. For the hardened property, density, compressive strength and split tensile strength tests were conducted.

4.1 Physical and chemical properties of eggshell and wastepaper ash

In this part the test results were the physical properties of ESP and WPA and chemical properties of ESP and WPA in the form of chemical composition.

4.1.1 sieve analysis of eggshell powder and wastepaper ash

This test was carried out to determine the percentage of fine particles of ESP and WPA that pass through a sieve opening of 75 μm. As shown in Table 4.1, 86% of WPA was passed through sieve opening of 75 μm, whereas 74.6% ESP passed. As a result, WPA is finer than cement and ESP, implying that WPA has a larger specific surface area than cement and ESP.

This is because as particle size decreases, the surface area of substances increases(Juenger & Siddique, 2015). This implies a reduction in particle size utilized to fill the gap between aggregates. However, an increase in the surface area leads to incremental water needs, which leads to compressive strength reduction and durability degradation when the WPA is employed in large amounts.

Table 4.1 sieve analysis of eggshell powder and wastepaper ash

	Cement		Wastepaper ash		Eggshell powder	
Sieve size(μm)	Wt. of retained	% of retained	Wt. of retained	% of retained	Wt. of retained	% of retained
150	175	0	190	0	175	0
90	175	0	190	0	175	0
75	42	24	26.6	14	44.5	25.4
Pan	133		163.4		129.5	
Total	175		190		175	

4.1.2 Specific Gravity of WPA, ESP and cement

The specific gravity of WPA, ESP and cement were 2.79,3.1 and 2.14 respectively. As shown in Table 4.3, the specific gravity of WPA and ESP is smaller than that of cement. This implies ESP and WPA was lighter than cement. Besides, computed specific gravity of cement is within a range of ASTM C188(2009) standard, which ranges (from 3.1 to 3.16). Low specific gravity of ESP and WPA is causes reduction in unit weight of concrete.

Table 4.2 Specific Gravity of WPA, ESP and cement.

Particulars(gram)	symbol	Samples in gram				
			Trail 1	Trail 2	Trail 3	Means value
Wt. of empty flask	W1	Cement	46.82	46.82	46.82	46.82
		ESP	46.82	46.82	46.82	46.82
		WPA	46.82	46.82	46.82	46.82
Wt. of pycnometer with WPA and ESP	W2	Cement	86.82	86.79	86.81	86.80
		ESP	76.79	76.83	76.78	76.80
		WPA	86.77	86.78	86.83	86.79
Wt. of pycnometer with WPA, ESP and Kerosene	W3	Cement	146	145.9	141.75	144.55
		ESP	138.3	139.8	140.5	139.53
		WPA	141	141.7	139.8	140.83
Wt. pycnometer with Kerosene	W4	Cement	124.76	124.73	`124.67	124.72
		ESP	121.3	120.3	119.87	120.49
		WPA	123.2	122.85	121.9	122.65

Water			96.5
Specific gravity	Sp. G	Cement	3.1
		ESP	2.14
		WPA	1.46

4.1.3 Unit Weight of wastepaper ash

Unit weight of ESP and WPA was calculated through obtained test results:

- Weight of empty cylinder (W1) was 4.740 kg.
- Volume of the cylinder was (V) 0.001375 m^3.
- Weight of the cylinder filled with WPA (W2) was 5.78 kg.

Unit weight = (W2-W1)/ V

$$= (5.78 - 4.740)\ kg / 0.001375\ m3 = 756.4\ kg/m^3$$

As the result, unit weight of WPA was lower than the cement that is 1440 kg/m^3.

that indicates wastepaper concrete was lighter than cement concrete.

4.1.4 Unit Weight of eggshell powder

Unit weight of ESP and WPA was calculated through obtained test results:

- Weight of empty cylinder (W1) was 4.740 kg.
- Volume of the cylinder was (V) 0.001375 m^3.
- Weight of the cylinder filled with ESP (W2) was 5.98 kg.

Unit weight = (W2-W1)/ V

$$= (5.98 - 4.740)\ kg / 0.001375\ m3 = 901.8 kg/m3$$

As the result, unit weight of ESP was lower than the cement that is 1440 kg/m3.

that indicates eggshell powder concrete was lighter than cement concrete.

4.2 Chemical composition of ESP and WPA

The chemical composition tests were carried for the elements that characterize the nature of ESP and WPA which included Silicon dioxide (SiO_2), Aluminium oxide (Al_2O_3), Iron oxide (Fe_2O_3), Sodium oxide (Na_2O), Potassium oxide (K_2O) Calcium oxide (Cao), Magnesium oxide (MgO), Sulfur trioxide (SO_3), Loss on ignition (LOI)(Balwaik & Raut, 2011; Kejela, 2020; Vaidya & Bastwadkar, 2019).

Table 4.3 chemical composition of cement(Bedaso, 2022), WPA and ESP.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	MnO	P_2O_5	TiO_2	H_2O	K_2O	LOI
OPC	26.02	5.09	3.48	60.40	1.76	0.34	-	0.1	0.16	0.19	0.56	1.89
ESP	0.09	0.03	0.02	50.7	0.01	0.05	-	0.21	-	-	0.04	43.3
WPA	10.66	<0.01	0.52	47.04	2.00	0.38	0.02	0.09	<0.01	0.01	<0.01	40.50

4.3 physical properties of fine aggregate and coarse aggregate

4.3.1 Silt content of fine aggregate

The material in fine aggregate which is finer than 75µm is generally regarded as silt. The amount of silt content greater than 6 % in the sand for concrete has a severe effect on the quality of concrete strength and workability. From the silt content test performed on the sand, it was found that the original average silt content was 3.3%.the Ethiopia standard of sand silt content does not exceed 6%. If it exceeds it recommend the sand properly wash or reject. According to (Dinku, 2002)construction materials laboratory manual, the average silt content of the sand used for the mix was determined using equation 3.1

$$\text{Silt content} = \frac{A}{B} \times 100\%$$

Whereas A = silt content layer height
B = sand +silt content layer height

Table 4.4 Silt content value of fine aggregate

Sample	Height of sand +silt content in ml (A)	Height of silt content in ml (B)	Calculation	value
Trail 1	800	23	=B/A*100	2.88
Trail 2	800	29	=B/A*100	3.63
Trail 3	800	27	=B/A*100	3.38
	Average silt content value of fine aggregate			**=3.3**

4.3.2 Sieve Analysis and fineness modules

This is a procedure for the determination of the particle size distribution of the aggregate. It is also used to determine the fineness modulus, an index to the fineness, coarseness, and uniformity of aggregates. These properties of the aggregate greatly affect the property of the concrete. There for, fine aggregate and coarse aggregate with gradation satisfying the grading requirement of Ethiopian standard (ES C.D3. 201 as shown in table below respectively) were used throughout the experiment.

Table 4.5 Fine aggregate gradation used for test.

Sieve size (mm)	Weight retained (g)	Percentage retained (%)	Cumulative retained (%)	Weight passing (g)	Percentage passing (%)	ASTM C33 requirements
9.50	0	0	0	0	0	100
4.75	0	0	0	500	100	95-100
2.36	49	9.8	9.8	490	90	80-100
1.18	96	19.2	29	467	67	50-85
0.63	123	24.6	53.6	402.6	35.6	25-60
0.3	180	36	89.6	309.6	7	10-30
0.15	45	9	98.6	212	2.4	2-10
Pan	7	1.4	100	112	0	0
Total	500		= 280.6			

Fineness modulus of fine aggregate = $\frac{\text{cumulative \% of retained}}{100\%}$ that means = $\frac{280.6}{100}$

Fineness Modulus limits for fine aggregate ranges from **2.5 to 3.1.** The FM of fine aggregate which is used for this research is become 2.81 so it is acceptable.

Figure 4.1 Sieve analysis test of fine aggregate

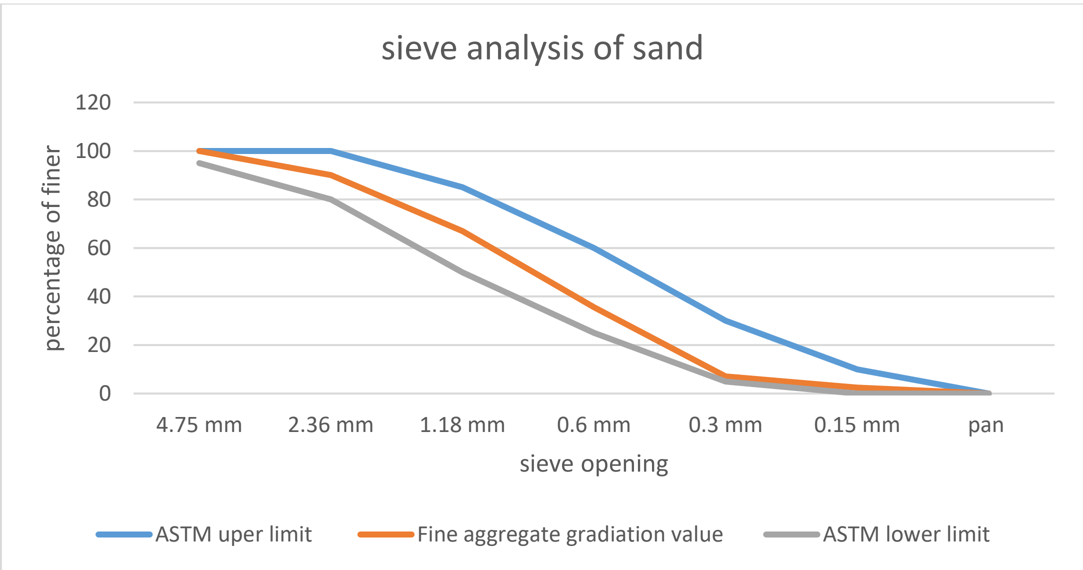


Figure 4.2 Gradation curve of fine aggregate sample vs ASTM lower and upper limit.

FM of the fine aggregate fraction is also an important predictor of other characteristics of both plastic and hardened concrete like workability, finish ability, shrinkage, porosity, permeability, strength, and the tendency to crack. A higher FM index indicates coarser aggregate that produce a “harsh” mix, prone to segregation and difficult to place and finish properly. A low FM indicates finer aggregate that require additional cement and increase water demand. This mix is easier to place and finish, but costlier, with increased potential for early-age cracking. According to ASTM C33 (2003) Fineness modules value in range from 2.3 to 3.1. So, this sand is acceptable in terms of gradation distribution since its FM is 2.8. To assure the existence of fine aggregate gradation lied in between ASTM standard lower and upper limit the following gradation curve is plotted and as shown in Figure 4.2 the fine aggregate used in this experimental research meet ASTM standard.

4.3.3 Unit weight, specific gravity, and water absorption capacity of aggregate

Unit weight, Specific gravity and water absorption of fine aggregate were computed through obtained test results:

- Weight of oven dry specimen in oven (A) was 490 grams.
- Weight of pycnometer filled with water (B) was 1465gram.
- Weight of saturated surface dry specimen (C) was 500 grams.
- Weight of pycnometer with specimen and water to calibration mark(S) was 1772 gram.

From the calculation in Table 4.6, bulk and apparent specific gravity of fine aggregate were 2.5 and 2.61 respectively. While obtained water absorption of fine aggregate result is 2.04 %. The obtained result, for specific gravity of fine aggregate was between limit (2.5 to 3.0) that specified by ASTM C127.

As specific gravity, unit weight, moisture content and absorption capacity affect quality and type of concrete and as such parameters are input for mix designing, these parameters were determined for both fine and coarse aggregate according to ASTM C29 and ASTM C127 test methods. The results of the tests are summarized on.

Table 4.6 Specific gravity, and water absorption capacity of fine aggregate

Aggregate type	Apparent specific gravity	Specific gravity (bulk SSD)	Absorption capacity (%)
Fine aggregate	ASG= A/(A+B-C)	BSG= S/(B+S-C)	WA=((S-A)/A) *100
	$= \frac{490}{(490+1465-1764)}$	$\frac{500}{(1465+500-1764)}$	$= \frac{500-490*(100)}{490}$
Result	**=2.61**	**= 2.5**	**=2.04**

4.3.4 Unit Weight Unit weight of fine aggregate was computed through the obtained test results:

- Weight of empty cylinder (A) was 4.734 kg.
- Volume of the cylinder was (V) 0.001375 $m^{3.}$
- Weight of the fine aggregate plus the cylinder (C) was 6.694 kg.
- Unit weight = (C-A)/ V

= (6.694-4.734) kg / 0.001375 m3 = 1,425.45 kg/m3

4.3.5 sieve analysis and fineness modulus of coarse aggregate

Concrete is made of many components but is mostly made up of materials known as coarse aggregates. Coarse aggregates have a wide variety of construction applications because they resemble standard rock particles, as opposed to fine aggregate, which more closely resembles sand. Coarse aggregates are an integral part of many construction applications, sometimes used on their own, such as a granular base placed under a slab or pavement, or as a component in a mixture, such as asphalt or concrete mixtures. Coarse aggregates are generally categorized as rock larger than a standard No. 4 sieve (3/16 inches) and less than 2 inches. Crushed gravel that adheres with ASTM C33/C33M standards will be obtained from a nearby quarry and utilized as the coarse aggregate in the concrete samples. The coarse aggregate used for the experiment should generally be durable, chemically inert, and durable, devoid of plant materials, absorb less than 5% water, and not be sharp or angular. For this experimental investigation, sieve analysis, specific gravity, unit weight, and water absorption are the most crucial coarse aggregate tests.

Table 4.7 Coarser aggregate gradation used for test.

Sieve size (mm)	Weight retained (g)	Percentage retained (%)	Cumulative retained (%)	Percentage passing (%)	ASTM C33 requirements
25	0	0	0	0	100
19	34	1.47	2.27	97.43	95-100
12.5	600	25.9	22.94	77.06	40-80

9.5	690	46	57.8	54	20-55
4.75	978	41.6	99.4	0	0-10
Pan	9	0.6	100		
Total	2000		=**682.4**		

Fineness modulus of coarse aggregate = $\frac{\text{cumulative \% of retained}}{100\%}$ that means = $\frac{682.4}{100}$

Fineness Modulus limits for coarse aggregate ranges from **5.5 to 8.0.** The FM of coarse aggregate which is used for this research is become 6.82 so it is acceptable.

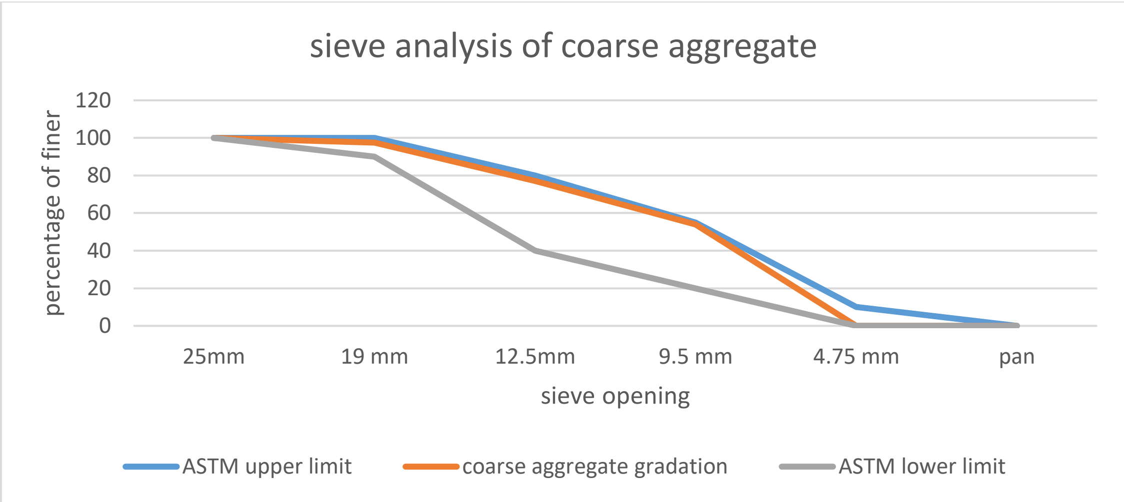


Figure 4.3 Gradation curve of coarse aggregate sample vs ASTM lower and upper limit.

4.3.6 Specific gravity, and water absorption capacity of aggregate

Specific gravity and water absorption of coarse aggregate were computed through obtained test results:

- Weight of oven dry specimen in oven (A) was 3000 grams.
- Weight of saturated surface dry specimen (B) was 3035 grams.
- Weight of specimen in the water with the wire basket (C) was 1851 gram.

From the calculation in Table 4.8 bulk and apparent specific gravity of coarse aggregate were 2.54 and 2.61 respectively. While obtained water absorption of aggregate result is 1.17.

Table 4.8 Specific gravity, and water absorption capacity of coarse aggregate.

Aggregate type	Apparent specific gravity	Bulk specific gravity (BSG)	Absorption capacity (%)
Coarse aggregate	ASG= A/(A-C)	BSG= B/(B-C)	WA=((B-A)/A) *100
	=3000/ (3000-1851)	=3035/ (3035-1851)	(3035-3000) *100/3000
	=2.61	**=2.54**	**=1.17%**

4.3.7 Unit weight of coarse aggregate was computed through the obtained test results:

- Weight of empty cylinder (T)=4.734kg
- Weight of empty cylinder plus aggregate=7.05kg
- Weight of coarse aggregate (A) was 2.316 kg.
- Volume of the cylinder was (V) 0.001375 $m^{3.}$
- Unit weight = A/ V

= 2.316 kg / 0.001375 m3 = 1684.36kg/m3

4.4 water

Portable water is used in the study for both mixing and curing. Clean water that is free from organic matter, silt, oil, and acidic materials was be used. The quantity of water is the most important parameter and is controlled by the w/c ratio. As the quantity of water in a mix goes up the strength decreases, durability decreases, and workability increases.

4.5 Workability of fresh concrete

In order to assess the workability of the fresh concrete the slump test was conducted. A concrete mix should be workable enough in order to be placed, compacted and finished. The ingredients in concrete should be in such a proportion as to allow a good workability of the concrete and sufficient strength to support the required load after hardening. Table 4.3 below gives these workability values for the control and blended concrete.

Table 4.9 slump test

S/N	Mix code	W/C(OPC+ESP+WPA)	Slump value in (mm)
1	Mix 0	0.58	25
2	Mix 1	0.58	24
3	Mix 2	0.58	23.5
4	Mix 3	0.58	23
5	Mix 4	0.59	23

As can be seen from Table 4.9 the slumps of the concrete containing ESP and WPA have shown a slight reduction as the ESP and WPA content increases. This can be an indication that OPC- ESP and WPA blended concretes needs higher water content than trail mix. The reason for this might be the higher specific surface area of the ESP and WPA and its lower density giving it a higher porosity, resulting in higher water demand. To get similar slump for the control and OPC- ESP and WPA concrete, the water content can be increased as the ESP and WPA content increases.

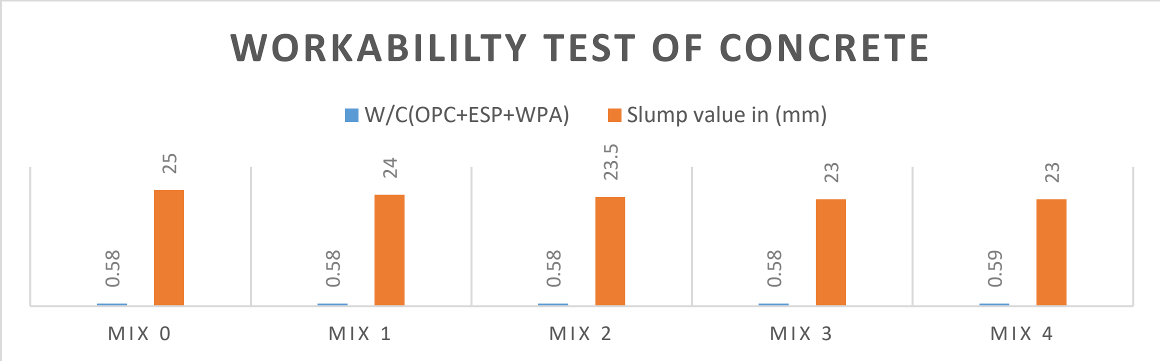


Figure 4.4 Workability test of concrete.

4.5 Density of concrete

At the end of the required curing days, 3 concrete cubes specimen were taken out for each mix from curing tank to measure the density of concrete before conducting compressive strength.

Table 4.10 Density of 150mm cubes OPC+WPA+ESP concrete on 7 days.

S/N	Mix code	Average weight of concrete in kg	Average density in kg/m^3
1	Mix 0	7.94	2352.6
2	Mix 1	7.91	2343.70
3	Mix 2	7.86	2328.89
4	Mix 3	7.56	2240.00
5	Mix 4	7.34	2170.08

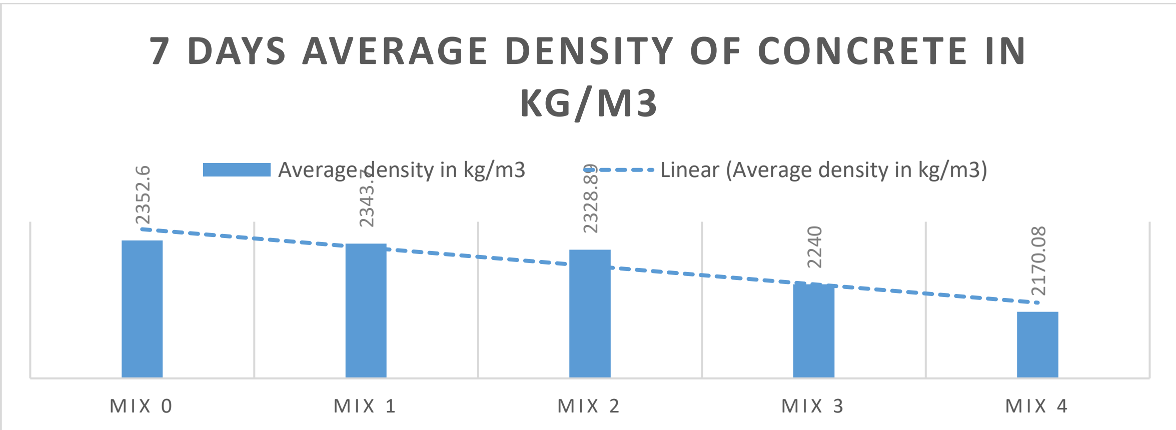


Figure 4.5 Density of 150mm cubes OPC+WPA+ESP concrete on 7 days

Table 4.11 Density of 150mm cubes OPC+WPA+ESP concrete on 14 days

S/N	Mix code	Average weight of concrete in kg	Average density in kg/m^3
1	Mix 0	7.62	2257.8
2	Mix 1	7.58	2245.9
3	Mix 2	7.54	2234.1
4	Mix 3	7.43	2201.5
5	Mix 4	7.42	2198.5

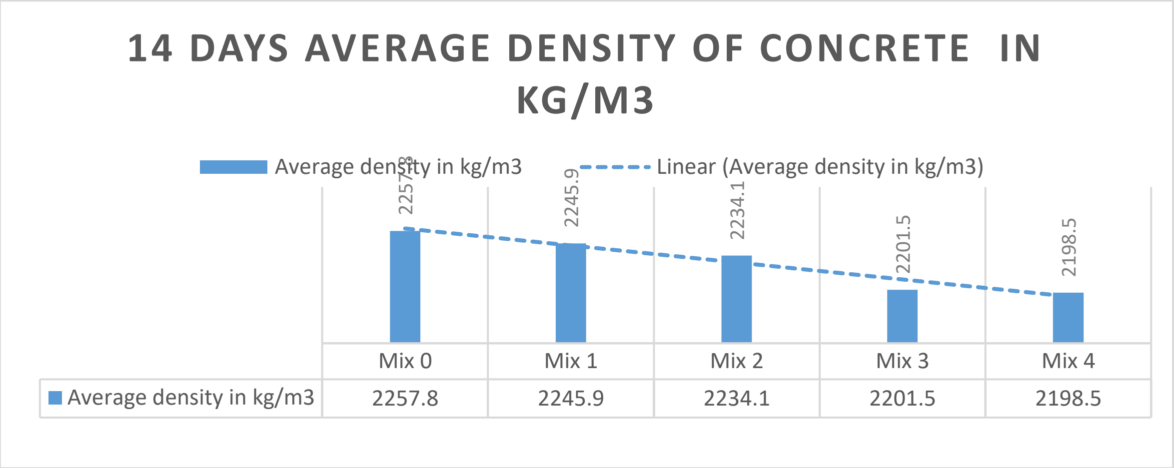


Figure 4.6 Density of 150mm cubes OPC+WPA+ESP concrete on 14 days.

Table 4.12 Density of 150mm cubes OPC+WPA+ESP concrete on 28 days.

S/N	Mix code	Average weight of concrete in kg	Average density in kg/m^3
1	Mix 0	8.09	2397.04
2	Mix 1	7.99	2367.4
3	Mix 2	7.87	2331.85
4	Mix 3	7.59	2248.89
5	Mix 4	7.27	2154.07

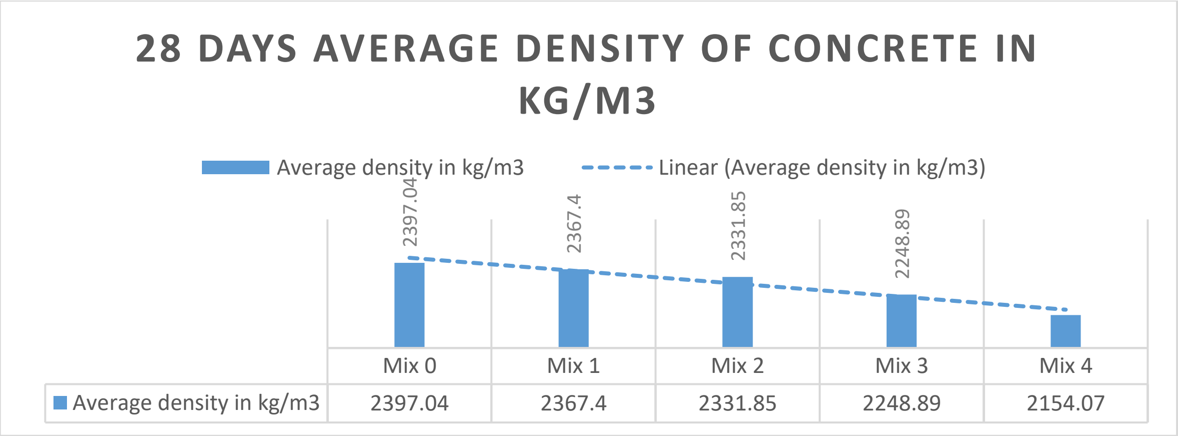


Figure 4.7 Density of 150mm cubes OPC+WPA+ESP concrete on 28 days

The above figure and table show the variation of weight and density of concrete made with OPC and variety of replacement at 7days ,14days and 28 days. The results show that there was a decrease in the density of concrete made off with a blend of wastepaper and eggshell powder compared to the control mix at 7days ;14days and 28 days. The density of a blend concrete decreased because, density of wastepaper and eggshell powder is less than density of cement. However, all the densities exceeded the 1850kg/m^{3}which is the maximum density required for lightweight aggregate concrete(A. M. Neville, 1995).

4.6 Hardened concrete properties.

4.6.1 Compressive strength of concrete

The compressive strength test of concrete is the most common test type for the hardened concrete. The reasons for these are many codes and design manuals are based on this property, many other properties of concrete depend on the compressive strength and when compared to other tests this is an easy one. Figure 4.4.1 below shows a compressive strength test under progress.

Figure 4.8 Compressive strength of concrete being tested.

The compressive strength of each of the concrete is determined by testing the cubes in a compression machine. For each of the mixes the average value of three samples is taken as their compressive strength.

Table 4.13 Shows this compressive strength values:

S/N	Mix code	Average compressive strength					
		7 days		14 days		28 days	
		Load (kN)	Strength (N/mm$_2$)	Load (kN)	Strength (N/mm^2)	Load (kN)	Strength (N/mm$_2$)
1	Mix 0	486	21.6	648	28.76	826	36.7
2	Mix 1	517	23	659	29.3	871	38.7
3	Mix 2	490	21.8	652	29	842	37.41
4	Mix 3	432	19.2	594	26.4	621	27.6
5	Mix 4	396	17.6	554	24.6	543	24.1

The compressive strength for control, WPA and ESP concrete were tested at 7days ,14days and 28days (Figure 4.9). The first mix (4%WPA and 6%ESP) showed better compressive strength than the other mixes include the control mixes at later and early ages (i.e.,7days ,14days and 28 days) and the second mix (6%WPA and 8%ESP) showed better compressive strength than control mix but less than mix one. i.e., Compressive strength of concrete decreased as WPA and ESP replacement level increased, 18%WPA and ESP and 22%WPA and ESP showed 8% and 14.3% less strength than the control concrete.

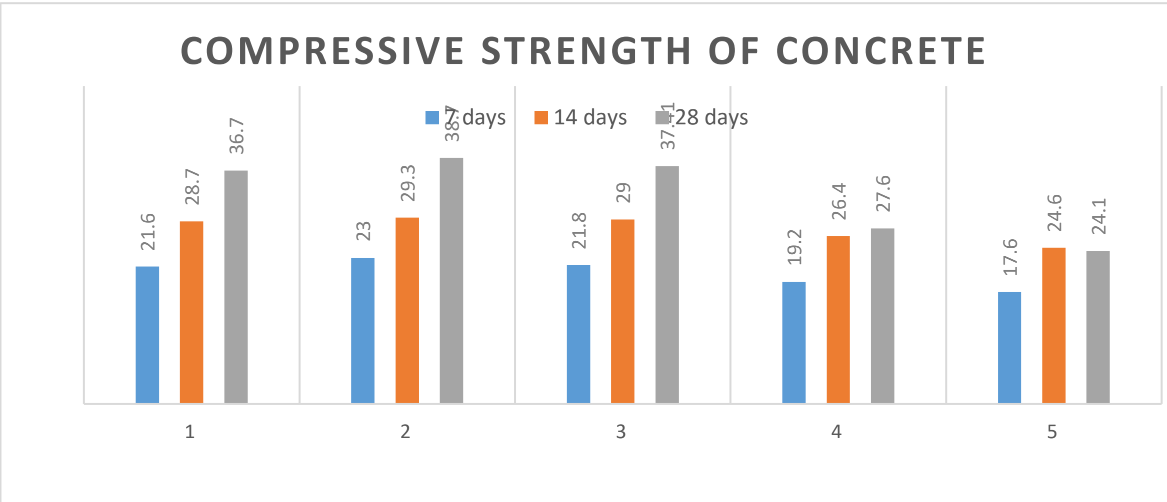


Figure 4.9 Compressive strength of concrete with WPA an ESP blend.

All concrete achieved the characteristic strength of 25 MPa at 28 days except 18% a blend of WPA and ESP and a blend of 22%WPA and ESP Figure 4.9 shows that WPA and ESP blend concrete produced the highest strength (37.41 MPa) at 28 days. However,14% a blend of WPA and ESP achieved compressive strength. The other mix concrete showed lower strength gain than other concrete.

Control concrete achieved a strength of 36.7 MPa at 28 days. A blend of 4%WPA and 6%ESP concrete achieved 5.4% strength than control concrete, whereas a blend of 6% WPA and 8%ESP, 8% WPA and 10%ESP, and 10% WPA and 12%ESP concrete obtained 1.93% increased, -6%decreased and -10.6% decreased respectively.

4.6.2 Split tensile strength of concrete

The split strength test of concrete is the most common test type for the hardened concrete. The reasons for these are many codes and design manuals are based on this property, many other properties of concrete depend on the split tensile strength and when compared to other tests this is an easy one. Figure 4.10 The split tensile strength tests of the concrete with WPA and ESP as a partial cement substitute were conducted at 7days and 28 days.

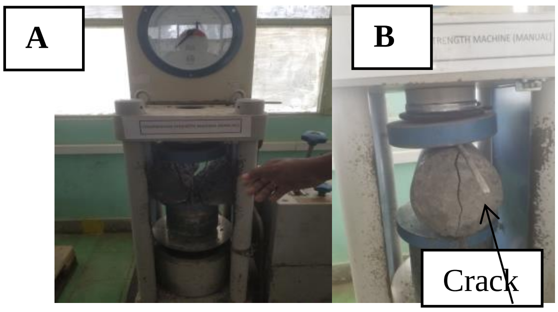


Figure 4.10 Failure pattern of concrete in split tensile stress(A) and crack pattern of ESP and WPA concrete(B).

The split tensile strength of each of the concrete is determined by testing the cylindrical Mold in a tensile strength machine. For each of the mixes the average value of three samples is taken as their compressive strength.

Table 4.14 shows this split tensile strength values:

		7 days			28 days		
S/N	Sample code	Average weight in (kg)	Average load of tensile in (KN)	Tensile strength in (MPa)	Average weight in (kg)	Average load of tensile in (KN)	Tensile strength in (MPa)
1	Mix 0	12.2	88	1.25	12.84	113	1.6
2	Mix 1	12.63	95	1.34	12.68	151.2	1.9
3	Mix 2	12.32	88	1.25	12.63	130	1.84
4	Mix 3	12.29	75	1.06	12.6	106	1.51
5	Mix 4	12.52	51.6	0.73	12.44	98.3	1.39

The split tensile strength for control, WPA and ESP concrete were tested at 7days and 28days (Figure 4.11). The first mix (4%WPA and 6%ESP) showed better split tensile strength than the other mixes include the control mixes at later and early ages (i.e.,7days and 28 days) and the second mix (6%WPA and 8%ESP) showed better split tensile strength than control mix but less than mix one. Split tensile strength of concrete decreased as WPA and ESP replacement level increased, 18%WPA and ESP and 22%WPA and ESP showed 15.2%; 5.6% at 7 days and 41.6; 13.13% at 28 days less strength than that of control concrete.

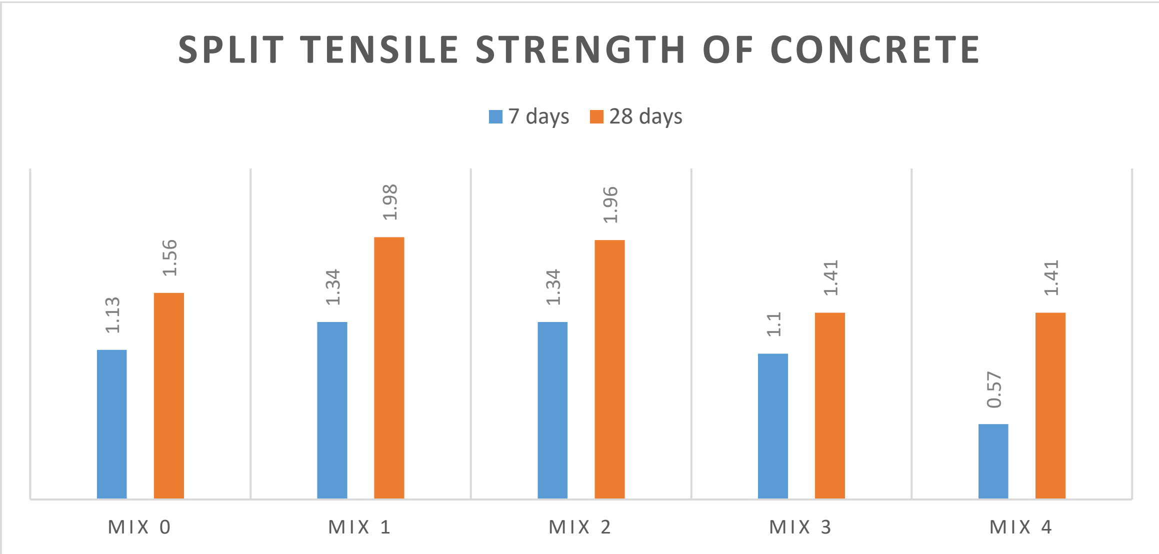


Figure 4.11 Split tensile strength of concrete with WPA an ESP blend.

4.6 microstructural properties of concrete

4.7.1 Scanning Electro-microscope properties of concrete.

Microstructural observation of mixes convectional concrete and with ESP and WPA concrete through SEM analysis can be seen in the Figure 4.13. convectional and 14% replaced mixes were investigated using SEM due to the maximum compressive strength, better workability, and split tensile strength observed at 14% replacement versus convectional concrete. SEM images are taken after a prolonged curing period of 28 days and explored under (x600 and x1000) magnification to investigate the microstructure of the concrete. The microstructure of concrete can be described in the aspects of hydrated cement paste, which represents the hydration products of cement and water reaction, and the main product of this reaction is the calcium silicate hydrate (C-S-H) gel; (ii) pore structure, which refers to the gel pores, capillary pores, and voids. In both samples, C-H (brightness and hexagonal panels) and C-S-H (irregular hexagonal panel and sheet-like structure) are the major hydration products. In OPC (Figure 4.14a), a needle-like structure is visible, which indicates the presence of ettringite. In samples containing ESP and WPA (Figure 4.8b), ettringite is not shown, because of the presence of calcium carbonate in the sample. While ESP and WPA concrete pore structure is becoming more refined, it is still dense at 14% replacement, as shown in Figure 4.14(b). The mix with 14% ESP and WPA replacement could be seen, as could reduce voids on the surface due to improved hydration and a high occurrence of calcium silica hydrate (C-S-H) gels on the surface, as short noted by the networked Fiber structure. This could account for the maximum compressive strength and Tensile strength achieved at 14% mixes.

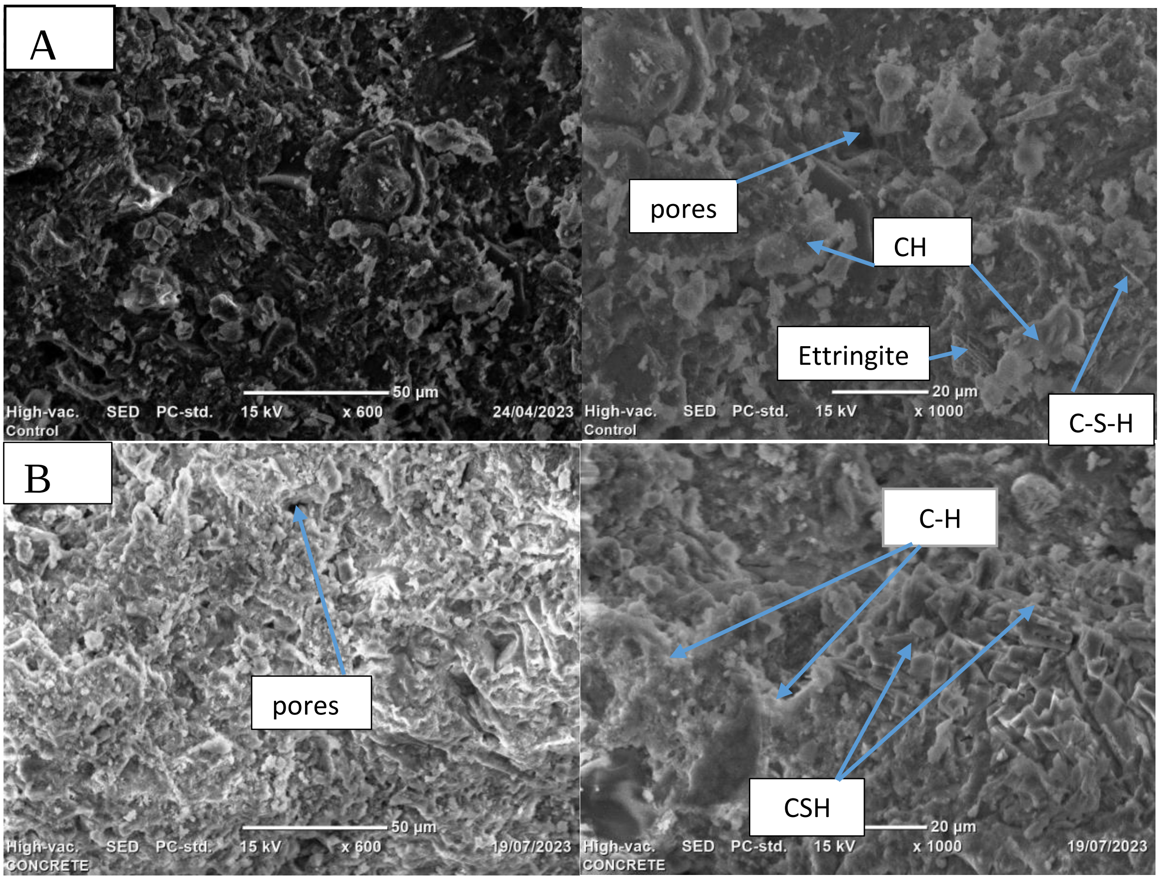


Figure 4.2 SEM images of concrete A) Plain concrete and B) 6%WPA and 8% ESP concrete.

4.7.2 X-Ray Diffraction (XRD) Analysis

X-ray diffraction (XRD) is crucial for characterizing and examining crystalline materials. This technique offers insights into materials' atomic structure, crystallography, and phase compositions (Bunaciu et al. 2015). This study used this analysis method to explore the oxide/hydroxide formation in concrete samples with and without adding ESP and WPA concrete samples. In addition to this, this study seeks to identify the development of crystalline structures, as well as to determine the size of the crystalline according to X-ray diffraction analysis.

The experiment involved X-ray diffraction (XRD) analysis using a Shimadzu XRD 7000 machine. The measurement conditions were set: the X-ray tube had a copper (Cu) target, operated at 40 kV voltage and 30 mA current. The slits used in the analysis included a divergence slit set at 1.0000 degrees and a receiving slit with a width of 0.300 nm. The scanning was performed along the Theta-2Theta drive axis, covering an angle range from 10.00 to 80.00 degrees. A continuous scan mode was used with a scan speed of 3.00 degrees per minute and a sampling pitch of 0.200 degrees between data points. Prior to the scan, a pre-set time of 0.40 seconds was allowed. The obtained XRD data was then processed and analyzed using Origin Pro 2022 software and X-pert high scope software, which facilitated the visualization of peaks and provided tools for further analysis of the generated graphs. By utilizing the Shimadzu XRD 7000 machine, specific measurement conditions, and the Origin Pro 2022 software, the experiment aimed to study the crystalline structure and phase composition of the samples under investigation.

Phase Assemblages in Cement Hydration

The X-ray diffraction (XRD) analysis revealed the presence of various crystalline phases. Figure 4.15 shows the XRD peaks of the cement concrete and ESP and WPA concrete. The peaks corresponding to the formation of calcium silicate hydrate (CSH) gel were observed at 2θ angles of 27.54°, 29.6°, 29.54°, 39.36°, 29.46°,34.16, and 37.32 which are consistent with the hkl values of 006, 221, 221, 131, 221, 131, and 221, respectively (ICDD card number 033-0306). Portlandite (calcium hydroxide) crystals were identified by peaks at 2θ angles of 18.08°, 29.26°, 47.22°, 47.38°, and 60.1°, corresponding to hkl values of 001, 100, 023, 102, and 110 (ICDD card number 004-0733). The addition of ESP and WPA at concentrations of 6% and 8% respectively resulted in the formation of calcite (calcium carbonate), observed at 2θ angles of 29.46°, 26.76°, and 49.54°, corresponding to hkl values of 104, 012, and 024 (ICDD card number 005-0586).

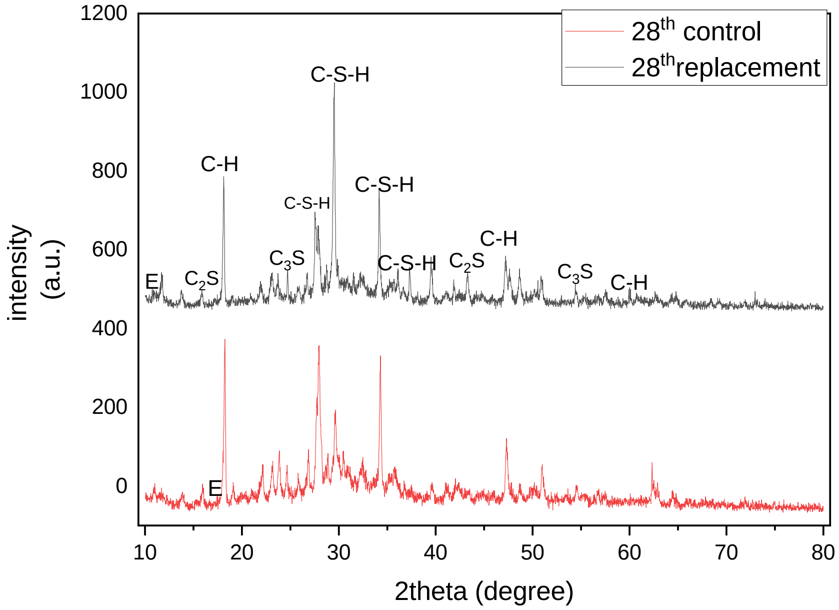


Figure 4.12 XRD pattern for OPC concrete and 8%ESP and 6%WPA concrete sample

Table 4.5 Crystalline size determination for XRD peaks

	2θ	d (A°)	FWH	int	Integrated int	D=λ*k/βcosθ
Control sample	27.983	3.1859	0.1109	450	3100	77.08
	18.172	4.8778	0.1254	340	3148	67.01
	29.523	3.0231	0.2022	253	2901	44.08
14%Blend Concrete	29.528	3.0226	0.2142	340	3995	40.1
	27.626	3.226	0.2302	134	1392	37.12
	18.170	4.8782	0.1906	198	2169	44.12

The table above provides significant findings regarding the samples' crystalline size and interplanar spacing. The results indicate that the sample without any addition (0% addition) exhibits the largest crystalline size, with a D value of 77.08. This sample also shows the highest interplanar spacing, with a value of 10.07. Based on visual observations and the XRD analysis of hydration products, it can be inferred that impurities, such as corroded particles and Friedel's salt formation, contribute to this sample's observed larger crystalline size.

On the other hand, among the samples with varying additions, the highest crystalline size (D value of 44.12) is observed in the sample with a 18% ESP and WPA addition. Furthermore, the table demonstrates a similar interplanar spacing (d) arrangement in all the concrete samples. This indicates that samples have larger crystalline sizes, further reaffirming their improved formation of hydration products.

In this study, XRD analysis has proven to be a valuable method for identifying the various crystalline phases present in a sample and determining their abundance and crystallographic properties. However, this technique does not directly reveal the sample's morphology, texture, or surface characteristics. Alternatively, SEM analysis employs an electron beam to produce high-resolution images of the sample's surface, providing insights into topography, texture, grain size, and elemental distribution.

4.8 Environmental and Economic analysis

4.8.1 Introduction

Today's world is concerned with sustainability of human activities. Concerns about the environment we will leave behind for future generations are at the heart of sustainability. Its main areas of concentration are the social, environmental, and economic aspects of our activities. It is known that cement is one of the basic materials used in the production of concrete. However, the production of cement is both environmental unfriendly and uneconomical as compared to the other constituents of concrete, showing that the cement industry has sustainability problems. In order to alleviate these problems of the cement industry different methods were being implemented specially in the developed countries. One of these methods is the use of different cement replacing materials which have lower cost of production, lower emission of CO2, and lower energy consumption implying a more environmentally friendly and economical material.

Eggshell powder and wastepaper ash was found to have a great potential to be used as a cement replacing material in some parts of the world. The use of this material as a cement replacement reduces the cost of cement, the CO2 emission, and energy.

4.8.2 Environmental advantages

This study used embodied energy and CO_2 emission coefficients of OPC 3.67 GJ/ton and 0.84 respectively, which is studied by (Beressa & Saradhi, 2021), in addition this study used (Woubishet & Abegaz, 2019)studies employed Senegal, embodied energy and CO_2 emission coefficient of coarse aggregate and fine aggregate due to a lack of research in Ethiopia.
As presented in the previous researcher, the cement industry releases about one ton of CO_2 for each ton of Portland cement production. In addition to this concrete consumes vast number of natural resources for aggregate and cement production. Replacing the portion of Portland cement with a blend of WPA and ESP can substantially reduce the environmental impact of concrete. The most significant environmental factors are virgin material use and CO_2 emissions.

4.8.3 Raw materials saving

Cement is a pillar to develop infrastructures in Ethiopia. At the same time, cement production affects the local environment and nearby communities. The main environmental issues associated with cement production are consumption of raw materials and energy use as well as emissions to air. Natural resources are limited therefore, they must be optimally consumed. This shall help not only to control degradation of environment but conserve them also for the use of future generation. This can be achieved by the process of recycling of waste materials, disposal of which otherwise is a serious problem.

4.8.4 Consumption of raw materials in cement production

Cement manufacture is a high-volume process. Typical average consumptions of raw materials to produce cement are indicated in Table 4.6. The production of one ton of Portland cement required approximately 1.46 tons of raw materials. Table 4.6 Consumption of raw materials in cement production in tones(Stajanča & Eštoková, 2012)

Table 4.16 raw materials consumption for 1 ton cement.

Materials (dry basis) Per ton cement	**Materials (dry basis) Per ton cement**
Limestone, clay, shale, marl, other	1.27
Gypsum, anhydrite	0.05
Mineral additions	0.14
Total Raw Materials	1.46

For example, to produce 2 billion tons of cement annually, we need about 2.92 billion tons of raw materials. A blend of eggshell powder and wastepaper ash as a replacement of cement can save an enormous number of raw materials. This waste materials may have an impact on the emissions behaviour of the process and an effect on the emissions. Therefore, utilization of eggshell powder and wastepaper ash have double advantage. Table 4.16 shows raw materials saved by replacement of cement with eggshell powder and wastepaper ash.

Table 4.17 Raw materials saving in one ton of cement production.

Percentage of blend concrete	0%	10%	14%	18%	22%
Total raw materials	1.46	1.31	1.26	1.2	1.14
Saving of raw materials (%)	0	10.3	13.7	17.8	21.9

As indicated in Table 4.17, replacing 10%, 14% ,18% and 22% of cement by a blend of eggshell powder and wastepaper ash will reduce 10.3%, 13.7%, 17.8 and 21.9% of raw materials respectively. To produce 2 billion tons of cement annually, we need about 2.92 billion tons of raw materials. By replacing 14% of cement by eggshell powder and wastepaper ash we can produce 2 billion tons of cement with 2.52 billion tons of raw materials. Therefore, we can save 0.4 billion tons of raw material using a blend of 14% replacement.

4.8.5 consumption raw material in concrete

Using wastepaper ash and eggshell powder, which is a recycled material, will save a great deal of virgin materials. This is because when inventorying the materials that are used to manufacture concrete, only the virgin materials are included in the comparative calculations not recovered materials (i.e., wastepaper ash and eggshell powder), because recovered materials already exist and would be disposed if not productively utilized. Table 4.19 shows the comparative calculation of virgin materials.

Different assumptions were made to get the virgin material saving. These are as follows:

- 6% wastepaper ash and 8%eggshell powder wastage was assumed for the wastepaper ash and eggshell powder production, even though only grinding is involved,
- the mass of raw materials to manufacture Portland cement is assumed to be 1.6 times as much as the mass of finished Portland cement (Prusinski, Marceau et al., 2004),
- wastepaper ash and eggshell powder is not included as a virgin material, because it is a recycled material.

Table 4.18 Raw material input for one cubic meter of concrete.

Mix code	WPA and ESP 0%	WPA and ESP 10%	WPA and ESP 14%	WPA and ESP 18%	WPA and ESP 22%
OPC (kg/m^3)	371	333.9	319.06	304.22	289.38
ESP (kg/m^3)	0	22.26	29.68	37.1	44.52
WPA (kg/m^3)	0	14.84	22.26	29.68	37.1
Water (kg/m^3)	184.8	184.8	184.8	184.8	184.8
Fine Aggregate (kg/m$^{3)}$	924	924	924	924	924
Coarse aggregate (kg/m^3)	1171	1171	1171	1171.8	1171.8
Total (kg/m^3)	2650.8	2650.8	2650.8	2650.8	2650.8
Virgin materials (kg/m^3)	2650.8	2613.7	2598.8	2584.02	2569.18
Saving in %	0	1.4	1.96	2.52	3.08

As can be seen from Table 4.18, in the above-mentioned 14%replacement of cement saved about 1.96% of virgin materials compared to the control sample, which is about 52kg/m^3.

4.8.6 Embodied energy

Embodied energy is the total energy required for the extraction, processing, manufacture, and delivery of building materials to the building site. Energy consumption produces CO2, which contributes to greenhouse gas emissions, so embodied energy is considered an indicator of the overall environmental impact of building materials and systems (Reddy & Jagadish, 2003) Calculating the embodied energy of concrete materials is crucial for choosing the optimal choice for decreasing a structure's entire energy consumption and environmental influence. The embodied energy (EE) is computed by summing the product of the quantity of each material (QM) with its embodied energy coefficient (EEC) (Nizam, Zhang et al., 2018).

4.8.6 Energy in transportation of concrete materials

Transportation of materials is a major factor in the cost and energy of a building. Bulk of the concrete materials in urban and semi-urban centers are transported using mini truck. The transportation distance may vary depending upon the location of construction materials.

The Table below shows the material's distance from the source to the place where experiment is conducted (ASTU) with their respective source location used for this study. Natural sand and crushed stone aggregate consume about 1.75 MJ/m^3 for every one km of transportation distance (A. Ali, Hagishima et al., 2013). Assuming cement are also transported using truck 1MJ/ton/km diesel energy is spent (Reddy & Jagadish, 2003). Based on the researcher the embodied energy of materials utilized in this study was computed in Table 4.16. The embodied energy of concrete materials including transportation energy.

Table 4.19 Material transportation distance from the source to ASTU

No	material type	location	distance (km)
1	Natural river sand	Metehara	94
2	Coarse aggregate	kurfa (crushing site) adama	7
3	Cement	national cement agent(adama)	2.5

Table 4.20 Transportation energy of materials per distance

material type	distance (km)	energy (MJ/m3/km)	total energy (MJ/m^3)
Natural river sand	94	1.75	164.5
Coarse aggregate	7	1.75	12.25
		Energy (MJ/kg/km)	Energy (MJ/kg)
Cement	2.5	0.001	0.0025

Table 4.21 Transportation energy of materials (MJ/1m^3) for C-25 conventional concrete.

Material Type	Quantity	Unit	total energy (MJ)	total energy (MJ)
Natural river sand	0.61	m^3	164.5	100.35
Coarse aggregate	0.68	m^3	12.25	8.33
Cement	0.434	m^3	2.14	0.93

Table 4.22 total embodied energy of materials (MJ/1m^3) for C-25 conventional concrete.

	Materials	QM Kg	EEC Kg	EE (MJ)	Transport. E (MJ)
1	Cement	371	3.67	1361.57	0.93
2	Natural river sand	924	0.06	55.44	100.35
3	Coarse Aggregate	1171	0.16	187.36	8.33
	Total			1604.37	109.6
	Grand total embodied energy				**1713.97MJ**

Table 4.23 Total embodied energy of materials (1m3) for C-25 concrete with 14% replacement.

Materials	QM (Kg)	EEC (MJ/Kg)	EE (MJ)	Transportation E. (MJ)
Cement	319.06	3.67	1170.95	0.93
Eggshell powder	29.68	-	-	-
Wastepaper ash	22.26	1.27	25.73	-
Natural river sand	924	0.06	55.44	100.35
Coarse Aggregate	1171	0.16	187.36	8.33
Sub Total			1494.92	109.6
Ground total embodied energy				1608.99

wastepaper ash burned 500 ^{o}C and Embodied energy of wastepaper ash conversion factor with cement and calculate by using the following formula: -

$$\text{Embodied energy of wastepaper} = \frac{\text{burning to wastepaper}}{\text{burning to cement}} * \text{embodied energy of cement}$$

4.8.7 Reduction of CO2 Emissions

One of the challenges is the sustainable development of the cement and construction industries in terms of environmental impact. One ton of Portland cement emits approximately one ton of CO2 into the atmosphere during the manufacturing process. The cement industry accounts for approximately 8% of total global CO2 emissions(Akpenpuun, Akinyemi et al., 2019). The majority of CO2 emissions and energy use in the cement industry are related to clinker production.The weighted average globally is approximately 0.84 kg of CO2 per kg of cement (Beressa & Vijaya Saradhi, 2021). When compared to cement, the use of WPA reduced CO2 emissions by 33.53kg of CO2 for 1m^3 of concrete. In general, using WPA as a partial cement replacement will help to minimize CO2 emission.

Table 4.24 CO_2 emission of Materials (kg/1m^3) of C-25 conventional concrete

Materials	QM Kg	CO2EC (Kg/Kg)	ECO2 (Kg)
Cement	371	0.84	311.64
fine aggregate	924	0.004	3.69
Coarse Aggregate	1171	0.01	11.71
total CO_2 emission			327.04kg

Table 4.25 CO_2 emission of Materials (kg/1m^3) for C-25 concrete with 14% replacement.

Materials	QM Kg	CO2EC (Kg/Kg)	ECO2 (Kg)
Cement	319.06	0.84	268.01
Wastepaper ash	22.26	0.498	10.09
Eggshell powder	29.68	-	-
Fine aggregate	924	0.004	3.69
Coarse Aggregate	1171	0.01	11.71
Total CO_2 emission			293.506

The amount of embodied energy consumed 1m^3 of concrete materials is 1713.97MJ, and the total amount of CO2 emissions by the materials is 327.04kg, a blend of 14% ESP and WPA 1m^3 concrete consumed 1499.39MJ embodied energy and 293.506 kg of CO_2 emission.

4.8.8 Economic analysis

The exploration of the economic implications of using a blend of ESP and WPA as a partial replacement of cement concrete was evaluated in terms of estimated materials costs to produce concrete without and with replacement. According to current market prices of construction materials presented in the below table.

Table 4.26 Estimated total cost of materials for production of one cubic meter concrete without eggshell power and wastepaper ash based on the current market price.

Ingredient	Unit	Quantity (QM)	Control mix	
			Rate	Cost(birr)
Cement	Kg	377	19	7049
Fine aggregate	M^3	0.61	2300	1403
Coarse aggregate	M^3	0.68	1500	1020
Water	M^3	0.185	40	7.4
Total				**9479.4**

Table 4.27 Estimated total cost of materials for production of one cubic meter concrete with 14% replacement based on the current market price.

Ingredient	Unit	Quantity	Control mix	
			Rate	Cost(birr)
Cement	Kg	319.06	19	6062
Fine aggregate	M^3	0.61	2300	1403
Coarse aggregate	M^3	0.68	1500	1020
WPA	Kg	22.26	-	-
ESP	Kg	29.68	-	-
Water	M^3	0.185	40	7.4
Total				**8496.54**

Generally, a blend of WPA and ESP as a partial replacement of cement reduces the use of non-renewable materials, which helps to preserve natural resource. In addition, it reduces the consumption of energy in cement production along with CO2 emissions reduction. The use of WPA and ESP in concrete production has economic and environmental advantages.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The research on using eggshell powder and wastepaper ash as cement substitutes in concrete has yielded promising results. The usage of 14% cement replacement by eggshell powder and wastepaper ash has been found to be an effective combination in terms of enhancing the mechanical and morphological properties of concrete. The addition of eggshell powder and wastepaper ash has been helping to enhancing the compressive strength and tensile strength of concrete, even in reduced cement content. Which could have significant benefits in terms of reducing construction cost.

- The test results demonstrated that a fresh concrete mix containing eggshell powder and wastepaper ash needs additional water to maintain workability and consistency for 10% 14% 18% and, 22% eggshell powder and wastepaper ash replacement. When both eggshell powder and wastepaper ash, hybrid maximum results obtained at cement replacing percentage of 14 % by eggshell powder and wastepaper ash, which yields high compressive strength than the control after 28th day of curing.
- Furthermore, split tensile strength upswing by 15% respectively from plain concrete.
- From the morphological analysis, it is observed that eggshell powder and wastepaper ash is effectively reactive with cement hydration product additional cementitious material other than C-H and C-S-H is investigated which called pumpellyite. It is a good indication that concrete with eggshell powder and wastepaper ash is durable and resistance to chemicals. SEM image also prevailed that concrete with eggshell powder and wastepaper ash have dense internal structure with less crack and pores. As a general incorporation of replacement of cement by eggshell powder and wastepaper ash ameliorate mechanical and morphological property of concrete.
- Moreover, the cost of 14% replacement concrete decrease by 10.35% with minimal embodied energy.

5.2 Recommendation

Based on the research conducted on using Eggshell powder and wastepaper ash as a cement substitute in concrete it yields delight full results. But further research needed in this area like: - Research on long-term durability and performance of concrete structures made with eggshell powder and wastepaper ash under different environmental conditions, such as

- Exposure to extreme temperatures,
- Chloride attack
- Sulphate attack
- Freeze-thaw cycles.
- Life cycle cost of replaced concrete.

This information could help to determine the suitability of these materials for use in a range of construction applications.

- Further research could be conducted to develop guidelines and recommendations for the use a blend of eggshell powder and wastepaper ash as cement substitutes in concrete, including guidance on optimal mix design, placement, and curing practices.

This information could help to ensure that these materials are used effectively and safely in construction projects. Overall, the use of eggshell powder and wastepaper ash as cement substitutes in concrete has shown great potential for enhancing the performance and sustainability of concrete structures.

REFERENCE

A, M. (June 1987.). Construction materials. *Teaching Material. AAU printing press. Addis Ababa Ethiopia*.

Abdulabbas, Z. H. (2016). Investigation of drying shrinkage and compressive strength of cement mortar with partial replacement of cement by egg shell powder and milled glass. *Al-Qadisiyah Journal for Engineering Sciences, 9*(3).

Adesanya, D., & Raheem, A. (2009a). Development of corn cob ash blended cement. *Construction and Building materials, 23*(1), 347-352.

Adesanya, D., & Raheem, A. (2009b). A study of the workability and compressive strength characteristics of corn cob ash blended cement concrete. *Construction and Building Materials, 23*(1), 311-317.

Adesanya, D., & Raheem, A. (2010). A study of the permeability and acid attack of corn cob ash blended cements. *Construction and Building materials, 24*(3), 403-409.

Adogla, F., Yalley, P. P. K., & Arkoh, M. (2019). *Improving compressed laterite bricks using powdered eggshells*: LAP LAMBERT Academic Publishing.

Afolayan, J., Oriola, F., Moses, G., & Sani, J. (2017). Investigating the effect of eggshell ash on the properties of sandcrete block. *International Journal of Civil Engineering, Construction and Estate Management, 5*(3), 43-54.

Ahmad, M. R., Chen, B., & Yu, J. (2019). A comprehensive study of basalt fiber reinforced magnesium phosphate cement incorporating ultrafine fly ash. *Composites Part B: Engineering, 168*, 204-217.

Ahmad, S., Malik, M. I., Wani, M. B., & Ahmad, R. (2013). Study of concrete involving use of waste paper sludge ash as partial replacement of cement. *IOSR Journal of Engineering, 3*(11), 06-15.

Akpenpuun, T., Akinyemi, B., Olawale, O., Aladegboye, O., & Adesina, O. (2019). Physical, mechanical and microstructural characteristics of cement-locust bean pod ash mortar blend. *Journal of Applied Sciences and Environmental Management, 23*(3), 377-382.

Al Robayie, J., Al-Azzawy, H. J., & Al-karawi, S. N. (2015). Use Alternative raw materials for concrete Production. *Diyala Journal of Engineering Science, 8*(4), 1-12.

Aldieb, M. A., & Ibrahim, H. G. (2010). *Variation of feed chemical composition and its effect on clinker formation–simulation process.* Paper presented at the Proceedings of the world congress on Engineering and Computer science.

Ali, A., Hagishima, A., Abdel-Kader, M., & Hammad, H. (2013). *Vernacular and Modern Building: Estimating the CO2 emissions from the building materials in Egypt.* Paper presented at the Building Simulation Conference, Cairo, Egypt.

Ali, M., Saidur, R., & Hossain, M. (2011). A review on emission analysis in cement industries. *Renewable and Sustainable Energy Reviews, 15*(5), 2252-2261.

Altwair, N. M., & Kabir, S. (2010). *Green concrete structures by replacing cement with pozzolanic materials to reduce greenhouse gas emissions for sustainable environment.* Paper presented at the 6th International Engineering and Construction Conference, Cairo, Egypt.

Amit, S. K. S., & Islam, M. R. APPLICATION OF PAPER SLUDGE ASH IN CONSTRUCTION INDUSTRY–A.

Amran, M., Makul, N., Fediuk, R., Lee, Y. H., Vatin, N. I., Lee, Y. Y., & Mohammed, K. (2022). Global carbon recoverability experiences from the cement industry. *Case Studies in Construction Materials, 17*, e01439.

Asman, N. S. A., Dullah, S., Ayog, J. L., Amaludin, A., Amaludin, H., Lim, C., & Baharum, A. (2017). *Mechanical properties of concrete using eggshell ash and rice husk ash as partial replacement of cement.* Paper presented at the MATEC Web of Conferences.

Asmare, G. (2015). Pulp Production from Cotton Stalks using Kraft Pulping. *Addis Ababa: Addis Ababa University*.
ASTM, C. (2001). ASTM C39: Standard test method for compressive strength of cylindrical concrete specimens. *ASTM international West Conshohocken, PA, USA*.
Astm, C. (2003). 125 Standard terminology relating to concrete and concrete aggregates. *Annual Book of ASTM Standards, 4*, 23.
ASTM, D. (2011). 6890 Standard Test Method for Determination of Ignition Delay and Derived Cetane Number (DCN) of Diesel Fuel Oils by Combustion in a Constant Vol. *American Society for Testing and Materials (ASTM)*.
Azar, J. P., Najarchi, M., Sanaati, B., Najafizadeh, M. M., & Mirhosseini, S. M. (2019). The experimental assessment of the effect of paper waste ash and silica fume on improvement of concrete behavior. *KSCE journal of Civil Engineering, 23*, 4503-4515.
Bai, J., Chaipanich, A., Kinuthia, J., O'farrell, M., Sabir, B., Wild, S., & Lewis, M. (2003). Compressive strength and hydration of wastepaper sludge ash–ground granulated blastfurnace slag blended pastes. *Cement and Concrete Research, 33*(8), 1189-1202.
Baláž, M. (2018). Ball milling of eggshell waste as a green and sustainable approach: a review. *Advances in colloid and interface science, 256*, 256-275.
Balwaik, S. A., & Raut, S. (2011). Utilization of waste paper pulp by partial replacement of cement in concrete. *Int J Eng Res Appl, 1*(2), 300-309.
Bandhavya, G., Sandeep, K., & Bindhushree, G. (2017). An experimental study on partial replacement of cement with egg shell powder in concrete. *International Research Journal of Engineering and Technology, 4*(6), 2318-2323.
Banfill, P., & Frias, M. (2007). Rheology and conduction calorimetry of cement modified with calcined paper sludge. *Cement and Concrete Research, 37*(2), 184-190.
Beall, C. (2001). *Masonry and concrete*: McGraw-Hill Education.
Bedaso, A. (2022). Experimental Investigation on Common Bean Straw Ash as A

Partial Replacement of Cement in Non-structural Concrete.
Benhelal, E., Zahedi, G., Shamsaei, E., & Bahadori, A. (2013). Global strategies and potentials to curb CO2 emissions in cement industry. *Journal of cleaner production, 51*, 142-161.
Beressa, L., & Saradhi, B. V. (2021). Life Cycle Assessment of Ethiopian Cement Manufacturing: A Potential Improvement on the Use of Fossil Fuel in Mugher Cement Factory. *Applied Environmental Research, 43*(4), 100-112.
Beressa, L., & Vijaya Saradhi, B. (2021). Life Cycle Assessment of Ethiopian Cement Manufacturing: A Potential Improvement on the Use of Fossil Fuel in Mugher Cement Factory. *Applied Environmental Research, 43*(4), 100-112. doi:10.35762/AER.2021.43.4.8
Black, L. (2016). Low clinker cement as a sustainable construction material. *Sustainability of Construction Materials*, 415-457.
Bui, N. K., Satomi, T., & Takahashi, H. (2019). Influence of industrial by-products and waste paper sludge ash on properties of recycled aggregate concrete. *Journal of Cleaner Production, 214*, 403-418.
Canfeng, Z., Shujie, Y., & Dong, L. (2012). Comprehensive control of the noise occupational hazard in cement plant. *Procedia Engineering, 43*, 186-190.
Chandra, R. K. B. S. H. S. S. (July 2022). Waste Paper Sludge Ash and Crushed Rock Sand Based on Concrete with Smart Materials - A Review.
chandran. (appril 2016). investigation on mechanical properties of concrete elements made with partial replacement of cement with card-board sludge. *6*(4), 65-74.
Chandrasekaran, V., Vasanth, M., & Thirunavukkarasu, S. (2018). Experimental investigation of partial replacement of cement with glass powder and eggshell powder ash in concrete. *Civ. Eng. Res. J, 5*, 1-9.

Change, I. C. (2014). Mitigation of climate change. *Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change, 1454*, 147.
Chong, B., Othman, R., Ramadhansyah, P., Doh, S., & Li, X. (2020). Properties of concrete with eggshell powder: A review. *Physics and Chemistry of the Earth, Parts A/B/C, 120*, 102951.
Concrete, A. C. C.-o., & Aggregates, C. (2008). *Standard test method for time of setting of concrete mixtures by penetration resistance*: ASTM international.
Concrete, S. F. ASTM C 172, except modified for slump to comply with ASTM C 94. a. *Slump: ASTM C, 143*(1).
Dembovska, L., Bajare, D., Pundiene, I., & Vitola, L. (2017). Effect of pozzolanic additives on the strength development of high performance concrete. *Procedia Engineering, 172*, 202-210.
Deshpande, A. S., Nanjunda, K., & Purushottam, T. (2018). A Comparative Study on Cow-dung Ash and Bagasse Ash Concrete with Partial Replacement of Cement by Egg Shell Powder.
Dhanalakshmi, M., Sowmya, N., & Chandrashekar, A. (2015). A comparative study on egg shell concrete with partial replacement of cement by fly ash. *International Journal for Research in Applied Science and Engineering Technology, 3*(Special Issue II), 12-20.
Ding, L., Chen, K.-l., Cheng, S.-g., & Wang, X. (2015). Water ecological carrying capacity of urban lakes in the context of rapid urbanization: A case study of East Lake in Wuhan. *Physics and Chemistry of the Earth, Parts a/B/C, 89*, 104-113.
Dinku, A. (2002). Construction materials laboratory manual. *Addis Ababa University Printing Press, Addis Ababa*.
Duan, S., Liao, H., Ma, Z., Cheng, F., Fang, L., Gao, H., & Yang, H. (2018). The relevance of ultrafine fly ash properties and mechanical properties in its fly ash-cement gelation blocks via static pressure forming. *Construction and Building Materials, 186*, 1064-1071.
en.wikipedia.org/wiki/Portland-cement. Portland Cement.
Environment, U., Scrivener, K. L., John, V. M., & Gartner, E. M. (2018). Eco-efficient cements: Potential economically viable solutions for a low-CO2 cement-based materials industry. *Cement and concrete Research, 114*, 2-26.
eshetu, e. (2020). Cost Optimization of (C-30 & C-40) Concrete Mixtures Using Superplasticizers.
Espíndola-Gonzalez, A., Martínez-Hernández, A., Angeles-Chávez, C., Castano, V., & Velasco-Santos, C. (2010). Novel crystalline SiO2 nanoparticles via annelids bioprocessing of agro-industrial wastes. *Nanoscale research letters, 5*(9), 1408-1417.
Gregg, J. S., & Andres, R. J. (2008). A method for estimating the temporal and spatial patterns of carbon dioxide emissions from national fossil-fuel consumption. *Tellus B: Chemical and Physical Meteorology, 60*(1), 1-10.
Güneyisi, E., Gesoğlu, M., & Özturan, T. (2004). Properties of rubberized concretes containing silica fume. *Cement and Concrete Research, 34*(12), 2309-2317.
Hama, S. M., Hamdullah, D. N., & Ashour, H. M. (2019). Effects of eggshell powder as partial replacement of cement on flexural behavior of one-way concrete slabs. *J Eng Sci Technol, 15*(5), 2509-2521.
Hongwu, G. (2003). Noise control engineering. *Wu Hang University of Science and Technology Press, Jiangsu Sheng*.
Hut, M. N. S. (2014). *The performance of eggshell powder as an additive concrete mixed.* UMP.
Imam, A., Kumar, V., & Srivastava, V. (2018). Review study towards effect of Silica Fume on the fresh and hardened properties of concrete. *Advances in concrete construction, 6*(2), 145.
Jadoon, S., Amin, A. A., Malik, A., & Kamal, H. (2016). Soil pollution by the cement industry in the Bazian vicinity, Kurdistan region. *J. Environ. Anal. Toxicol, 6*(1000413), 2161-0525.1000413.
Jaramillo-Murcia, D., Abellán-García, J., Torres-Castellanos, N., & García-Castaño, E. (2022). Properties analysis of ultra-high-performance concrete with recycled glass and limestone powders. *ACI Materials Journal, 119*(5), 153-163.

Jhatial, A. A., Sohu, S., Memon, M. J., Bhatti, N.-u.-K., & Memon, D. (2019a). Eggshell powder as partial cement replacement and its effect on the workability and compressive strength of concrete. *International Journal of Advanced and Applied Sciences, 6*(9), 71-75.

Jhatial, A. A., Sohu, S., Memon, M. J., Bhatti, N.-u.-K., & Memon, D. (2019b). Eggshell powder as partial cement replacement and its effect on the workability and compressive strength of concrete. *Int. J. Adv. Appl. Sci, 6*(9), 71-75.

John, V. M., Damineli, B. L., Quattrone, M., & Pileggi, R. G. (2018). Fillers in cementitious materials—Experience, recent advances and future potential. *Cement and concrete Research, 114*, 65-78.

Juenger, M. C., & Siddique, R. (2015). Recent advances in understanding the role of supplementary cementitious materials in concrete. *Cement and Concrete research, 78*, 71-80.

Kamal, M. R. (2019). Mix design for durable concrete using fly ash, slag and locally available aggregate.

Kaur, E. P., & Talwar, E. K. Utilization of Rice Husk Ash and Waste Paper Sludge Ash as Partial Replacement of Cement in Concrete.

Kejela, B. M. (2020). Waste paper ash as partial replacement of cement in concrete. *American Journal of Construction and Building Materials, 4*(1), 8-13.

Kosmatka, S., Kerkhoff, B., & Panarese, W. (2003). Design and control of concrete mixtures 14th editi. *Skokie, IL: Portland Cement Assosiation*.

Kosmatka, S. H., Panarese, W. C., & Kerkhoff, B. (2002). *Design and control of concrete mixtures* (Vol. 5420): Portland Cement Association Skokie, IL.

Kucche, K., Jamkar, S., & Sadgir, P. (2015). Quality of water for making concrete: a review of literature. *International Journal of Scientific and Research Publications, 5*(1), 1-10.

Kumar, R., & Dhaka, J. (2016). Review paper on partial replacement of cement with silica fume and its effects on concrete properties. *International Journal for Technological Research in Engineering, 4*(1).

Lee, H., Cody, R., Cody, A., & Spry, P. (2005). The formation and role of ettringite in Iowa highway concrete deterioration. *Cement and Concrete Research, 35*(2), 332-343.

Lin, L.-K., Kuo, T.-M., & Hsu, Y.-S. (2016). The application and evaluation research of coffee residue ash into mortar. *Journal of Material Cycles and Waste Management, 18*(3), 541-551.

Madlool, N. A., Saidur, R., Hossain, M. S., & Rahim, N. (2011). A critical review on energy use and savings in the cement industries. *Renewable and sustainable energy reviews, 15*(4), 2042-2060.

Marinamarican, M. H. (2015). *The Effect of Eggshell Powder on Concrete Brich Performance as Partial Replacement of Cement.* UMP.

Mehta, P. K., & Monteiro, P. J. (2014a). *Concrete: microstructure, properties, and materials*: McGraw-Hill Education.

Mehta, P. K., & Monteiro, P. J. (2014b). Concreto. *Microestrutura, propriedades e materiais, 2*.

Mirel, D. (2007). Disappearing act: advanced technology cuts back on paper use. *Journal of Property Management, 72*(3), 30-35.

Mitikie, B. B., & Waldtsadik, D. T. (2022). Partial Replacement of Cement by Waste Paper Pulp Ash and Its Effect on Concrete Properties. *Advances in Civil Engineering, 2022*.

Mohamad, N., Muthusamy, K., Embong, R., Kusbiantoro, A., & Hashim, M. H. (2022). Environmental impact of cement production and Solutions: A review. *Materials Today: Proceedings, 48*, 741-746.

Naqi, A., & Jang, J. G. (2019). Recent progress in green cement technology utilizing low-carbon emission fuels and raw materials: A review. *Sustainability, 11*(2), 537.

NASA. The Causes of Climate Change. 2020.

Nawy, E. G. (2008). *Concrete construction engineering handbook*: CRC press.

Neville, A., & Aitcin, P.-C. (1998). High performance concrete—An overview. *Materials and structures, 31*(2), 111-117.

Neville, A. M. (1995). *Properties of concrete* (Vol. 4): Longman London.

Nizam, R. S., Zhang, C., & Tian, L. (2018). A BIM based tool for assessing embodied energy for buildings. *Energy and buildings, 170*, 1-14.

Okeyinka, O. M., & Idowu, O. J. (2014). Assessment of the suitability of paper waste as an engineering material. *Engineering, Technology & Applied Science Research, 4*(6), 724-727.

Olafusi, O. S., & Olutoge, F. A. (2012). Strength properties of corn cob ash concrete. *Journal of Emerging Trends in Engineering and Applied Sciences, 3*(2), 297-301.

Olorunnisola, A. O., & Okanlawon, S. A. (2017). Development of passive evaporative cooling systems for tomatoes Part 1: construction material characterization. *Agricultural Engineering International: CIGR Journal, 19*(1), 178-186.

Outlook, I. A. E. (2014). URL: https://www. iea. org/publications/freepublications/publication. *WEO2014_AfricaEnergyOutlook. pdf*.

Owaid, H. M., Al-Rubaye, M. M., & Al-Baghdadi, H. M. (2021). Use of waste paper ash or wood ash as substitution to fly ash in production of geopolymer concrete. *Przegląd Naukowy Inżynieria i Kształtowanie Środowiska, 30*.

Ozola, Z. U., Vesere, R., Kalnins, S. N., & Blumberga, D. (2019). Paper waste recycling. circular economy aspects. *Environmental and Climate Technologies, 23*(3), 260-273.

Pane, I., & Hansen, W. (2008). Predictions and verifications of early-age stress development in hydrating blended cement concrete. *Cement and Concrete Research, 38*(11), 1315-1324.

Parkash, A., & Singh, E. R. (2017a). Behaviour of concrete containing egg shell powder as cement replacing material. *Int. J. Latest Res. Eng. Comput.(IJLREC), 5*(4), 1-5.

Parkash, A., & Singh, E. R. (2017b). Behaviour of concrete containing egg shell powder as cement replacing material. *International Journal of Latest Research In Engineering and Computing (IJLREC), 5*(1), 2347-6540.

Parthasarathi, N., Prakash, M., & Satyanarayanan, K. (2017). Experimental study on partial replacement of cement with egg shell powder and silica fume. *Rasayan Journal of Chemistry, 10*(2), 442-449.

Pathan, F. S., Nagalkar, S. K., Matkar, R. V., Digrase, B. B., Palaspagar, M. S., Donadkar, A. S., . . . Harinkhede, S. (2021). Experimental Investigation On Development Of Binder And Mortar By Partial Replacement Of Cement Using Sugarcane Bagasse Ash, Copper Slag And Egg Shell Powder. *Int. J. of Aquatic Science, 12*(3), 2300-2311.

Pillai, G. G., & Mathew, M. (2021). Effects of Eggshell Powder and Granite Powder on the Strength Properties of Concrete by Partial Replacement of Cement and Fine Aggregate *Advances in Civil Engineering* (pp. 289-297): Springer.

Prusinski, J. R., Marceau, M. L., & VanGeem, M. G. (2004). *Life cycle inventory of slag cement concrete.* Paper presented at the Eighth CANMET/ACI International Conference on Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete.

Rahman, M., Hussain, A., & Basri, H. (2014). A critical review on waste paper sorting techniques. *International journal of environmental science and technology, 11*, 551-564.

Raji, S., & Samuel, A. (2015). Egg shell as a fine aggregate in concrete for sustainable construction. *International journal of scientific & technology research, 4*(09), 8-13.

Ramamurthy, K., Nambiar, E. K., & Ranjani, G. I. S. (2009). A classification of studies on properties of foam concrete. *Cement and concrete composites, 31*(6), 388-396.

Rashid, K., Javed, S., & Ahmad, T. (2017). Experimental Study on Compressive Strength of Concrete by Partial Replacement of Cement with Eggshell Powder. *Technical Journal, 22*(3).

Rathnam, A. V., & SomBabu, Y. A COMPREHENSIVE ENHANCEMENT IN FINDING THE PROPERTIES OF EGGSHELL CONCRETE WITH REPLACEMENT OF CEMENT BY FLYASH.

Reddy, B. V., & Jagadish, K. (2003). Embodied energy of common and alternative building materials and technologies. *Energy and buildings, 35*(2), 129-137.

Sabir, B. (1995). High-strength condensed silica fume concrete. *Magazine of Concrete Research, 47*(172), 219-226.

Sandhu, A. R., Rind, T. A., Kalhoro, S. A., Lohano, R., & Laghari, F. H. (2019). Effect on the Compressive Strength of Mortars Using Ground Granulated Blast Furnace Slag as a Partial Replacement of Cement. *Journal of Applied Engineering Sciences, 90*(2).

Segui, P., Aubert, J.-E., Husson, B., & Measson, M. (2012). Characterization of wastepaper sludge ash for its valorization as a component of hydraulic binders. *Applied Clay Science, 57*, 79-85.

Seifan, M. (2018). *Self-healing concrete: a novel nanobiotechnological approach to heal the concrete cracks.* The University of Waikato.

Selvapriya, R. (2019). Silica fume as Partial Replacement of Cement in Concrete. *International Research Journal of Multidisciplinary Technovation (IRJMT), ISSN*, 2582-1040.

Seyyedalipour, S. F., Kebria, D. Y., Malidarreh, N. R., & Norouznejad, G. (2014). Study of utilization of pulp and paper industry wastes in production of concrete. *Int J Eng Res Appl, 4*(1), 115-122.

Shabbir, F., Ejaz, N., Khan, D., Ahmad, N., & Hussain, J. (2015). Investigation of using paper industry waste (hypo sludge) in concrete mix. *Journal of Engineering and Applied Sciences (JEAS), 34*(2).

Sharma, S., & Netula, O. (2018). *Experimental investigation of partial replacement of OPC (43 Grade) cement by egg shell powder for M-35 concrete grade.* Paper presented at the International Conference on Recent Research and Innovations in Social Science, Humanities, India.

Shen, W., Cao, L., Li, Q., Zhang, W., Wang, G., & Li, C. (2015). Quantifying CO2 emissions from China's cement industry. *Renewable and Sustainable Energy Reviews, 50*, 1004-1012.

Shetty, M. (2005). Concrete Technology, Theory and Practice, revised ed. *S. Chand and Company Ltd., Ram Nagar, New Delhi*, 124-217.

Shiferaw, N., Habte, L., Thenepalli, T., & Ahn, J. W. (2019). Effect of eggshell powder on the hydration of cement paste. *Materials, 12*(15), 2483.

Singh, L. R., Saleem, A., & Geeta, B. (2015). Application of paper waste in cement concrete. *Int. Journal of Engineering Research and Applications, 5*(4), 95-98.

Sivakumar, M., & Mahendran, N. (2014). STRENGTH AND PERMEABILITY PROPERTIES OF CONCRETE USING FLY ASH (FA), RISE HUSK ASH (RHA) AND EGG SHELL POWDER (ESP). *Journal of Theoretical & Applied Information Technology, 66*(1).

Srivastava, V., Kumar, R., Agarwal, V., & Mehta, P. (2012). Effect of Silica Fume and Metakaolin combination on concrete. *International Journal of Civil & Structural Engineering, 2*(3), 893-900.

Stajanča, M., & Eštoková, A. (2012). Environmental impacts of cement production.

Stang, A., & Hawthorne, C. (2005). *The green house: New directions in sustainable architecture*: Princeton Architectural Press.

Suresh, D., & Nagaraju, K. (2015). Ground granulated blast slag (GGBS) in concrete–a review. *IOSR journal of mechanical and civil engineering, 12*(4), 76-82.

Tappi, T. (2002). 211 om-02. Ash in wood, pulp, paper and paperboard: Combustion at 525◦ C. *TAPPI test methods, 5*.

Teshome, F. B. (2021). Municipal solid waste management in Ethiopia; the gaps and ways for improvement. *Journal of Material Cycles and Waste Management, 23*(1), 18-31.

Ujin, F., Ali, K. S., & Hanur Harith, Z. Y. (2017). *The effect of eggshells ash on the compressive strength of concrete.* Paper presented at the Key Engineering Materials.

Vaidya, N., & Bastwadkar, M. (2019). Experimental Study of Partial Replacement of Cement with Eggshell Powder in Concrete. *International Journal of Engineering Development and Research, 7*(4).
Van Oss, H. G., & Padovani, A. C. (2003). Cement manufacture and the environment part II: environmental challenges and opportunities. *Journal of Industrial ecology, 7*(1), 93-126.
Vegas, I., Frías, M., Urreta, J., & San José, J. (2006). Obtaining a pozzolanic addition from the controlled calcination of paper mill sludge. Performance in cement matrices. *Materiales de Construcción, 56*(283), 49-60.
Wakchaure, M., Shaikh, A., & Gite, B. (2012). Effect of types of fine aggregate on mechanical properties of cement concrete. *International Journal of Modern Engineering Research, 2*(5), 3723-3726.
Wang, K. (2004). *Proceedings of the International Workshop on Sustainable Development and Concrete Technology, Beijing, China, May 20-21, 2004*: Center for Transportation Research and Education Iowa State University.
Woubishet, Z. T., & Abegaz, K. A. (2019). Embodied Energy and CO 2 Emissions of Widely Used Building Materials: The Ethiopian Context. *Buildings, 9*(6), 136.
Yusuf, R. O., Noor, Z. Z., Din, M. d. F. M. d., & Abba, A. H. (2012). Use of sewage sludge ash (SSA) in the production of cement and concrete–a review. *International Journal of Global Environmental Issues, 12*(2-4), 214-228.
Zaini, M. S. I., Hasan, M., Yie, L. S., Masri, K. A., Jaya, R. P., Hyodo, M., & Winter, M. J. (2022). THE EFFECT OF UTILIZING SILICA FUME AND EGGSHELL ASH ON THE GEOTECHNICAL PROPERTIES OF SOFT KAOLIN CLAY. *Jurnal Teknologi, 84*(1), 159-170.
Zaki, H., Gorgis, I., & Salih, S. (2018). *Mechanical properties of papercrete.* Paper presented at the MATEC Web of Conferences.
Zewdie, M., Zewdie, G., & Shanmugavadivu, P. (2020). Waste Paper Pulp Ash as Partial Replacement of cement in Cement Mortar. *Authorea Preprints*.
Zhang, J., Weissinger, E. A., Peethamparan, S., & Scherer, G. W. (2010). Early hydration and setting of oil well cement. *Cement and Concrete research, 40*(7), 1023-1033.
Zhang, P., Liao, W., Kumar, A., Zhang, Q., & Ma, H. (2020). Characterization of sugarcane bagasse ash as a potential supplementary cementitious material: Comparison with coal combustion fly ash. *Journal of Cleaner Production, 277*, 123834.

Appendix A: Mix Design

Step 1:

Computing required average compressive strength from the given characteristic strength of 40MPa.

According to ACI-318

Specified characteristic compressive. strength (f'c, MPa)	Required average compressive strength in (f'cr, MPa)

<21	f'c + 7
21-35	f'c + 8.5
>35	1.1*f'c + 5

- ✓ While designing the mix, it should be targeted for higher strength called 'Target mean strength' (f'ck) so that *no more than 5% test results fall below a desired strength 'fck' i.e.,*

Table 1. specific characteristic compressive strength

- ✓ *Characteristics strength (CS).*
- ✓ Calculating the required mean compressive strength based on characteristic strength of 25 Mpa which gives; fck = f'ck + 8.5 = 25 + 8.5 = 33.5 Mpa

Step 2.

- ☐ Specifying minimum cement content

From durability considerations cement content should not be reduced below 300Kg/m3 for RCC. Higher cement contents for more severe conditions of exposure of weathering agents to the concrete.

- ☐ Minimum cement content = 300 kg/m3

STEP 3 Choice of slump

Table 2. Recommended slumps for various types of constructions

	Slump (cm)	
Types of construction	***Max.**	**Min.**
Reinforced foundations, walls and footings	8	2

Plain footings, cessions and substructure walls	8	2
Beams and reinforced walls	10	2
Building columns	10	2
Pavements and slabs	8	2
Heavy mass concrete	8	2

For C-25, a concrete of Beams, reinforced walls and Building columns slump of 2-10 cm is recommended.

Step 4. Selecting the maximum size of Aggregate

Maximum aggregate size will affect such PCC parameters as amount of cement paste, workability and strength. In general, ACI recommends that maximum aggregate size be limited to 1/3 of the slab depth and 3/4 of the minimum clear space between reinforcing bars. Aggregate larger than these dimensions may be difficult to consolidate and compact resulting in a honeycombed structure or large air pockets. Pavement PCC maximum aggregate sizes are on the order of 25 mm (1 inch) to 37.5 mm (1.5 inches)

Table3. Maximum size of aggregate recommended for various types of constructions.

Type of element	Dimensions of sections (cm)			
	10-15	15-20	20-35	35-75
Un reinforced or slightly reinforced foundations or slabs	Maximum size of aggregate (mm)			
	25-40	40	40-50	50

Reinforced foundations or slabs, un-reinforced or lightly reinforced walls or columns	20-25	25	25-40	40
Reinforced beams, columns, walls, hollow block slabs	15-20	20-25	25-30	30

N.B. Maximum size should not be greater than 1/5 of minimum dimensions of sections or larger than ¾ of minimum clear spacing between reinforcing bars.

Let’s take 20 mm.

Step 5. Estimate mixing water, and air content.

Slump is dependent upon nominal maximum aggregate size, particle shape, aggregate gradation, temperature, the amount of entrained air and certain chemical admixtures. It is not generally affected by the amount of cementitious material. Therefore, ACI provides a table relating nominal maximum aggregate size, air entrainment and desired slump to the desired mixing water quantity. Table 3 is a partial reproduction of ACI Table 3

Table 4. Approximate mixing water requirements for different slumps and maximum sizes of aggregates.

Slump (cm)	Water kg/m3 of concrete for indicated max. sizes of agg. in mm *							
	10	12.5	20	25	40	50+	70+	150+
Non –Air entrained concrete								
3- 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	185	180	170	--
Approx. amount of entrapped air in non entrained conc(%)	3	25	2	15	1	0.5	0.3	0.2
Air entrained concrete								
3 to 5	180	175	165	160	145	140	135	120
8 to 10	215	205	190	185	170	165	160	--
Recommended average total air content (%)	8	7	6	5	4.5	4	3.5	3

In table 3.2 above, with a slump of 2-10 cm and a maximum size aggregate of 20 mm, the water content becomes 185 Kg/$\boldsymbol{m^3}$ and 2%, or 20 liters and entrapped air.

- ☐ Step 6. Computing water cement ratio (W/C ratio)

The water-cement ratio is a convenient measurement whose value is well correlated with concrete strength and durability. In general, lower water-cement ratios produce stronger, more durable concrete. If natural pozzolans are used in the mix (such as fly ash) then the ratio becomes a water-cementitious material ratio (cementitious material = Portland cement + pozzolanic material). The ACI method bases the water-cement ratio selection on desired compressive strength and then calculates the required cement content based on the selected water-cement ratio.

Table 5. Average Compressive Strength with water Cement Ratio

Compressive strength at 28 days (Mpa)	Water cement ratio (by mass)
45	0.38
40	0.42
35	0.47
30	0.54
25	0.61

The ACI table above can't provide the exact value of the water-cement ratio for a 33.5 MPa mean strength. This can be calculated via interpolating the above and below value as follows: 33.5 MPa.

35	0.47	by interpolation, $\frac{33.5-35}{30-35} = \frac{x-0.47}{0.54-0.47}$
33.5	x	by solving the above equation, x=0.491
30	0.54	Hence, the minimum water cement ratio is 0.491.

Step 7. Determining the mix cement content

Once the water content and the w/c ratio are determined, the amount of cement per unit volume of concrete is found by dividing the estimated water content by the w/c ratio.

Cement content is determined by comparing the following two items:

- The calculated amount based on the selected mixing water content and water-cement ratio.
- The specified minimum cement content, if applicable

Cement content = water content/ water cement ratio

Cement content = 185kg/m3/0.491

Cement content = 376.8 kg/m3 ~377 kg/m3

Step 8. Estimating the bulk volume of dry rodded as per unit volume of concrete

Volumes are based on aggregate in dry rodded condition as described in ASTEC29 for unit weight of aggregate. These volumes are selected empirical relationship to produce concrete with a degree of workability suitable for usual reinforced construction. For less workable concrete such as required for pavement construction they may be increased about 10%. For more workable concrete, such as required may be required when placement is to be by pumping, they may be reduced up to10%.

Table 6. Volume of coarse Aggregate per unit Volume of concrete

Maximum size of aggregate	Volume of dry rodded coarse aggregate per unit volume of concrete for different fineness modulus		
	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

The bulk volume of dry rodded aggregate was not found in the above table directly. It can be calculated by interpolation Since the fitness modulus of 2.98 is found between 2.8 and 3 for a 20 mm maximum size aggregate.

2.8 0.62 by interpolation, $\frac{2.8-2.98}{0.62-x} = \frac{2.98-3}{x-0.6}$

2.98 x by solving the above equation, x=0.602

3.0 0.6 Hence, the dry volume of aggregate per volume of concrete is 0.602.

Step 9. Calculating the weight of coarse aggregate (WCA) per m3 of concrete

WCA = bulk volume of dry rodded agg. per unit volume of concrete * bulk density C.A

Were, volume of dry rodded agg. = 0.602

bulk density C.A = 1681 kg/m3

WCA= bulk volume*bulk density

WCA = 0.602 m3 * 1681 Kg/m3

WCA = 1012 kg

Step 10. Determining the solid volume of the coarse aggregate

Solid volume of C.A. = WCA / Sp. gravity

Solid volume of C.A. = 1012 kg / 2.85,

=**355 kg/m3**

were, Specific gravity of C.A.: 2.85

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

Volume of cement (VC) = Weight of cement / unit weight of cement

= 377/3.15

= 119.68Kg/m^3 = 120Kg/m^3

Volume of Water (VW) = 185 Kg/m^3

Volume of Air (VA) = 2% = 20 Kg/m^3

Step 12. Determining solid volume of sand (Solid volume of sand is then calculated by subtracting from the data volume of concrete).

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

1000 – (354.576 (VCA)+120 (VC)+185 (VW)+20(VA))

= 1000 – (359.5 +120 + 185 + 20)

= 1000 – 679.57

Solid volume of sand = 320.424 Kg/m^3

Solid Weight of sand = dry volume * specific gravity of sand

= 320.424 * 2.76 = 884.37 Kg/m^3

	Volum(lit)	Wt. (kg/m3)
Air	20	-
Cement	120	377
Water	185	185
Coarse aggregate	359.5	1017.38
Fine aggregate	315	867.62
Total	1000	2,447 kg/m3

Step 13. Adjustment for moisture in the aggregate.

- ✓ Since the moisture level of the fine aggregate in our storage vary, we will apply a simple rule to adjust the water required.
- ✓ Decrease the amount of water required by surface moisture content of the weight of the fine aggregate.

- ✓ Increase the amount of aggregate by the amount equal to the surface moisture.

2.7 % of moisture absorption by coarse aggregate.

1.1% of moisture adsorption by fine aggregate.

The amount of water absorbed by coarse aggregate.

The amount of water absorbed by coarse aggregate.

1017.38 kg/m3 * 0.027 = 27.47 kg/m3

The amount of water supplied by fine aggregate.

867.62 kg/m3 * 0.011 = 9.54 kg/m3

Therefore, the estimated amount of water needed for the mix is.

(185 kg/m3 + 10.42 kg/m3) – 10.6 kg/m3 = 184.82 kg/m3

Therefore, the estimated batch wt. for cubic meter of concrete is.

Water	184.82	184.82
Cement	377	377
Fine aggregate	867.62+9.54	877
Coarse aggregate	1017.38+27.47	1044

Finally, the mix ratio becomes: -

	Cement	Fine aggregate	Coarse aggregate
Quantity in m3	377	877	1044
Ratio	1	2.32	2.77

ESP and WPA replacement amount

Amount of bentonite replaced by percentage weight of cement which was 377 kg/m^3 is used for 10% replacement= 37.7 kg/m^3, for 14%replacement =52.78 for 18 % replacement =67.86 kg/m^3 and for 22% replacement both ESP and WPA content was 82.94 kg/m^3 used.

APPENDEX B: Detail Result of Hardened Concrete

Appendix B1: Detail result of compressive strength of OPC+ESP+WPA concrete:

S/N	Mix code	compressive strength		
		7 days	14 days	28 days

		Load (kN)	Strength (N/mm_2)	Load (kN)	Strength (N/mm^2)	Load (kN)	Strength (N/mm_{2})
1	Mix 0	486	21.6	648	28.7	826	36.7
		478	21.2	655	29.1	789	35.06
		494	21.96	641	28.49	863	38.36
2	Mix 1	517	23	659	29.3	871	38.7
		498	22.13	678	30.13	878	39.02
		536	23.82	640	22.44	865	38.44
3	Mix 2	490	21.8	652	29	842	37.41
		476	21.16	664	29.5	845	37.56
		504	22.4	641	28.48	839	37.29
4	Mix 3	432	19.2	594	26.4	621	27.6
		412	18.31	588	26.13	607	27
		452	20.08	600	26.67	635	28.2
5	Mix 4	396	17.6	554	24.6	543	24.1
		410	18.22	545	22.22	539	23.96
		392	17.42	563	25.02	552	24.53

Appendix B2: Detail result of split strength of OPC+ESP+WPA concrete.

Split tensile strength							
		7 days			28 days		
S/N	Sample code	Sample weight in (kg)	Sample load of tensile in (KN)	Tensile strength in (MPa)	Sample weight in (kg)	Sample load of tensile in (KN)	Split strength in (MPa)
1	Mix 0	12.73	80	1.13	12.7	110	1.56
		11.53	95	1.35	13.22	120	1.7
		12.34	90	1.27	12.61	110	1.56
2	Mix 1	12.86	95	1.34	12.75	160	1.98
		12.68	100	1.41	12.58	155	1.92
		12.34	90	1.27	12.72	140	1.79
3	Mix 2	12.75	95	1.34	12.73	140	1.96
		11.76	80	1.13	12.34	130	1.84
		12.46	90	1.27	12.82	120	1.7
4	Mix 3	12.45	75	1.06	12.56	100	1.41
		12.34	70	0.99	12.62	120	1.7
		12.09	80	1.13	12.64	100	1.41
5	Mix 4	12.6	40	0.57	12.29	100	1.41
		12.54	50	0.71	12.43	95	1.34
		12.42	65	0.93	12.61	100	1.41

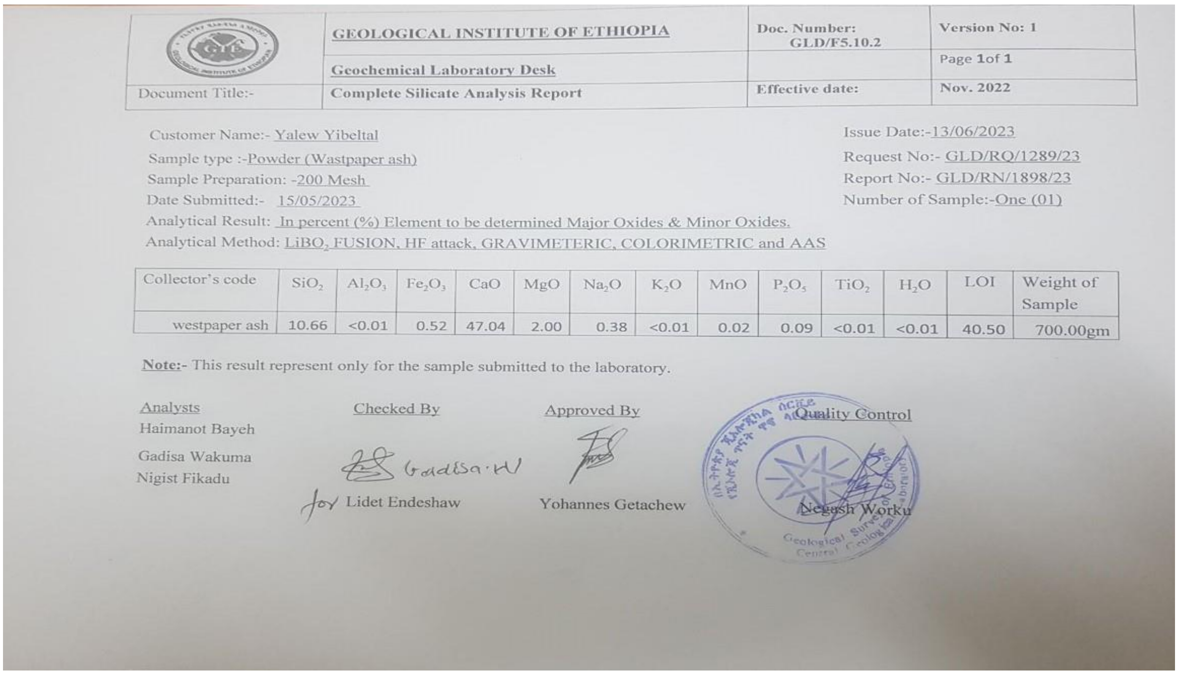
Appendix C: Pictures taken during experimental works.

C1.1: Pictures taken during testing property of material.

C1.2: Pictures taken during preparation of Wastepaper.

C1.3: Pictures captured during casting of concrete.

C1.4: Pictures captured during Curing and testing of concrete



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:- Yalew Yibeltal
Issue Date:-13/06/2023
Sample type :-Powder (Wastpaper ash)
Request No:- GLD/RQ/1289/23
Sample Preparation: -200 Mesh
Report No:- GLD/RN/1898/23
Date Submitted:- 15/05/2023
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
westpaper ash	10.66	<0.01	0.52	47.04	2.00	0.38	<0.01	0.02	0.09	<0.01	<0.01	40.50	700.00gm

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

Analysts
Haimanot Bayeh
Gadisa Wakuma
Nigist Fikadu

Checked By
Gadisa.W
for Lidet Endeshaw

Approved By
Yohannes Getachew

Quality Control
Negash Worku

C1.5: Pictures taken during testing Chemical composition of wastepaper ash.