Impact of Filter Cake on Compressive Strength of Concrete as a partial Replacement for cement

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A Thesis submitted to Department of Civil Engineering

School of civil Engineering and Architecture

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

Office of Graduate Studies

Adama Science and Technology University

June, 2024

Adama, Ethiopia

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DECLARATION

I, hereby declare that this Master Thesis entitled "**Impact of filter cake on compressive strength of concrete as a partial replacement of cement"** is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "**Impact of filter cake on compressive strength of concrete as a partial replacement of cement**" prepared under my guidance by Lidiya Aragaw submitted in partial fulfillment of the requirements for the degree of Master's of science in construction engineering and management. Therefore, I recommend the submission of the revised version of the thesis to the department following the applicable procedure.

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I, the advisor of this thesis entitled “**Impact of filter cake on compressive strength of concrete as a partial replacement of cement**” and developed by Lidiya Aragaw; hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis open defense by Lidiya Aragaw have read and evaluated the thesis entitled “**Impact of filter cake on compressive strength of concrete as a partial replacement of cement**” and examined the candidate. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of science in construction engineering and management.

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ACKNOWLEDGMENT

I would like to express my gratitude and deep appreciation to my advisor Dr. Bahiru Beweket, for his good follow up by having regular and frequent discussions and invaluable comments while the project is in progress and also for his insight and patience with this project.

I want to acknowledge Adama science and Technology University, Faculty of engineering Department of civil engineering Mrs.Yodit, for giving me support. I also wish to acknowledge the sugar factory and Awash melkasa aluminum factory to give me the project material for experiment. Finally, I like to thank my classmates for their kind support and cooperation.

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ABBRIVATIONS

EBCS =	Ethiopian building codes of standards
ASTM =	Americans society for testing of materials
ES =	Ethiopian standard
PPC =	Portland Pozzolana Cement
QC =	quality control
FC=	Filter cake
Mpa=	Megapascal
RCC =	Reinforced Cement Concrete
OPC =	Ordinary Portland Cement
XRD =	X-Ray Diffraction
Cm =	Centimeter
Mm =	Millimeter
KN =	Kilonewton
ES =	Ethiopian Standard
Cao =	Calcium Oxide
Fe2O3=	Iron Oxide
Al2O3 =	Aluminum Oxide

ABSTRACT

In the construction business, concrete is an essential building material. By altering the quantities and characteristics of the ingredients used to make concrete, concert can have different characteristics. Since cement is the main component of concrete, the qualities of the material have the biggest impact on its characteristics. Concrete can be created to have a wide range of qualities, including durability, water tightness, strength, and elasticity. This concrete component is essential to take into account since it is the main factor influencing how well concrete can support loads that have an impact on its size. Like every other component of concrete, cement can directly affect the material's compressive strength. Additionally, the compressive strength of concrete prepared using varying percentages of filter cake in place of cement may vary. Since cement is the main ingredient in concrete, we can alter it by partially replacing waste materials, like filter cake, to create high-quality, reasonably priced concrete. The primary area of unmet research need in this field is the careful documentation of the chemical and mineralogical composition of filter cake in previous investigations. Further research is necessary to fully understand the impact of physical characteristics including surface area, specific gravity, and particle size distribution on concrete performance. This thesis' main objective is to examine how adding filter cake waste to cement affects concrete's strength-related performance. Different source of filter cake might have varying properties that could affect its suitability as a cement replacement so in this study the filter cake was taken from one resource. Using 0%–40% of filter cake as a partial replacement in cement with a fluctuation of 10% is the appropriate amount of mixing proportion. The concrete created in this study is cost-effective because filter cake debris is a waste material that is readily available from various manufacturers and can be manufactured at a lower cost by partially substituting with cement. By exploring the use of filter cake as a cement replacement, the study may provide insight into reducing construction costs, enhancing environmental sustainability and optimizing material usage in construction project. This could lead to advancements in construction practices, resource management and overall project efficiency within the field of construction management. Based on the test findings, the concrete made with Dangote cement and 20% filter cake has a higher compressive strength at the specified ages and also it is the most cost-effective option.

KEY WORDS: Filter Cake, Compressive Strength**,** Concrete**,** Partial Replacement, pozzolanic material

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Concrete, as a quintessential construction material, has undergone significant scrutiny for its environmental impact, particularly in the context of cement production. Cement is a major constituent of concrete, is known for its high energy consumption and greenhouse gas emissions during manufacturing. (scrivener, K.L, & John, V.M., 2010). Consequently, there is a growing emphasis on exploring alternative materials and supplementary cementations additives to enhance the sustainability of concrete without compromising its performance.

One such alternative material under investigation is filter cake, a byproduct generated in industries like oil and gas during the filtration of drilling fluids. Filter cake exhibits unique chemical and physical properties, suggesting its potential as a partial replacement for cement in concrete mixtures. The utilization of industrial byproducts, like filter cake, aligns with the principals of circular economy and sustainable construction practices, offering a solution to reduce both waste generation and the environmental impact associated with conventional concrete production. Traditionally viewed as waste, filter cake exhibits distinct properties that make it a valuable resource for enhancing concrete sustainability.

Filter is known to contain siliceous and aluminous components, resembling pozzolanic materials that have shown promise in enhancing the strength and durability of concrete. Incorporating filter cake with pozzolanic properties into concrete can significantly improve various performance aspects while contributing to sustainability. However, the degree of these benefits depends on the specific characteristics of the filter cake and the mix design used. (Bentz, D.P., 2006).

Filter cake typically consists of fine particles that are rich in silica, alumina, and other pozzolanic materials, making it a potential candidate for use in concrete. Filter cake's composition can vary significantly depending on the source and type of industrial process from which it is derived. This variability can lead to inconsistent properties in the final concrete product (Goretti et al., 2019).

However, despite the potential benefits, the specific impact of filter cake on the performance of concrete remains underexplored. Most existing studies have focused on its use in specific regions or industries and their lack of comprehensive data on how different types of filter cake affect concrete properties across various contexts (Kumar et al., 2018).

The environmental concerns associated with cement production are well documented. Cement manufacturing contributes significantly to carbon dioxide emissions, with estimates suggesting that it accounts for approximately 8% of global anthropogenic Carbon dioxide emissions (Lechtenbohmer, S, Pfluger, B, & Rock, J. ,2017).

As the demand for concrete continues to rise globally, there is a pressing need to address the ecological footprint of this essential construction material. Understanding the performance implications including factors such as compressive strength, workability, and durability, is crucial for optimizing concrete mix designs and promoting the responsible use of industrial byproducts in construction. The findings of this thesis contribute to the broader goal of developing sustainable concrete solutions, aligning with global initiatives aimed at reducing the environmental impact of construction materials. The construction industry is continually seeking sustainable alternatives to traditional building material to mitigate environmental impact and improve resource efficiency. Cement production a cornerstone of concrete manufacturing, is responsible for approximately 8% of global CO_2 emissions making it a significant contributor to climate change (Andrew, 2018).

1.2 Statement of the Problem

The conventional production of cement, a fundamental component of concrete, is known to exert a significant environmental toll through high energy consumption and CO_2 emissions. As the construction industry grapples with the imperative to adopt more sustainable practices, there is a critical need to explore alternative material that can reduce the ecological footprint of concrete without compromising its performance. In this context, filter cake, emerges as a potential supplementary material. However, despite its promise, there exists a notable gap in the understanding of how the incorporation of filter cake as a partial replacement for cement influences the key properties and performance of concrete (Andrew, 2018).

The specific challenges and uncertainties surrounding the utilization of filter cake in concrete production necessitate a focused investigation. Firstly, the effects of varying proportion of filter cake on the compressive strength of concrete, a fundamental indicator of structural performance remain inadequately explored. Understanding how different levels of substitution influence the mechanical strength of the resulting concrete is crucial for optimizing mix design and ensuring structural integrity. Secondly, the impact of filter cake on the workability and durability of concrete remains unclear.

Moreover, the potential chemical interaction between filter cake and cementations components in concrete need thorough investigation. Finally, as sustainability is a key motivator for exploring alternative materials, the environmental implications of using filter cake in concrete production require thorough examination (Malek Batayneh, 2006).

However, the construction industry is growing quickly in Ethiopia. There are currently numerous building projects going on all around the nation. Practice has shown that concrete may be used in more building applications than other materials. It is true that safety and economy are the main considerations in the design of any building project. Nevertheless, issues with construction projects included poor job quality, cost overruns, and delays. Thus, the main issue this study attempts to solve is the dearth of thorough information about how filter cake, used in part instead of cement, affects the important mechanical, workability, durability, and environmental elements of concrete. It is essential to close these gaps in order to promote sustainable practices in the manufacturing of concrete and to offer a well-founded scientific foundation for the appropriate use of filter cake in the building sector.

1.3 Objective of the Study

1.3.1 General Objective

The project's overarching goal is to determine the impact of filter cake as a partial replacement of cement on the compressive strength, workability and cost effectiveness of concrete.

1.3.2 Specific Objective

- To characterize the individual components or ingredients intended for combination in the specified context.
- To mention specific workability aspects to be measured and desired range for optimal workability.
- To evaluate the effect of varying filter cake percentages on compressive strength compared to control concrete without filter cake.
- To analyze the cost incorporating filter cake as a partial replacement of cement in concrete.

1.4 Research Questions

- ❖ How can the individual components or ingredients intended for combination be characterized in the specified context?
- ❖ What is the impact of varying proportions of filter cake on the workability of concrete?
- ❖ How does the inclusion of filter cake as a partial replacement for cement affect the compressive strength of concrete and without adding filter cake?
- ❖ What is the comparative cost analysis between concrete incorporating filter cake as a partial replacement of cement and traditional concrete considering procurement, processing?

1.5 Significance of the Study

This study is important because it fills in a crucial knowledge need and provides a workable plan for improving the sustainability of concrete production. The findings, which encourage the ethical use of industrial wastes like filter cake, may open the door to new environmentally friendly construction methods.

The potential benefits of using filter cake concrete in specific application, include improved sustainability which means using filter cake helps reduce the environmental footprint of concrete production by lowering CO_2 emission and minimizing waste, the other benefits are cost efficiency, enhanced durability and improved mechanical properties.

Cement production has significant environmental impacts including, high CO_2 emissions, energy consumption, resource depletion, and pollution. This study could contribute to sustainability in several ways: reduction in CO_2 emissions, utilization of industrial byproducts, lower energy consumption, resource conservation and enhanced durability and longevity.

In summary, this study aims to provide important new information to the growing field of sustainable building materials by investigating the unexplored use of filter cake as a partial substitute for cement in concrete.

1.6 Scope of the Study

Numerous laboratory experiments and several forms of literature are used to support this study. Nevertheless, the study's conclusions are restricted to the sample that was examined. The outcomes are also particular to the kind of material at the project location and the testing protocols used in the investigation. And also developing and testing concrete mix with varying proportions of filter cake to identify optimal replacement levels for balanced performance (Smith al et, 2018).

The most important characteristics of concrete are its compressive, tensile, and shear strengths. For this reason, this study will concentrate on the compressive strength of concrete that has varying percentages of filter cakes substituted for cement. This study's main objective is to make concrete by varying the percentage of filter cake used as a partial cement substitute and then assess the concrete's compressive strength.

1.7 Limitation of the Study

The study makes the assumption that filter cake is consistently available as a byproduct, and that variations in its quality and availability may affect how useful it is to utilize in the manufacturing of concrete. The study might be carried out on a laboratory scale, and additional factors that aren't taken into consideration in carefully controlled laboratory settings could have an impact on how well concrete with filter cake performs in the real world. Furthermore, the results may alter over time due to external factors like market dynamics, legislative changes, or technical improvements that the study may not have taken into consideration. Since it was difficult for me to locate either magnesium or sodium sulfate, this study did not include soundness test of the aggregate. Omitting this soundness test can compromised structural integrity, leads to higher maintenance costs and safety risks.

1.8 Research Gap

Depending on the source and industry, the composition of filter cake might vary greatly; however, present research may not have adequately examined this diversity. To fully comprehend the relationship between cement hydration products and filter cake particles, there may not be enough microstructural study. Research might be needed to comprehensively assess one of the type of research gap which is the long-term durability of filter cake concrete under various environmental conditions and exposure scenarios. This includes evaluating resistance to chemical attacks, freeze-thaw cycles, and effects on structural integrity over extended service life. There is a gap in quantifying the full environmental benefits of using filter cake in concrete production, including life cycle assessments (LCA) that compare CO2 emissions, energy consumption, and waste reduction with conventional concrete practices.

CHAPTER TWO

LITRATURE REVIEW

2.1 Introduction

Concrete can be traced back to the Latin verb *concrescere,* meaning "to grow together." Appropriately, when if first entered English "concrete" could mean "connected by growth." It was not until the 19th century that the noun "concrete," and its related adjective, began to be used for the building material composed of cementing material and sand, gravel, or similar materials (Meriam, 2017).

Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementitious materials such as fly ash and slag cement, aggregate generally a coarse aggregate made of gravels or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water and chemical admixtures. The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, proportion of the mix, the method of compaction and other controls during placing, compaction and curing. Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a robust stonelike material.

The environmental aspects involved in the production and use of cement, concrete and other construction materials are of growing importance. Substitution of waste materials will conserve dwindling resources, and will avoid the environmental and ecological damages caused by quarrying and exploitation of the raw materials for making cement. To som e extent, it will help to solve the problem otherwise encountered in disposing of the wastes. The output of waste materials suitable as cement replacement (slags, fly ashes, silica fumes, rice husk ash, filter cake etc.) is more than double that of cement production. These waste materials can partly be used, or processed, to produce materials suitable as aggregates or fillers in concrete. New grinding and mixing technology will make the use of these secondary materials simpler. Developments in chemical admixtures: superplasticizers, air entraining agents, etc., help in controlling production techniques and, in achieving the desired properties in concrete. Use of waste products is not only a partial solution to environmental and ecological problems; it significantly improves the microstructure, and consequently the durability properties of concrete, which are difficult to achieve by the use of pure Portland cement. The aim is not only to make the cements and concrete less expensive, but to provide a blend of tailored properties of waste materials and Portland cements suitable for specified purpose. This requires a better understanding of chemistry, and materials science. There is an increasing demand for better understanding of material properties, as well as better control of the microstructure developing in the construction material, to increase durability. The combination of different binders and modifiers to produce cheaper and more durable building materials will solve to some extent the ecological and environmental problems (Satish Chandra, 1996).

Following a normal growth in population, the amount and type of waste materials have increased accordingly. Many of the non-decaying waste materials will remain in the environment for hundreds, perhaps thousands of years. The non-decaying waste materials cause a waste disposal crisis, thereby contributing to the environmental problems. The problem of waste accumulation exists worldwide, specifically in the densely populated areas. Most of these materials are left as stockpiles, landfill material or illegally dumped in selected areas (Malek Batayneh, and Al., 2006)

In the last decades, due to the modern lifestyle, the progresses in industry and technology had led to an important increase in the amount and type of wastes. The problem of waste accumulation occurs every year in all over the world. The wastes represent a major problem for the environment because the air pollution (the dust and very fine particles which spread in the atmosphere) and leaching toxic chemicals, when are dumped in landfills, quarries, rivers or oceans. The capitalization of waste is difficult because of their variety, as well as their unknown properties over time. The building material industry is a domain of interest for using the wastes and researchers have tried to produce new construction materials incorporating wastes. The new generation of building materials is developing on other theories in concordance with the sustainability of environment (Marinela Barbuta, and Al., 2015).

In the last years, the degradation of environment is more pronounced because the measures of protecting the surrounding natural places were not respected and maybe, not understood. The increase of population, the huge energy which is needed, the development of industrial processes, all these resulted in a higher consumption of natural resources, more wastes and a higher pollution (Barbuta Marinela, and Al., 2013).

Utilization of industrial waste materials in concrete compensates the lack of natural resources,solving the disposal problem of waste and to find alternative technique to safeguard the nature. There are a number of industrial wastes used as fully or partial replacement of coarse aggregate, fine aggregate and cement. Regular resources are exhausting largely while in the meantime the produced wastes from the industries are expanding significantly. To safeguard the environment, efforts are being made for using industrial waste in concrete for conserving natural resources and reduce the cost of construction material. The utilization of waste items in concrete makes it inexpensive and reutilize of wastes is supposed as the best ecological option for taking care of the issue of waste disposal. Now a day, new construction materials have emerged as a result of new trends in procuring eco- materials and protecting natural resources. Concrete of any sort may be made by combining wastes, as well as conducting experimental research and statistical optimization, which aid in characterizing the new materials (Morris al et., 2010).

2.2 Definition of Filter Cake

Filter cake, a byproduct of wastewater treatment plants, has been increasingly recognized for its potential applications in the construction industry. Filter cake is a deposit that forms on the surface of a filter over time as particulates become trapped because they cannot pass through the filter. Filter cake is the compacted solid or semisolid material remaining on a filter after pressure filtration (Garcia & Lee, 2020).

Filtration is a process used in a variety of industries so the content of filter cake varies greatly but often it is nutrient rich and beneficial to recycle. If the filter cake content is non-toxic then recycling filter cake can recover resources that for example can be reintroduced into production process, composted or where possible or sold for use as soil enrichment in the agricultural industry. Recycling filter cake also reduces the amount of waste going to landfill and helps prevent environmental contamination. The incorporation of filter cake into concrete mixtures can significantly enhance both the environmental and mechanical performance of the material (Williams & Brown, 2019).

Filter cake possesses a fine particle size distribution and a composition rich in silicates and aluminates, which are conducive to the hydration process in concrete. The researchers conducted a series of experiments, including compressive strength tests, durability assessments, and microscopic examinations, to evaluate the performance of concrete incorporating various percentages of filter cake (Zhang & Kumar, 2021).

2.3 Pozzolanic Properties of Filter Cake

Filter cake has a potential to react with calcium hydroxide and contribute to the formation of additional binding phases in concrete. This pozzolanic activity is crucial for enhancing the mechanical properties of the resulting concrete (Smith al et., 2018).

Table 2.1: Chemical composition of filter cake (Smith al et., 2018)

Chemical composition	Percent (%)
Quartz (SiO2)	**39.991**
Kaolin	**8.883**
Al2(SO4)3	**1.778**
Al(OH)3	**0.878**
CaSO4	**0.194**
Fe2(SO4)3	**0.023**
Fe2O3	**0.001**
MgSO4	**0.008**
Na2SO4	**0.007**
K2SO4	**0.005**
H2SO4	**0.001**
H2O	**48.178**
Others	**0.059**

Filter cake plays an important and essential role in stabilizing porous permeable formations. The ideal (thin, tough, impermeable and flexible) filter cake can isolate the wellbore fluids from the pore fluids at the wellbore wall. This is important in terms of wellbore stability and to prevent differential sticking. If there is poor or no filter cake, the pore pressure near the wellbore increases to the hydrostatic pressure and the effective radial stress is zero. The simultaneous decrease in effective hoop stress reduces the stability of the formation and causes the stress state to move left in the stability envelope. In simple terms, the ideal filter cake provides a more stable wellbore (silva, 2021).

The pozzolanic properties of filter cake have garnered significant attention in recent years, particularly in the context of eco-efficient concrete. The Role of Filter Cake in Modern Construction," published in the Journal of Environmental Management, filter cake exhibits notable pozzolanic characteristics that make it a valuable additive in concrete production. Filter cake, a byproduct of wastewater treatment processes, contains a high content of silica and alumina, which react with calcium hydroxide in the presence of water to form calcium silicate hydrate (C-S-H). This reaction is instrumental in enhancing the strength and durability of concrete (Nguyen & Patel, 2022).

The use of filter cake reduces the reliance on conventional cement, which is known for its high carbon footprint. By substituting a portion of cement with filter cake, the overall environmental impact of concrete production is mitigated. Additionally, the utilization of filter cake addresses waste management issues by repurposing an industrial byproduct that would otherwise be disposed of in landfills (Nguyen & Patel, 2022).

2.4 Ingredients in Concrete

The primary ingredients of concrete are cement, water, aggregates, and admixtures. Each of these components plays a crucial role in determining the properties and performance of the final product.

Concrete is composed of two parts: Aggregates and paste. Aggregates are divided into two types: fine and coarse, and account for 60 to 80 percent of the volume of concrete. The paste is made up of cement, water, and entrained air and typically accounts for 20 to 40% of the overall volume. Concrete performance is determined by the quality of the constituent materials, as well as their proportion and the type of construction that includes placing, compaction, and curing. As a result, in order to examine the performance of concrete, it is necessary to first understand about the materials used to make concrete as well as some of the other elements that influence its performance (Ferraris, 1999).

2.4.1 Cement

Cement is a finely ground mineral powder that is typically grey in color. Limestone, clay, and marl are the three most important raw materials used in the manufacture of cement. Cement, when mixed with water, acts as an adhesive to hold sand, gravel, and hard rock together as concrete. Cement hardens both in the air and under water, and once set, it remains cemented. Cement is often provided as a homogenous bulk dry commodity. Its features are specified to guarantee the application's requisite stability, dependability, and process ability. Cement acts as the binder in concrete, holding the mixture together once it hardens. The type of cement used can significantly influence the concrete's characteristics, including its strength and durability (Wang & Shah, 1997).

Cement is typically composed of clinker , gypsum, and additives. The clinker, obtained through calcination of raw material like limestone and clay, is ground with gypsum to form the final product (Smith et al., 2018).

Various types of cement cater to specific construction needs. Ordinary Portland cement remains the most widely used, while Portland cement incorporates pozzolanic materials.

2.4.1.1 Ordinary Portland Cement

Ordinary Portland cement (OPC) is commonly used in construction. Portland cement is composed of four main oxides, namely; lime (Cao), Silica (Si O2), Alumina (Al2O3) and Iron Oxide (Fe2O3). Portland cement means the product obtained by grinding clinker with the possible addition of a small quantity of calcium sulphates and/or water and it is manufactured by thoroughly mixing together calcareous or other lime bearing materials with argillaceous and/ or other silica, alumina or iron oxide bearing materials burning them at a clinkering temperature and grinding the resulting clinker so as to produce a cement capable of complying with the requirements stipulated in the same standard (Ethiopian standard, 1990).

Portland cement is composed of four main oxides, namely: lime (Cao), Silica (SiO2), Alum ina (Al2O3) and Iron Oxide (Fe2O3). The Iron oxide added to the raw mixture is to aid in controlling the composition. Minor amounts of other materials, such as magnesia, MgO, and alkalis, Na2O, K2O are usually present in relatively small amount as impurities. The function of the gypsum is to control the time of setting of the cement when it is mixed with water in job. However, the principal compounds, in Portland cement exist not in the form of simple oxides but as minerals of more complex molecular structure.

These four principal chemical compounds that make up Portland Cement are: Tricalcium silicate (3CaOSiO2), Dicalcium silicate (2CaOSiO2), Tricalcium aluminate (3CaOAl2O3) and Tetra calcium aminopherase (4CaOAl2O3Fe2O3) Therefore, depending on the relative proportions of its four prominent chemical compounds, the degree of fineness of the clinker grinding and/or by incorporating pozzolanic materials, it is possible to produce different Portland cement types (Damtoft et al., 2008).

As previously stated, the raw ingredients used in the making of Portland cement consist of four major oxides: lime (Cao), silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3). However, the main constituents of Portland cement do not exist as simple oxides, but rather as minerals with more complicated molecular structures. The production of one ton of OPC releases approximately one ton of CO_2 into the atmosphere highlighting the need for alternative materials that can reduce the environmental foot print of concrete (Scrivener et al., 2018).

Table 2. 2 Main Chemical Compounds of Portland cement

Name of compounds	Oxide Composition	Abbreviation
Tricalcium silicate	$3CaOSiO_2$	C_3S
Dicalcium silicate	$2CaOSiO_2$	C_2S
Tricalcium aluminate	$3CaOAl_2O_3$	C_3A
Tetra calcium aminopherase	$4CaOAl_2O_3Fe_2O_3$	C_4AF

The above table shows the names, oxide compositions, and abbreviations of the four major reactive compounds found in clinker and un hydrated Portland cement.

Table 2.3 characteristics of principal compounds that occur in Portland cement

Property	Relative behavior of each compound			
	C_3S	C_2S	C_3A	C_4AF
Rate of reaction	Medium	Slow	Slow	Fast
Heat liberated	Medium	Small	Large	Small
Cementing value, per unit compound				
Early	Good	Poor	Good	Poor
Ultimate	Good	Good	Poor	Poor

The primary function of cement in concrete is to bond the aggregate particles, resulting in high strength, long-lasting concrete. The hydration of the cement, which is regulated by the composition and fineness of the cement, is perhaps the single most critical component that has a substantial effect on these qualities. When Portland cement comes into contact with water, it undergoes a chemical process known as hydration. The hydration of Portland cement, on the other hand, is a significantly more complicated occurrence. This is due to the fact that Portland cement is a heterogeneous combination of numerous chemical substances, each of which is complicated in its own right. Hydration of cement exerts an influence of primary importance on practically all other properties of the paste (Damtoft et al., 2008).

2.4.1.2 Rapid Hardening Portland Cement

Rapid hardening cement is finely ground and has more percentage of tricalcium silicate and dicalcium aluminate, which results in rapid hardening and quick development of the strength. This type of cement is used in places where faster construction works are to be done, so that the form work can be removed early. For example, in road works etc. Rapid Hardening Portland Cement is designed to develop strength more quickly than OPC. It achieves this by having a higher content of tricalcium silicate (C3S), which accelerates the hydration process. This makes RHPC particularly useful in situations where early strength gain is critical, such as in repair works, precast concrete, and situations requiring a quick turnaround (Komatke et al., 2011). The faster strength development of RHPC can also lead to economic benefits by reducing construction times and allowing earlier load application (Mindess et al., 2003).

Despite its advantages, the production of RHPC is not without environmental concerns. Like OPC, the manufacturing process for RHPC is energy-intensive and contributes significantly to CO2 emissions. Therefore, there is a growing interest in finding sustainable alternatives and supplementary cementitious materials (SCMs) that can partially replace RHPC in concrete mixtures (Habert et al., 2011).

2.4.1.3 Low Heat Portland Cement

Low heat Portland cement has lower percentage of tricalcium silicate and dicalcium m aluminate, which results in slow hydration of cement and hence low heat of hydration is evolved. This type of cement is used in mass concrete works, such as gravity dams, retaining wall, bridge abutments etc., (Metha & Monterio, 2014).

2.4.1.4 Portland Slag Cement

Blast furnace slag is the waste product of Pig Iron industry. This slag is mixed with the cement clinker and ground properly to obtain Portland slag cement. The slag imparts high resistance against sulphate attack to the cement. Therefore, it is widely used in places where chances of sulphate attack are there, such as under soil construction works (subjected to ground water exposure) and near the industries emitting waste containing sulphates. Portland Slag Cement is a blended cement that includes a significant proportion of granulated blast furnace slag, a by-product of the steel manufacturing process. The inclusion of slag not only helps in the efficient utilization of industrial waste but also imparts beneficial properties to the cement. PSC typically exhibits improved workability, reduced permeability, and enhanced durability compared to OPC (Dhir et al., 2017). The use of slag in cement production reduces the clinker content, thereby lowering CO2 emissions and contributing to more sustainable construction practices (Mehta & Monteiro, 2014).

The environmental benefits of using PSC are significant. By incorporating slag, PSC reduces the overall carbon footprint of cement production. The production process of PSC emits less CO2 compared to OPC because it requires less energy to grind the slag than to produce clinker from limestone (Schneider et al., 2011). Additionally, the use of slag improves the sustainability profile of concrete by enhancing its long-term durability and resistance to aggressive environments, such as sulfates and chlorides, which can lead to longer service life and reduced maintenance costs (Juenger & Siddique, 2015).

2.4.1.5 Sulphate Resisting Cement

Sulphate resisting cement has very low percentage of tricalcium aluminate and is ground much finer than ordinary Portland cement. This cement has very high sulphate resistance and is widely used for under soil/ground water construction works. Sulphate Resisting Cement is a type of Portland cement with a low tricalcium aluminate (C3A) content, typically less than 5%, which provides increased resistance to sulphate attack. Sulphate attack occurs when sulphate ions from sources such as soil or groundwater react with the hydration products of cement, leading to expansion and cracking of the concrete (Taylor, 1997). This type of deterioration is particularly prevalent in environments such as coastal areas, sewage treatment plants, and structures in contact with soil or water containing high sulphate concentrations (Neville, 2011).

The inclusion of SRC in concrete helps mitigate the deleterious effects of sulphate attack by limiting the formation of expansive ettringite and other sulphate salts. This enhances the durability and longevity of structures exposed to sulphate-rich environments (Lea, 2004).

2.4.1.6 Portland Pozzolana Cement

Portland Pozzolana cement contain pozzolanic material like burnt clay or fly ash. This cement is obtained by grinding pozzolana and cement clinker together. The pozzolana have no cementitious properties themselves but when they combine with free lime, they produce a compound having cementitious properties. Portland Pozzolana cement is cheaper and has a lower rate of development of strength as compared to OPC. Portland Pozzolana cement is being used widely now for all general construction works (W.H Tayler,1997).

Portland Pozzolana cement is defined as Cement resulting from a homogeneous mixture of finely ground Portland clinker and less than 25 Percent by mass of Pozzolana and it does not necessarily satisfy the test for pozzolan city. Pozzolan city is assessed by comparing the quantity of Ca (CH)2 present in a liquid phase in contact with the hydrated cement with the quantity of Ca (OH)2 capable of saturating a medium of the same alkalinity. Pozzolana Cement means cement resulting from a homogeneous mixture of finely ground Portland clinker from 25 to 40 percent by mass of Pozzolana and it satisfies the test for pozzolan city (W.H Tayler,1997).

According to the same criterion, pozzolanic properties are inherent in natural volcanic materials like pozzolana. A material's ability to combine with lime at room temperature and in the presence of water to form compounds that set and harden with the formation of hydrated phases is referred to as its pozzolanic characteristics.

The primary application in constructional work for Pozzolana cements and for natural and artificial Pozzolana as a substitution for part of the cement is in the building of large dams and Mass structures generally where the reduction effected in the heat of hydration is of great importance and the slower gain in strength is not of much consequence. Possible other uses are for mass retaining walls, mass foundations, breakwaters and harbor works, culverts and drains. The improvement in workability which the incorporation of the Pozzolana causes is a considerable advantage in the lean harsh mixes normally used in the construction of dams. (D.F, Orchard, 1973).

2.4.1.7 White Cement

White Cement is a type of Portland cement that is characterized by its white color, which is achieved by reducing the iron oxide content and using raw materials with low levels of metal oxides. The manufacturing process of white cement involves high-purity limestone and kaolin, along with other materials that contribute to its distinct color and properties (Taylor, 1997). This type of cement is highly valued for its aesthetic appeal in architectural concrete, terrazzo, and decorative applications, where appearance is a critical factor (Lea, 2004).

The production of White Cement is more complex and energy-intensive compared to OPC. The raw materials need to be carefully selected and processed to avoid contamination that could affect the color. Additionally, the kiln temperature required to produce white cement is higher, which increases the overall energy consumption and CO2 emissions (Schneider et al., 2011). Despite these challenges, the demand for white cement remains strong due to its aesthetic and functional benefits.

White Cement is not only prized for its color but also for its performance characteristics. It generally offers similar mechanical properties to OPC, making it suitable for structural as well as decorative purposes. The high reflectance of white cement-based surfaces can also contribute to energy savings in buildings by enhancing natural lighting (Gartner & Hirao, 2015). Moreover, its use in precast concrete elements and architectural features can lead to visually striking and durable constructions (Neville, 2011).

2.4.2 Water

Water is an essential component of concrete. It chemically interacts with cement to give the necessary concrete characteristics. The amount of water that comes into contact with the cement, influences the slump of the concrete, and is used to calculate the water to cement ratio (w/c) of the concrete mixture. The w/c ratio of concrete influences its strength and durability to a great extent. Aside from its amount, the quality of the mixing water has a significant impact on the qualities of fresh concrete, such as setting time and workability; it also has a significant impact on the strength and durability of hardened concrete. Water plays a crucial role in concrete mixing and significantly influences the properties of the final product. It is essential not only for the hydration of cement, which is the chemical reaction that allows concrete to harden, but also for providing the necessary workability during the mixing and placing processes (Neville, 2011). The quality of water used in concrete mix is vital, as impurities can adversely affect the strength and durability of the concrete. For instance, the presence of organic materials, salts, or other contaminants in mixing water can lead to reduced strength, delayed setting times, and potential long-term durability issues (Mindess et al., 2003).

In general, quality of water for construction works is same as drinking water (potable water). This is to ensure that the water is reasonably free from such impurities as suspended solids, organic matter and dissolved salts, which may adversely affect the properties of the concrete. Despite these standards, the sustainability of using large quantities of potable water in concrete production is a growing concern, particularly in regions facing water scarcity. This has led to increased interest in finding alternative water sources, such as recycled water from concrete production processes, treated wastewater, and seawater, which can be used without compromising the quality of the concrete (Silva et al., 2020). The use of alternative water sources in concrete mixing not only conserves fresh water but also reduces the environmental impact associated with concrete production (Shi et al., 2018).

Table 2.4: Permissible limits of solids in water for concrete mix

Type of Solid in water	Permissible Limits for Construction
Organic matter	**200 mg/l**
Inorganic matter	**3000 mg/l**
Sulphates (SO4)	**500 mg/l**
Chlorides (Cl)	**a) 1000 mg/l for RCC work and, b) 2000 mg/l**
Suspended matter	**2000 mg/l**

Water used in freshly mixed concrete has three main functions. The first one is it reacts with the cement powder, thus producing hydration products. and the next one is it acts as a lubricant, contributing to the workability of the fresh mixture. Finally, it secures the necessary space in the paste for the development of hydration products (Silva et al., 2020).

In addition to affecting the strength and setting time of concrete, excessive contaminants in the mixing water can also result in staining, efflorescence, reinforcement corrosion, volume instability, and decreased durability.

2.4.3Aggregate

Aggregates, which include materials such as sand, gravel, and crushed stone, play a critical role in the construction industry. They are the fundamental components of concrete, asphalt, and other building materials. The history and use of aggregates date back to ancient civilizations. For instance, the Romans are renowned for their advanced concrete technology, which relied heavily on volcanic ash and lime as binding materials mixed with aggregates (Jackson et al., 2017).

Aggregates are pieces of a bigger parent material that have been manufactured to have certain qualities or have broken naturally due to weathering. The characteristics of the parent rock determine everything, including the chemical and mineral composition, specific gravity, hardness, strength, physical and chemical stability, pore architectures, and hues. These qualities are essential for producing concrete of the highest caliber. In addition to the characteristics of the parent material, aggregate characteristics including grading, shape, and surface texture are more important in producing concrete that is robust, long-lasting, and reasonably priced.

Aggregates can be categorized based on their content, size, origin, and manner of fragmentation. To effectively utilize the full potential of the various types of concrete aggregates during construction, it is crucial to comprehend their respective applications. Natural sources of aggregate materials include quarries, deposits, subterranean sediments, and sand and gravel mines. Aggregate materials examples include:

Crushed rock: To create these goods, rocks must first be extracted and then crushed to the appropriate size and texture. Sources of rock might be sedimentary, metamorphic, or igneous.

Sand - Sand is found in nature. It is a fine composition of stone material and mineral particles and its composition is variable, depending on the source. It can be used for the construction of roads or for the manufacture of concrete.

Gravel - Gravel deposits are produced by a natural process of moisture and erosion. There are different types of gravel - ¾ " and 1 ½ ", seal, hydraulic base, and subbase, for example - which can be used for constructing roads, producing concrete, or for decorative and aesthetic purposes.

Recycled concrete - Recycled concrete is obtained by breaking, grinding or cutting existing concrete to a desired size. It is usually used as a base on which other construction materials are placed thanks to its compact nature. This creates a firm surface which can be easily built upon.

The aggregates in a concrete mixture are the inert mineral filler material that the cement paste binds together. Cement is the costliest of the concrete materials. Because of this, and because aggregates are a very inexpensive filler, it is best to utilize as many aggregates as a given amount of paste will bind together. In addition to being a low-cost Filler, aggregates prevent volume variations caused by the setting and hardening processes, as well as moisture changes in the paste. Aggregate impacts not only the qualities of the concrete but also its economy, contributing about 75% by volume of concrete, producing stability from volume change, and being significantly less expensive than cement. As a result, attention should be used while selecting aggregate for concrete manufacturing. When selecting an aggregate for the creation of a certain concrete, three crucial factors should be considered. The first one is Strength and durability**, t**he aggregate should be free of contaminants that reduce strength and durability, be stronger than the required concrete strength, be resistant to weathering action and not have an unfavorable interaction with the cement. The next one is workability **i.e.** The aggregate size and gradation should be such that no additional work in mixing and putting is necessary the last one is economy**,** that the aggregate should be available from local and easily accessible deposit or quarry and adequately graded in order to reduce paste.

In contemporary construction, the production and processing of aggregates have become highly specialized. According to the U.S. Geological Survey (USGS), over 2.5 billion tons of aggregates are produced annually in the United States alone, highlighting their indispensable role in infrastructure development (USGS, 2020).

The importance of sustainable aggregate production has gained attention in recent years. Researchers emphasize the need for environmentally responsible practices, including the recycling of concrete and asphalt, to reduce the ecological footprint of construction activities (Gower et al., 2019).

The compressive strength of concrete cannot considerably exceed that of the majority of the aggregate included within in regular concrete; however, the same may not be true for aggregates in high strength concrete. As a result, while determining the strength of individual particles is difficult, measuring aggregate crushing strength is critical, especially for high strength concrete. Indeed, testing the crushing strength of individual aggregate particles is difficult, and the required information is usually obtained through indirect tests of physical or mechanical properties such as aggregate crush value, aggregate impact value, force required to compact bulk aggregate, and aggregate performance in concrete (Jackson et al., 2017).

Concrete strength is controlled not only by the mechanical strength of the aggregate but also, to a large extent, by its absorption and bonding characteristics. As a result, it is critical to understand aggregate qualities that influence the binding between aggregate and cement paste.

The aggregate should be adequately compacted for a concrete to have superior strength, and grading, shape, and surface texture are other important aspects in deciding the degree of Compaction with a fair effort and without creating segregation. There are criteria such as flakiness index and elongation on aggregate form, and the effects of aggregate shape and texture on compaction are well established, but it is difficult and costly to restrict aggregate shape and texture for its use. As a result, most standards place a greater emphasis on aggregate grading than on shape and texture (Neville, 2011).

2.4.4Admixture

Concrete admixtures are one of the most significant elements in today's high -performance, long- lasting, durable, and aesthetic concrete. Concrete admixtures are natural or synthetic chemicals or additions that are mixed into fresh or hardened concrete to improve certain attributes such as workability, durability, or early and final strength. An admixture is defined as a material other than water, aggregates, cementitious materials, and fiber reinforcement, used as an ingredient of a cementitious mixture to modify its freshly mixed, setting, or hardened properties and that is added to the batch before or during its mixing. The admixture of concrete has a long and evolving history, reflecting the advancements in materials science and engineering over centuries. Concrete, as a composite material, combines aggregate materials with a binder, typically cement. The concept of admixtures, substances added to the concrete mix to alter its properties, dates back to ancient times. According to "Concrete Admixtures Handbook" by V.S. Ramachandran, early forms of admixtures included natural materials like animal fats, milk, and blood, which were used to improve the workability and durability of concrete (Ramachandran, 1984).

Modern concrete admixtures, however, have become far more sophisticated and specialized. Admixtures can be classified into various categories, including water reducers, retarders, accelerators, and superplasticizers, each serving a distinct function to enhance the performance of concrete. The development of these compounds has been driven by the need for high-performance construction materials capable of meeting the demands of contemporary architecture and infrastructure. In "High-Performance Construction Materials: Science and Applications" by Cajun Shi, the author emphasizes that the introduction of chemical admixtures has significantly revolutionized the concrete industry, enabling the production of high-strength, high-durability concrete suitable for a wide range of applications (Shi et al., 2018).

2.5 Requirements of Good Quality

A good quality concrete needs to be strongest, thickest, workable. A good concrete should meet the compressive strength requirements, meet the durability criteria to withstand the environment in which the structure is intended to serve, be mixed, transported, and compacted as efficiently as possible, and be as economical as possible. There are many requirements should consider to produce the best quality concrete which are: Use well graded, hard and durable aggregates, use sufficient quantity of cement to achieve required water tightness and strength, keep the water-cement ratio as minimum as possible, mix the concrete thoroughly for getting better homogeneity, compact the freshly placed concrete to remove air bubbles and voids Maintain the concrete temperature above the freezing point until it becomes hard enough and lastly cure the concrete properly at least for 28 days (Neville, 2011).

Furthermore, The importance of curing in achieving good quality concrete. Proper curing maintains adequate moisture and temperature conditions, which are necessary for the hydration of cement. This process significantly influences the development of the concrete's microstructure and, ultimately, its performance. They suggest that prolonged curing improves the concrete's strength, durability, and resistance to environmental factors. Therefore, adhering to these rigorous standards and practices is crucial for producing high-quality concrete that meets the demands of modern construction (ACI, 2019).

2.6 Performance of Concrete

The capacity of a concrete to supply the necessary functions over the design life of a concrete building is referred to as concrete performance. Concrete may be constructed to have varied qualities according on the service required, such as strength, flexibility, water tightness, durability, and so on. Concrete strength includes compressive, tensile, and shear strengths; elasticity refers to modulus of elasticity and creep; and concrete durability refers to the capacity of concrete to keep its quality during its intended service life. Because the principal function of almost all constructions is to bear weights or resist applied forces of any kind, concrete utilized for such purposes must be strong. This is why the strength of concrete is often regarded as its most valued attribute, even if other properties may be more vital in other instances. Nonetheless, strength often provides an overall picture of concrete quality, and it is regarded as a good indication, whether direct or inverse, of the majority of the other qualities (Kosmatka et al.,2011).

2.7 Compressive Strength

Compressive strength is a frequently used measure for assessing the performance of a concrete mixture. Compressive strength is a critical property of concrete, reflecting its ability to withstand axial loads without experiencing failure. Historically, the concept of compressive strength has been foundational to civil engineering and construction, determining the suitability of concrete for various structural applications. This element of concrete is crucial to consider since it is the fundamental determinant of how effectively concrete can bear loads that impact its size. It properly tells you whether a given blend is appropriate to match the needs of a specific project. Among the different strength qualities of concrete, compressive strength is typically the most interesting since it is used in developing building units of structural or simple load bearing quality. Furthermore, it has a significant practical and economic value since it determines the sections and sizes of concrete constructions. Because most concrete buildings are built to withstand compressive stress, codes or standards frequently specify this feature (Neville, 2011).

Concrete is extremely resistant to compressive loading. This is why it may be used to build arches, columns, dams, foundations, and tunnel linings. The strength of normal concrete varies between 25 and 40 MPa. Above 50 MPa, the term High Performance Concrete is used.

The compressive strength of concrete is measured using cylindrical specimens constructed of new concrete. It is then compressed and tested at various ages. The suggested strength may also be affected by the size and form. Additional tests are further conducted to obtain detailed information on the competence of strength development. The compressive strength of concrete is influenced by several factors, including the water-cement ratio, the properties of the aggregates used, and the curing conditions (Mehta & Monteiro, 2014).

2.7.1 Concrete Strength Influencing Factors

The strength of concrete is determined by the strength of the aggregate, cement paste, the link between the aggregate and the cement pastes around it, and the total adhesion and compaction of the concrete particles. The cement paste properties are determined by the cement's properties, the water/cement ratio, and the degree of hydration. Aggregate qualities such as strength, shape, and texture influence concrete strength through aggregate strength, its effect on aggregate cement paste binding, and compaction (Mehta & Monteiro, 2014).

Concrete strength is affected by many factors, and the factors are detailed below: Quality of Raw Materials, the raw materials are Cement which Provided the cement conforms with the appropriate standard and it has been stored correctly (i.e., in dry conditions), it should be suitable for use in concrete. The next raw material is aggregates, under aggregate Quality of aggregates, its size, shape, texture, strength etc. determines the strength of concrete. The presence of salts (chlorides and sulphates), silt and clay also reduce the strength of concrete. the third one is water which is frequently the quality of the water should be fit for drinking. The second factor affected concrete strength is water/Cement Ratio. The higher the water/cement ratio, the greater the initial spacing between the cement grains and the greater the volume of residual voids not filled by hydration products. For a given cement content, the workability of the concrete is reduced if the water/cement ratio is reduced. A lower water cement ratio means less water, or more cement and lower workability. However, if the workability becomes too low the concrete becomes difficult to compact and the strength reduces. For a given set of materials and environment conditions, the strength at any age depends only on the water-cement ratio, providing full compaction can be achieved. The strength of concrete increases as the water/cement ratio decreases provided that there is sufficient water for hydration of cement. The third factor is Coarse/fine aggregate ratio**.**

If the proportion of fines is increased in relation to the coarse aggregate, the overall aggregate surface area will increase. And also, If the surface area of the aggregate has increased, the water demand will also increase. Assuming the water demand has increased, the water cement ratio will increase. Since the water cement ratio has increased, the compressive strength will decrease.

The fourth factor is Aggregate/cement ratio**.** If the volume remains the same and the proportion of cement in relation to that of sand is increased the surface area of the solid will increase. If the surface area of the solids has increased, the water demand will stay the same for the constant workability. Assuming an increase in cement content for no increase in water demand, the water cement ratio will decrease. If the water cement ratio reduces, the strength of the concrete will increase. The fifth factor is Degree of Compaction under this Concrete should be compacted as soon as it is placed in the forms to ensure tight contact of the component elements with themselves and with adjacent forms. Hand tools can be used to accomplish this consolidation, although vibrators are more preferable. This consolidation removes air holes and achieves maximum density, which increases the strength and longevity of the concrete. Any entrapped air resulting from inadequate compaction of the plastic concrete will lead to a reduction in strength. If there was 10% trapped air in the concrete, the strength will fall down in the range of 30 to 40%.

The other factor affecting the compressive strength is Temperature**.so** the rate of hydration reaction is temperature dependent. If the temperature increases the reaction also increases. This means that the concrete kept at higher temperature will gain strength more quickly than a similar concrete kept at a lower temperature. However, the final strength of the concrete kept at the higher temperature will be lower. This is because the physical form of the hardened cement paste is less well-structured and more porous when hydration proceeds at faster rate. This is an important point to remember because temperature has a similar but more pronounced detrimental effect on permeability of the concrete.

And also, age of Concrete is a factor that affects the concrete strength. The degree of hydration is synonymous with the age of concrete provided the concrete has not been allowed to dry out or the temperature is too low. In theory, provided the concrete is not allowed to dry out, then it will always be increasing albeit at an ever-reducing rate. For convenience and for most practical applications, it is generally accepted that the majority of the strength has been achieved by 28 days.

The last factor is Curing. It should be clear from what has been said above that the detrimental effects of storage of concrete in a dry environment can be reduced if the concrete is adequately cured to prevent excessive moisture loss. Curing is the final and most crucial process in the production of concrete. Because cement hydration occurs only in the presence of moisture and at proper temperatures, these conditions must be maintained for a sufficient time interval known as curing time. The degree of completeness of hydration, which is an essential aspect in cement paste characteristics, is determined by the capacity to keep moisture in concrete, which is referred to as curing. When concrete is mixed, enough water is added to make it workable. Normally, the amount of mixing water utilized is excessive. As a result, if the original water can be preserved, there is more than enough for curative purposes. There are also other types of Concrete Strengths. These are: tensile strength, flexural strength, and shear strength. Concrete is very weak in tension. The tensile strength of ordinary concrete ranges from about 7 to 10 percent of the compressive strength. The flexural strength of plain concrete is almost wholly dependent upon the tensile strength. However, experiments show that the modulus of rupture is considerably greater than the strength in tension. Shear strength is the real determining factor in the compressive strength of short columns. The average strength of concrete in direct shear varies from about half of the compressive strength for rich mixtures to about 0.8 of the compressive strength for lean mixture. (Neville, 2011)

2.7.2. Durability

A durable concrete is one that operates satisfactorily under current exposure circumstances during the structure's specified life. Concrete durability refers to its capacity to survive the circumstances for which it was intended for an extended length of time without degrading or being damaged. Concrete durability may also be described as the capacity of concrete to withstand weathering, environmental factors, chemical assault, and abrasion while preserving its desirable technical qualities. the durability of concrete is significantly influenced by its composition, the quality of materials used, and the environmental conditions to which it is exposed. Proper mix design, adequate curing, and the use of supplementary cementitious materials can enhance the longevity of concrete structures (Neville, 2011).

Concrete durability often refers to the length of a life span of trouble-free functioning of concrete. Depending on the exposure environment and intended qualities, different types of concrete require varying degrees of durability. It is essential that every concrete structure should continue to perform its intended functions, that is, maintain its required strength and serviceability, during the expected service life. It follows that concrete must be able to withstand the process of deterioration to which it can be expected to be exposed. Such concrete is said to be durable (A.M. Neville,1994).

In addition to material enhancements, maintenance and monitoring are critical for ensuring the long-term durability of concrete structures. Regular inspections and timely repairs can prevent minor issues from escalating into major structural problems. Implementing proactive maintenance strategies and utilizing advanced diagnostic tools can extend the service life of concrete infrastructure. The integration of new technologies, such as self-healing concrete and corrosion inhibitors, also holds promise for future advancements in concrete durability (Bentur & Mitchell, 2008).

CHAPTER THREE

MATERIAL AND METHOD

3.1 Introduction

As stated earlier, the purpose of this study is to determine or examine the impact of filter cake waste as a partial cement substitute by experimenting with different percentages of filter cake addition on concrete performance.

The compressive strength of concrete made with filter cake waste partially substituted for cements and concrete made without filter cake waste replacement are compared in a lab test. With the exception of replacing the filter cake waste, every class of concrete was mixed under the same conditions, allowing for a direct correlation between the characteristics of the filter cake and variations in the quality of the concrete. In order to meet Ethiopian grading requirements, aggregates were additionally cleaned. In addition, the water used complies with standards and is suitable for drinking.

3.2 Material Used

3.2.1 Filter Cake

To meet the goals of this research, filter cake waste is collected from Awash Melkasa, Aluminum Sulfate and Sulfuric Acid Factory which is found 15 km from Adama on the way to Assella. It is white in color and is a byproduct of the factory.

Figure 3.1 Filter Cake sample taken

3.2.2 Cement

One type of brand cement was used for this thesis. Which is pozzolanic cement and its name is Dangote cement.

Figure 3.2 Dangote cement

3.2.3 Aggregate

In the creation of concrete, aggregates are hard inert filler materials used with a binding substance such as cement lime. Aggregates account for 70 to 75 percent of the entire volume of a mass of concrete; hence the characteristics of concrete are heavily influenced by the qualities of the aggregates in it. The coarse aggregate nominal size for this project is 19mm -5mm, and the aggregate maximum size is 19mm. The coarse aggregates were cleaned to eliminate harmful elements before being sieved and kept in grades.

Figure 3.3 coarse aggregate

3.2.4 Water

Potable water is used for this research. In every laboratory work throughout the research, tap water of the campus is used.

3.3 Research Design

Concrete strength (compressive, tensile, and shear) are the most important characteristics; this study will concentrate on the compressive strength of concrete utilizing various cement brands. The major purpose of this study is to make concrete using various percentage of filter cake as a partial substitute for cement, and to test the compressive strength of the concrete. The compressive strength of 60 concrete cube samples made from different percentage of filter cake as a partial replacement of cement will be examined.

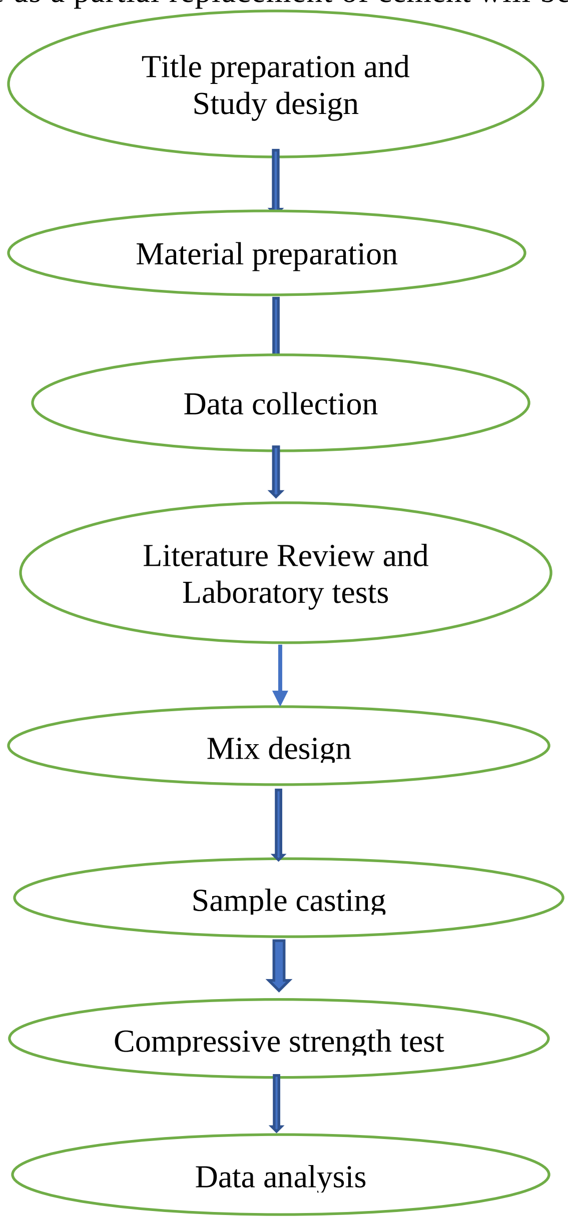

Figure 3.4 Research design Skeleton

3.4 Study Procedure

This study examined the effects of partially substituting various percentages of filter cake waste into cement in a lab setting. The study examines adding 0%–40% filter cake to cements and looks at the compressive strength of 3 specimens per batch that means 60 concrete cube samples.

Various methods of gathering data and methods of analysis were used to accomplish the aforementioned goals.

Material testing and sampling techniques are essential because they must be used to characterize the material and physical characteristics of the materials that may have an impact on the concrete's performance.

Sampling Procedures: The program comprises a number of laboratory tests on the samples, including tests for specific gravity, aggregate impact, slump, silt content of the sand, cube (compressive strength test), and XRD. preparation of the experimental samples, including concrete mixing, specimen casting, and compaction. Analysis and discussion of test results: the findings have been carefully examined and explained in light of the theories and laboratory experiments conducted. On the basis of the findings, conclusions and suggestions are developed.

3.5 Laboratory Test

3.5.1 Sieve Analysis

A fundamental test that is required of all aggregate technicians is the sieve analysis, also referred to as the gradation test. To assess compliance with design, production control criteria, and verification requirements, the sieve analysis calculates the gradation—that is, the distribution of aggregate particles, by size, inside a given sample. To mention a few applications, the gradation data can be used to compute relationships between different aggregates or aggregate blends, assess compliance with such blends, and forecast production patterns through the graphic representation of gradation curves. The sieve analysis is an excellent quality control and quality acceptance tool when used in conjunction with other tests. The main objective of this test is to determine the grain size distribution of the given aggregate by dry sieving.

Test apparatus is set of IS sieves, brushes to clean the sieves, mechanical sieve shaker, balance, trays and thermostatically controlled hot air oven.

Test procedures used for this test are first measure appropriate weight of coarse aggregate samples, arrange the sieve from75mm-4.75mm for coarse aggregate, arrange the sieve from 9.5mm-150µm for fine aggregate, arrange the remaining sieves one above the other. Place a cover at the top and receiver at the bottom, fix the set of sieves to the mechanical sieve shaker. Operate the sieve shaker. And finally, carefully collect and record the mass of the aggregate fraction retained on each sieve and also in the receiver.

Figure 3.5 sieve set

Figure 3.6 sieve shaker

3.5.2 Silt Content of Sand

Sand is the result of minerals and rocks disintegrating naturally or artificially. Sand is found in deposits found in glaciers, rivers, lakes, seas, residual areas, and wind-blown (extremely fine) sand. However, pure sand is not provided by these deposits. They frequently contain materials that are finer than sand, like dust, loam, and clay. Such components weaken the link between the materials to be brought together and, consequently, the mixture's strength when present in the sand used to build concrete or mortar.

Test apparatus used for this test are graduated cylinder or any glass jar, dish for taking sample of sand, funnel, clean water (tap water), sample size spoon and sample sand.

Test procedures are first taking graduated cylinder of 1000ml, pour 300ml of sand to the cylinder, fill approximately ¾ of the cylinder with water, shake the cylinder for about a minute, leave the cylinder for about an hour to allow the silt to settle and finally measure the amount of fine.

Silt content (%) =A/B*100 Where; A: amount of silt deposited above the sand

B: Amount clean sand

According to Ethiopian standard, if the silt content of the sand is more that 6% if shall not be used be for construction.

Figure 3.7 silt content of salt

3.5.3 Moisture content test

The sand and aggregate are dried at constant temperature of 105°C for 24 hours. Their respective mass was recorded and moisture content.

The moisture content is obtained as follow:

$$\text{Moisture content} = \frac{\text{Mass of aggregate - Mass of dried aggregate}}{\text{Mass of dried aggregate}} \text{x}100$$

3.5.4. Bulk density of sand

sand particles are so tiny, they weigh very little. Because of this, they lose their physical intergranular contact and are readily pulled apart by surface moisture. Technically speaking, bulking of sand is the apparent increase in volume of sand caused by surface moisture. On the other hand, to calculate the appropriate volume of sand, utilize ES to calculate the surface moisture content of fine aggregate.

Test apparatus is graduate cylinder, sample of sand and clean water.

I did this test step by step first I measured 400ml of wet sand and place on the cylinder then filled water approximately ¾ of the cylinder after that I Shaked the cylinder and measure the height of fully saturated sand finally I calculated the bulk volume Calculation by the formula;

$$\text{Bulking (\%)} = \frac{A-B}{B} \times 100$$

Where; A=volume of partially saturated sand

B=volume of saturated sand

Figure 3.8 Bulk density of salt

3.5.5 Specific gravity test

A specific gravity is considered when creating the mix. The specific gravity test is carried out using Le Chatelier flasks or clear gravity bottles. The test equipment consists of a 100 ml density bottle with a stopper that has an axial hole in it.

Figure 3.8 weight balance

3.5.6 Slump Test

The slump test is a concrete consistency test that can be performed in a lab or on-site. The consistency of concrete in various batches is shown by the slump test. The workability and quality of the concrete are indicated by the shape of the slumps.

Following the completion of the slump test, a concrete mix (C25) by weight with an appropriate water/cement ratio is pre-paid in the laboratory.

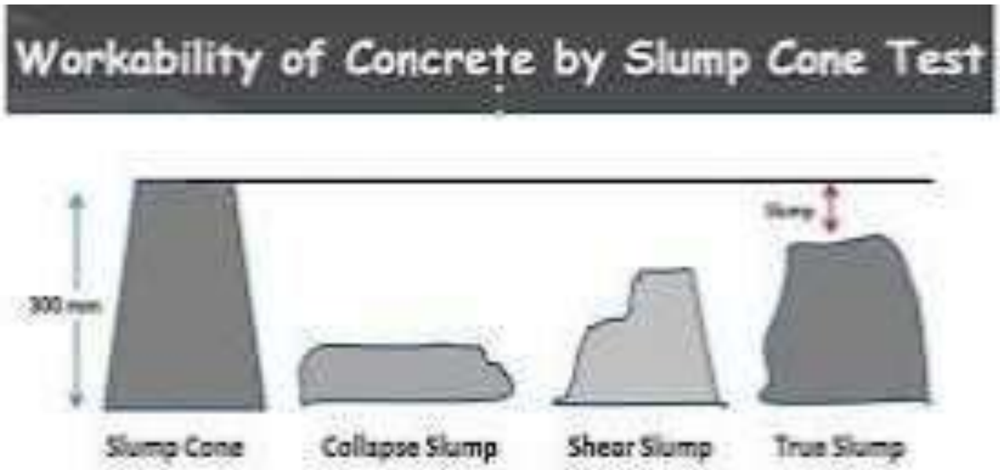

Figure 3.10: Different Slump Type

To ensure the cone is firmly planted on the ground, place it on a level, smooth surface and stand on the footholds on either side. Next, fill the cone with three layers of concrete, tamping or compacting the concrete after each layer in an even, uniform manner (this should be done 25 times per layer) using a steel tamping rod. Make sure the concrete fills the cone precisely to the top and remove any excess concrete from the top once it has been filled. Also, clean up any concrete that may have poured at the cone's base. Then lift the cone vertically, using a slow and steady motion until the cone is clear of the concrete. Place the cone upside down on the surface next to the concrete. And the concrete will subside or slump. To measure the slump, place the steel rod across the top of the upturned cone so it overhangs the concrete. Now, measure from the rod down to the top of the slump. The level of slump is measured to the nearest 5mm.

Figure 3.11 slump test

3.5.7 Aggregate Impact test

Toughness is the ability of a material to withstand impact. The aggregates are impacted by the passage of vehicles on the road, which causes them to fragment into smaller pieces. As a result, the aggregates should be strong enough to withstand impact-induced disintegration. The impact value test is used to quantify this attribute. The resistance to abrupt impact or shock is measured by the aggregate impact value, which may be different from the resistance to a gradually applied compressive strength.

Objective: The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to a slow compressive load.

The apparatus of tests is Impact value test machine, weighting balance, glass rod, about 150 mm and 3 mm diameter, sieves and oven.

Figure 3.12 Impact test machine

3.5.8 Aggregate abrasion test

The quality of aggregate that gives it resistance to deterioration is called hardness. The accepted technique for figuring out aggregate hardness is the Los Angeles Abrasion test. The cylinder is rotated 500 times at a speed of 30 to 33 rpm in order to abrasively treat the sample.

Test apparatus are steel balls, Los Angeles machine, Sieve no. 12(1.7 mm), Sample of coarse aggregate.

The procedure of the test is first Prepared sample is placed in the abrasion testing machine then specified number of steel spheres are then placed in the machine and the drum is rotated for 500 revolutions at a speed of 30 – 33 revolutions per minute (RPM), finally the material is then separated into material passing the 1.70 mm (No. 12) sieve and material retained on the 1.70mm (No. 12).

Figure 3.13 Aggregate abrasion test machine

3.5.9 Flakiness index test

It is the proportion of sample aggregates, expressed in weight terms, whose least dimension is less than 0.6 times the mean dimension. Thickness Gauge is used in its performance.

The test instruments include a sample divider with multiple slot type, a balance with a minimum capacity of 3 kg and a readable level of 0.1 g or better, and a slot gauge. To begin the test procedure, at least one sample must be taken in accordance with the test method. Next, the test portion's particle size distribution must be determined in accordance with the test method, and any sieve fractions that make up less than 5% of the test portion pass must be discarded. Finally record the mass to at least the nearest 1g of each of the individual sieve fractions retained for testing.

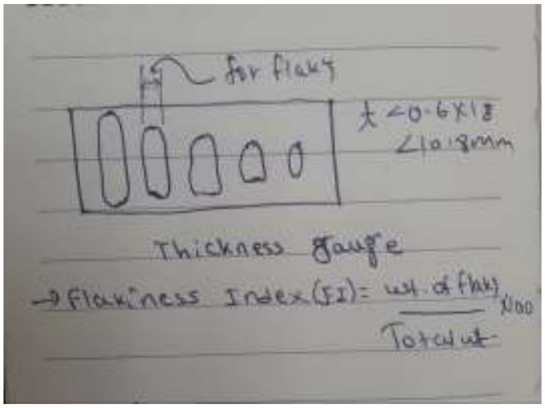

Figure 3.14 flakiness index formula

Figure 3.15 flakiness index gauge

Fig 3.16 Aggregate sample that are taken for flakiness and elongation index test

3.5.10 Elongation index test

The weight proportion of particles whose largest dimension surpasses 1.8 times (9/5 times) their mean dimension is the aggregate's elongation index. Particles that are retained on a 6.3 mm mesh size after passing through a 63 mm mesh size are used for this measurement.

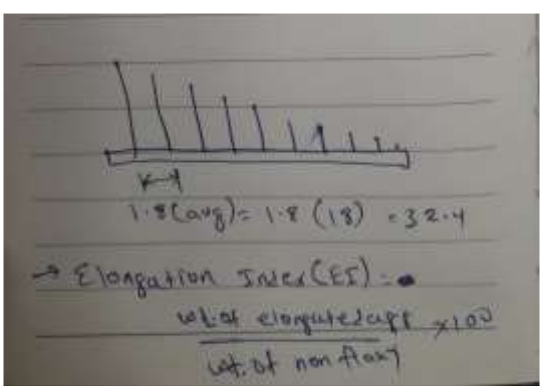

Figure 3.17 Elongation index formula

Figure 3.18 Elongation index gauge

3.5.11 Water absorption test on Aggregate

It can be determined by taking the weight of dry aggregate and the weight of aggregate in saturated surface dry conditions.

Water absorption (%) = [(W1-W2) *100]/W2

Weight of saturated aggregates in air (W1 g)

Weight of oven dry aggregates in air (W2 g)

3.5.12 Soundness test of aggregate

The percentage of material lost from an aggregate blend in the soundness test using magnesium or sodium sulfate is known as soundness. This test determines the aggregate's resilience to in-service weathering and is outlined in ASTM C88 and AASHITO T104. Both coarse and fine aggregate can be used for it.

The apparatus required for the test are containers for aggregates are Sieves, Balance of capacity 5kg to weight accurate to at least 0.1g, and Oven to maintain 105 c to 110 c.

The procedure of the test is first immersing the test samples in the sodium sulfate solution for 17+-1h then suspend the sample containers from racks over the tank in such a manner that the solution covers the samples to a minimum depth of 0.5 in 2. Finally remove the samples from the solution and allow to drain for about 15 min.

3.5.13 XRD test for filter cake

X-ray A strong analytical method for figuring out a material's phase composition and crystalline structure is X-ray diffraction (XRD). When utilized on filter cakes, XRD can yield significant insights into the solids retained by the filter's mineralogical makeup.

The steps involved in this test comprise Preparing the sample in this phase Gather a typical filter cake sample and get it ready for XRD examination. To guarantee homogeneity and optimize the surface area accessible for X-ray interaction, the sample ought to be finely milled. the as directed by the manufacturer, set up the XRD instrument. This include setting up the detector, sample stage, and X-ray source for maximum efficiency and position the produced filter cake sample onto the XRD instrument's sample holder or stage. X-rays produced by the device will interact with the sample's crystalline structure. The X-rays create diffraction patterns that are indicative of the mineralogical composition of the sample as they are diffracted by the crystal lattice planes within the sample. Lastly, gather and examine the diffraction patterns that the XRD device produced. The raw data is processed by software, which then finds the diffraction peaks that match particular crystallographic planes in the sample. The mineralogical makeup of the filter cake is then ascertained by comparing these peaks to a database of recognized mineral phases.

Figure 3.19 XRD machine

3.5.14 Thickness measurement of filter cake

Finding the depth or thickness of the accumulated solids that build up on the filter medium's surface throughout the filtration process is the method of measuring the thickness of a filter cake. This measurement is crucial for determining the filter cake's properties and evaluating the filtration process' effectiveness. Sample preparation is a step in the testing process. Make sure the filter cake sample is ready before starting the thickness measurement. This could entail taking the filter cake out of the filter media with care and putting it on a level surface so that measurements can be taken. Next, the measurement technique is chosen. Select a suitable method to determine the filter cake's thickness. Typical techniques include using calipers or a micrometer, which are simple tools for measuring thickness directly at different locations on the filter cake surface. The second method is non-destructive ultrasound thickness gauges, which can also be used to measure the filter cake's thickness. The filter cake is subjected to ultrasound, and the thickness is determined by measuring the time it takes for the signal to return. I have to position the micrometer or calipers at the required measurement spot, perpendicular to the filter cake's surface, after deciding on the method. Carefully shut the device until it touches the surface, being careful not to crush or move the filter cake. Note the thickness measurement. To get an average thickness measurement, repeat the procedure at several different sites. Regarding Ultrasound, Place the ultrasonic probe on the filter cake surface at the selected measurement spot. To guarantee optimal contact between the probe and the filter cake, apply coupling gel. When you release the ultrasonic signal, the gadget will estimate the thickness by measuring how long it takes for the signal to return. Lastly Determine the filter cake's average thickness if several measurements are made. This gives a more representative number and assists in taking surface variances into consideration.

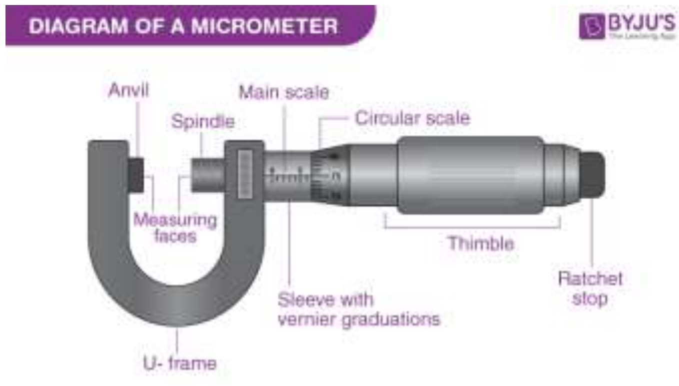

Figure 3.20 Micrometer

3.6 Secondary Data

Secondary data is information that has not been gathered directly from the researcher but has instead been gathered, analyzed, and published by another party. Data from publications published by the government, scholarly journals, market research studies, and other sources may be included in this.

3.7 Preparing Concrete Mix

The concert mix method employed for this specific project is hand mixing the concrete. The act of manually combining the components of concrete without the aid of mixer equipment is known as hand mixing. The steps involved in manually mixing concrete are as follows: A sturdy, clean, and non-porous base composed of masonry or flat iron sheet plates is used for hand mixing concrete. Measured sand is spread out on the platform, and cement is then poured over the sand. Using shovels, thoroughly mix the sand and cement many times while the mixture is dry until it becomes a uniform color without any streaks. Next, the measured number of coarse aggregates is spread out in uniform layer on the above mixture and mixed properly. Later, the whole mixture is blended properly like turning over by twist from the center to the side, then back to the center and again to the sides several times. After that, depression is made at the center of the mixed materials. And, 75% of the required quantity of water is added in the depression and mixed with the help of shovels. Lastly, the remaining amount of water is added and the mixing process is continued till a uniform color and consistency of concrete is obtained. The total time taken for mixing of concrete should not exceed 3 minutes.

Figure 3.21 Hand mixing

3.8 Casting of Specimen

Cast iron is the material of choice for the casting molds. To prevent the creation of honeycombs, the specimen needs to be cast in three layers, each measuring five centimeters, and then appropriately compacted. For testing purposes, a minimum of three specimens from distinct batches must be obtained. The true strength of the batch is ascertained using the specimen's mean compressive strength.

Figure 3.22 casting of specimen

3.9 Compressive Strength or Cube Test

The steps used in this test consist of the following: Fill the steel cube mold with the ready-to-cast concrete mixture. Take the concrete cube out of the mold after a full day, once it has hardened. Next For the allotted period, keep the test specimens underwater. The specimen needs to be submerged in water for 7, 14, 21, or 28 days, as previously stated. Next, make sure the concrete specimen is completely dry before putting it on the machine for compressive strength. Additionally, it is important to avoid having any grit or loose material on the machine's or specimen block's metal plates. moreover, the concrete cubes are positioned on bearing plates so that they line up correctly with the testing machine plates' center of thrust. After that, the specimen must be loaded axially without shock, and the loading must be raised at a rate of 140 kg per square centimeter per minute until the specimen collapses. Finally, because of the continuous stress application, the specimen eventually begins to crack; this final breakdown of the specimen needs to be recorded.

Figure 3.23 compressive strength testing machine

3.10 Data Analysis

The process of transforming, cleansing, and analyzing unprocessed data to extract pertinent, usable information that aids in decision-making for businesses is known as data analysis. By offering helpful information and insights—which are frequently shown in the form of tables, graphs, charts, and images—the process helps lower the risks associated with making decisions. We shall employ a descriptive data analysis style in this study.

CHAPTER FOUR

RESULTS AND DISSCUTION

4.1 Introduction

The laboratory test results on filter-treated concrete are presented in this chapter, together with a discussion of their practical implications. The test results are shown, and a brief discussion of their analysis follows. Sieve analysis, silt content, bulk density, specific gravity, flakiness index, elongation index, aggregate impact, aggregate abrasion, water absorption, soundness, moisture content, slump, chemical composition, XRD, thickness measurement, and compressive strength tests are among the tests.

4.2. Characterization of Ingredients Used in the Study

4.2.1 Sieve analysis

Table.4.1 Sieve analysis for fine aggregate 500gm (sample weight)

Size (mm)	Weight Retained (g)	Percentage Retained (%)	Cumulative wt. retained (%)	Cumulative wt. passing (%)	Lower Limit (%)	Upper Limit (%)
4.75	9	1.8	1.8	98.2	95	100
2.36	13	2.6	4.4	95.6	80	100
1.18	45	9	13.4	86.6	50	85
0.6	189	37.8	51.2	48.8	25	60
0.3	163	32.6	83.8	16.2	10	30
0.15	63	12.6	96.4	3.6	2	10
Pan	18	3.6	100	0		
Total	500gm	100				

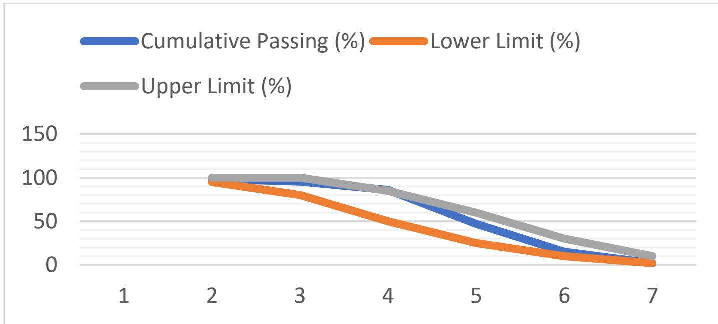

Figure 4.1 fine aggregate sieve analysis

The Fineness Modules is 3.

As a result, according to (F.M), our sample's average size is (0.7mm). Most of the fine aggregate particles are in the range of sizes that are equal to or smaller than 0.7 mm. The ASTM standard has been followed in the evaluation of the fine aggregate sample sieve analysis result. The outcome shows that the fine aggregate size utilized in the project falls between the lower and upper bounds. Furthermore, this implies that the fine aggregate's particle sizes are distributed somewhat uniformly. Concrete qualities like workability, strength, and durability can only be attained by consistent particle size distribution. A constant result, such as 0.7 mm, indicates that the fine aggregate is homogenous, and this can help ensure consistent concrete performance. A size of 0.7mm indicates the material's efficacy in capturing particles of a specific size, which is necessary for the material to perform its intended function, in situations where the fine aggregate is utilized for filtration. The sample has so given its approval for the planned mix design.

Table.4.2 Sieve analysis for coarse aggregate 5000gm (sample weight)

Size (mm)	Weight Retained (g)	Percentage Retained (%)	Cumulative wt. retained (%)	Cumulative wt. passing (%)	Lower Limit (%)	Upper Limit (%)
37.5	0	0	0	100	100	-
19	21	0.42	0.42	99.58	90	100
12.5	2325	46.5	46.92	53.08	40	80
9.5	1267	25.34	72.26	27.74	20	55
4.75	1345	26.9	99.16	0.84	0	10
Pan	42	0.84	100	0	0	5
Total	5000	100				

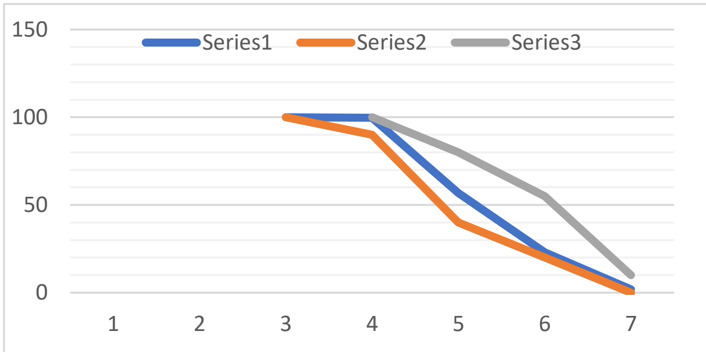

Figure 4.2 Coarse aggregate sieve analysis

Likewise, the coarse aggregate sample sieve analysis result was assessed in compliance with ASTM guidelines. This test's maximum coarse aggregate size is 19 mm. Concrete's strength and durability are mostly attributed to the presence of coarse particles. The aggregate may help achieve the specified concrete qualities, particularly with regard to structural integrity, according to a 19mm sieve test result. The workability of concrete can be impacted by the size of the coarse aggregates. Depending on the precise mix design, larger aggregates can require more water or other steps to maintain workability. But the result in this test indicates that the size of course aggregates which is used for the project is between the lower and upper limit. Therefore, the sample has approved for the intended mix design.

4.2.2 Silt content of sand

The test results indicate that 2.4% of the sand is silty. Any sand that has more than 6% silt concentration ought to be rejected, according to ES. Given that the result satisfies the standards of the Ethiopian Standard and has less than 6% silt, the sand was utilized for concrete testing. Additionally, A 2.4% silt concentration indicates that, in relation to the overall volume of sand, the sand sample has comparatively few tiny particles. For building purposes, a lower silt concentration is often preferred because too much silt might negatively impact the qualities of mortar or concrete. The workability of mortar or concrete can be affected by silt in sand. A silt content of 2.4% is within an acceptable range for most construction applications and should not significantly impair the workability of the mix.

4.2.3 Moisture content test

100g sample from all ingredients were taken then I put it in the oven at 105 c for 24 hr. so the results of moisture content of ingredients are become as follows:

Table 4.3 moisture content of material used

No.	Types of ingredients	Moisture content in %
1	Aggregate	**2.9**
2	Sand	**4.8**
4	**Filter cake**	**9.5**

The amount of moisture in aggregates can affect how workable asphalt or concrete mixtures are. 2.9% moisture content is within a normal range and shouldn't have a major impact on the mix's workability. To attain the appropriate workability, the mix proportions may need to be adjusted if the moisture content is too high or too low. The strength, durability, and workability of concrete or asphalt can be affected by the moisture level of the particles. 2.9% moisture content is generally considered acceptable; nevertheless, in order to guarantee constant quality and performance of the final product, moisture levels must be monitored and controlled. 4.8% moisture content is rather high and could lead to an excessively wet mixture. Owing to the increased moisture content, the mix design may need to be modified to account for the extra water in the sand. To keep the mix performing and remaining consistent, this may include adjusting the amounts of other components, like aggregate or cement. Therefore, before adding the sand to a mix, it could be required to dry it out in order to lower its moisture level. To guarantee that the sand sample has a consistent moisture content throughout, appropriate drying methods must be used. The sand was dried to lower its moisture level before combining. The efficiency of processing in downstream processes can be impacted by the moisture level of the filter cake. To meet the required product quality or requirements, excess moisture may necessitate additional drying or processing procedures. therefore prior to combining, the filter cake was dried.

4.2.4 Bulk density of sand

The accessible sand used has a bulk density of 10.9%. A lower number implies that the particles are less tightly packed, and a higher value indicates that the particles are more densely packed. Bulk density is a measure of how densely packed the particles are within a specific volume. Furthermore, a low bulk density raises the possibility of a high porosity in the sand sample, which denotes a sizable number of voids or open space between the sand particles. Thus, to obtain low porosity, a higher bulk density is required. As a result, this type of sand has been taken into consideration for the anticipated mix design, as advised by ES.

4.2.5 Specific gravity test

Table 4.4 specific gravity of filter cake

No	Particulars	Number of Trials		
		1	**2**	**3**
1	Weight of pycnometer w_1(g)	46	46	**46**
2	Mass of Pycnometer + dry sample(w_2), g	77	78	**77**
3	Mass of Pycnometer + water + sample (w_3), g	163	164	**163**
4	Weight of pycnometer full of water (w_4)	156	156	**156**
5	Weight of dry soil (w_2-w_1) g	28	30	**28**
6	Weight of an equal volume of water(w2-w1) -(w3-w4)	21	22	**19**
7	Specific gravity G	1.47	1.52	1.47

Specific gravity of Filter Cake is taken average of three trials = 1.5 g/cm^3

The filter cake material has a specific gravity of 1.5 g/cm^3, which indicates that it is 1.5 times denser than water of the same volume. This implies that, in comparison to water, the filter cake has a comparatively high density. A material's specific gravity might reveal information about its composition. A specific gravity of 1.5 indicates that there might be heavy or thick materials in the filter cake that add to its overall density.

Table 4.5 specific gravity of cement, aggregate and Filter cake

Material	**Density(g/cm^3)**
Cement	**3.15**
Coarse Aggregate	**2.67**
Fine Aggregate	**2.65**
Filter cake	**1.5**

The specific gravity of aggregates normally used in construction ranges from about 2.5 to 3.0 with an average value of about 2.68.

4.2.6 Slump test

Slump test results indicates that the slumps of the concrete slightly reduced with the addition of filter cake. From laboratory results, the workability of the concrete will reduce with the addition of filter cake.

Table 4. 6 range for slump test of concrete

Mix design	Observed slump (mm)	Range
Dangote cement with FC0	33	Medium
Dangote cement with FC10	33	Medium
Dangote cement with FC20	32	Medium
Dangote cement with FC30	31	Medium
Dangote cement with FC40	31	Medium

A "medium range" slump usually denotes a moderate degree of concrete mix workability. The ease of placing, consolidating, and finishing concrete is gauged by the slump test. A medium slump indicates that the concrete is appropriate for a range of construction applications because it is neither excessively fluid nor too rigid. Pouring or pumping concrete with a medium slump is a simple way to lay and consolidate it using typical building techniques. It prevents excessive bleeding or segregation and enables good flow and consolidation around formwork and reinforcement. For the finished construction to have the appropriate strength, longevity, and finish, the uniformity of the concrete is essential. A balanced mix that offers sufficient workability while preserving cohesiveness and stability during placement and finishing is indicated by a medium slump. Slump test results in the medium range generally point to a concrete mix that has a balanced degree of workability and is appropriate for a variety of construction applications.

4.2.7 Aggregate Impact test

The aggregate impact value is 26.6%. The outcome of the Aggregate Impact Test is used to evaluate the quality of aggregates used in the manufacturing of concrete. Greater percentages of fines could be a sign of lower-quality aggregates, which could have an adverse effect on the concrete's durability and performance. However, my aggregate index value (AIV) falls inside the allowed range, indicating high-quality aggregate that may have a beneficial effect on concrete performance. AIV values between 20% and 30% are also frequently accepted for aggregates in concrete mix design C25, which normally translates to a characteristic compressive strength of 25 MPa at 28 days.

4.2.8 Aggregate Abrasion test

From 500g coarse aggregate sample the retained sample on 1.7mm sieve is 110g and the sample that are passing through 1.7mm sieve is 390g. so the Abrasion value become 78%.

According to this abrasion value, the aggregate is resilient and able to withstand abrasive forces without losing its physical integrity. For concrete constructions to function well over time and last a long time, especially in high-traffic areas like roads and pavements, this durability is essential. Abrasion-resistant aggregates provide concrete that performs better overall in terms of strength, durability, and service life. It is resistant to severe weather, repeated use, and big loads without suffering appreciable damage. It guarantees adherence to quality standards and requirements and promotes improved performance, cost savings, and sustainability.

4.2.9 Flakiness Index test and Elongation Index test

Table 4.7 sample of aggregate for flakiness and elongation test

Size fraction	Weight of sample in kg	Weight of aggregate passing in length gauge (kg)	Weight of aggregate passing in thickness gauge (kg)
63mm-50mm	2	1	0.2
50mm-37.5mm	2	1.5	0.5
37.5mm-28mm	3	2	0.8
28mm-20mm	4	3.2	1.5
20mm-14mm	3	0.5	1.6
14mm-10mm	2	1	1
10mm-6.3mm	2	1.5	0.8

Flakiness index value is 35.5%. Flaky particles in aggregates can affect the workability of concrete mixes. Due to more voids and inadequate particle interlocking, higher flakiness index values may provide a less workable mix, which may affect the concrete's consistency and finish. This test yielded a lower flakiness score, which indicates a greater workability mix because there were less voids. This information is useful for modifying the mix proportions to account for the aggregate's unique properties. This implies that adding more cementitious or fine particles to the mix won't help it cohesive and fill in any gaps.

Elongation index value is 92.2%.

4.2.10 Water Absorption test

The Water absorption of aggregate test result is 5.57%, suggests that the aggregate has a relatively low porosity, meaning it cannot absorb a significant amount of water. Furthermore, it cannot make concrete containing such aggregates more susceptible to chemical attacks, freeze-thaw cycles, or other climatic conditions, which could shorten the concrete's lifespan. It has no effect on concrete mixes' water-to-cement ratio. This level of water absorption in the aggregates may help reduce shrinkage and improve the workability and strength of the concrete mix.

In general, meeting quality standards for construction projects, assuring durability, and improving concrete mix designs all depend on comprehending and acting upon the test results.

4.2.11 XRD test for Filter cake

The XRD graph of filter cake can provide detailed information about its mineralogy, crystallinity, and structural characteristics, aiding in the understanding of its formation process, properties, and potential applications. The standard range of XRD test covers 3 to 90 degrees(2θ).

After 600 heat treatment

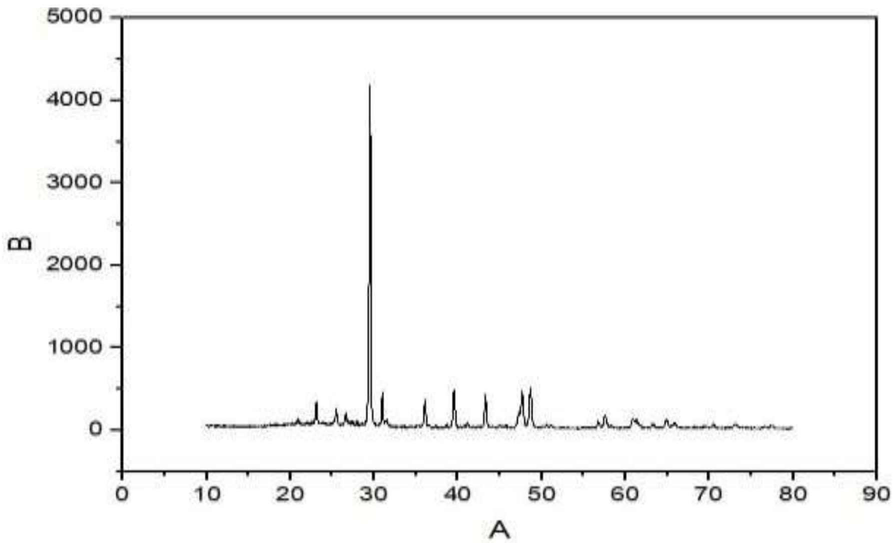

Figure 4.3 XRD test graph

The peak value indicates the calcite ($CaCO_3$) and magnesia (MgO). And the medium values are indicating quartz (SiO_2). The reactivity and characteristics of the filter cake can be affected by calcite and magnesia. For instance, magnesia might influence the material's stability and hydration behavior, while calcite can contribute to alkalinity and possible pozzolanic activity. The reactivity and characteristics of the filter cake can be affected by calcite and magnesia. Higher calcite and magnesia values in the filter cake's XRD test results show the existence of these mineral phases and may have consequences for applications, reactivity, composition, and quality control.

A=2 Theta(degree)

The x-axis of an XRD graph represents the diffraction angle (2θ), which is the angle of incidence of the X-ray beam relative to the sample surface. This angle is measured in degrees and corresponds to the angle at which X-rays are diffracted by the crystal lattice of the sample. The diffraction angle is related to the spacing between atomic planes in the crystal lattice according to Bragg's law.

B= Intensity

The y-axis of an XRD graph represents the intensity of the diffracted X-rays, typically measured in counts per second (cps) or arbitrary units. The intensity corresponds to the number of X-rays detected at each diffraction angle and provides information about the abundance of the diffracting crystalline phases in the sample. Higher intensity peaks indicate higher concentrations of the corresponding mineral phases or compounds in the filter cake.

4.2.12 Thickness Measurement of Filter Cake

The specifications of the particular industrial process in which filter cake is employed may specify the permissible thickness of the material. For higher separation or filtration efficiency, for instance, a thicker filter cake might be desired in some processes, but a thinner filter cake might be preferable in others for quicker processing or simpler handling.

So, the thickness of the filter cake itself isn't the main factor to take into account when utilizing it to partially substitute cement in building materials like concrete. Rather, the important factor is the ratio of filter cake to cement volume in the concrete mixture.

4.3 Preparation of the Mixture

For the purposes of this study, I used ppc cement which is Dangote cement. Mix preparations were performed to compare the compressive strength of each sample prepared from adding different percentage of filter cake with Dangote cement. as well as to determine the compressive strength of the sample at different ages.

For C25, the proportion (the mix ratio) is 1:2:3, which means one bag of cement, two boxes of sand, and three boxes of coarse aggregate are used, and the water cement ratio should be between 0.4 and 0.6. We mixed the ingredients using the following calculation.

Wastage factor=1.05, Shrinkage factor=1.3, Volume of the cube= 0.003375m^3

Sand=2/6*1.05*1.3*1840 kg/m^3(specific gravity of sand) *0.003375m^3

=2.83kg this amount of fine aggregate should be used for each cubic sample

Coarse aggregate=3/6*1.05*1.3*2250 kg/m^3*0.003375m^3

=5.182kg amount of coarse aggregate are used for each

Cement=1/6*1.05*1.3*1400kg/m^3*0.003375m^3

=1.075kg (hence this indicate that we have to use 1.075 kg cement for one cubic sample ofconcrete.

Water/cement=0.4-0.65, Water(kg)/1bag(50kg) =0.5, Water(kg)=0.5*50=25kg of water used for 50 kg of cement

so50kg of cement=25 kg of water

1.075kg of cement = X =0.5375kg (lit) of water is needed for one cubic sample

To calculate the filter cake, mix, take 10%, 20%, 30% and 40% of the cement quantity.

Totally 169.8kg sand, 310.92kg coarse aggregate, 32.25lit water, 51.1kg cement and 12.9k filter cake for 60 cube samples were used for this study.

4.4 Compressive Strength Test Result

According to studies and research, the compressive strength of concrete increases with age. The majority of studies were conducted to investigate concrete's 28th-day strength. However, the strength at the 28th day is less than the long-term strength that it can gain with age. The dimension of cube in cm, the length is 15cm, the width is 15cm and also the height is 15cm. And the volume is $3373cm^3$. As hydration progresses, concrete will get stronger. The concrete's strength will gradually grow with age if the surrounding conditions allow for better hydration. But this hydration rate increases quickly at first and decreases over time. Therefore, on the 28th day, the compressive strength of the concrete is measured; thereafter, the strength decreases at a slower rate. Later-life compressive strength is evaluated by non-destructive testing. It will be easier to avoid moisture escape under ideal curing condition, which will speed up strength growth rxn.

Table 4.8 standard percentage of compressive strength at different stage

Age in Days	Strength in Percentage
1 Day	16%
3 Days	40%
7 Days	65%
14 Days	90%
21 Days	94%
28 Days	99%

Table 4.9 compressive strength test result for the age of 7th days and 14th days

No	Mix design	Weight (gm)for 7days sample	Weight (gm) for 14days sample	Failure load (KN) (7days)	Failure load (KN) (14days)	Ave. Compressive strength(mp_a) for 7days	Ave. Compressive strength(mp_a) for 14days
1	FC0	7660	7670	191	252	8.72	11.51
		7460	7450	220	257		
		7575	7665	180	266		
2	FC10	7540	7640	205	292	8.88	12.47
		7545	7575	200	270		
		7430	7460	195	282		
3	FC20	7460	7230	215	290	9.61	12.82
		7425	7655	225	275		
		7340	7240	210	303		
4	FC30	7235	7255	120	254	5.53	11.3
		7260	7270	135	245		
		7345	7345	120	270		
5	FC40	7230	7200	115	225	5.67	10.4
		7200	7250	140	230		
		7190	7150	130	248		

At the 7th days, the compressive strength of concrete produced with 20% of filter cake is increased by 9.61 MPa, with adding 40% of filter cake is decreased by 5.53 MPa, indicating that Dangote brand cement with the addition of 20% filter cake produced greater compressive. In general, the result shows that when I added more percentage strength of filter cake in to cement the compressive strength of concrete become decreased to get higher strength adding a small amount means 20% or 10% of filter cake is preferable. At the 14th days, the compressive strength of concrete produced with 20% of filter cake is also increased by 12.82 MPa, with adding 40% of filter cake is decreased by 10.4 MPa, indicating that Dangote brand cement with the addition of 20% filter cake produced greater compressive strength. The value of compressive strength in 14th age shows the same conclusion result to the age of 7th days.

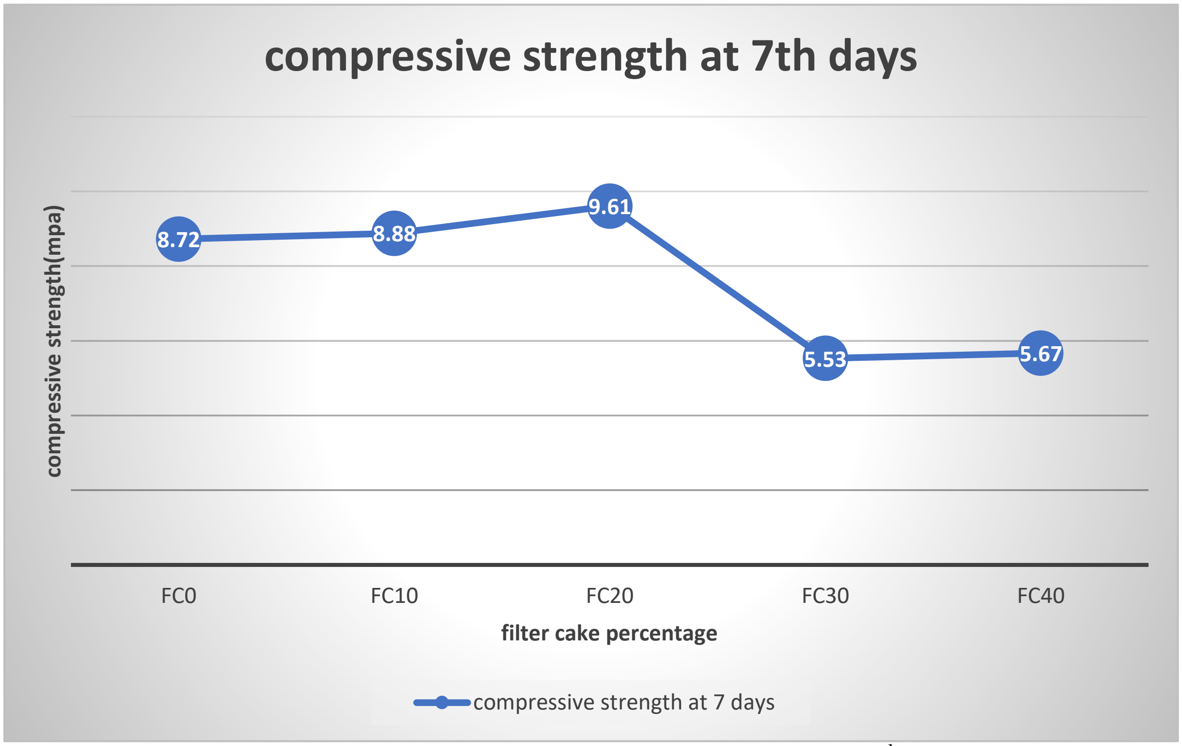

Figure 4.4 compressive strength at the age of 7th days

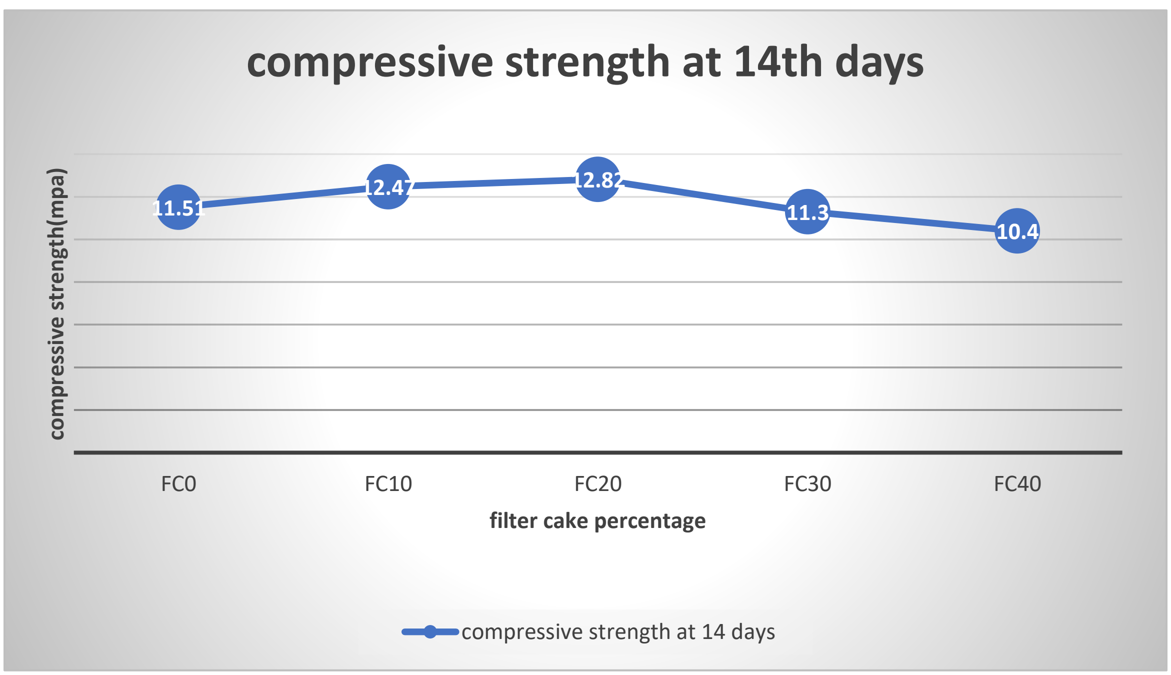

Figure 4.5 compressive strength at the age of 14th days

Table 4.10compressive strength test result for the age of 21th days and 28th

No	Mix design	Wt.(gm) for 21day sample	Wt.(gm) for28day sample	Failure load(KN) 21 days	Failure load(KN) 28 days	Average C.S(mpa) for21 days	Average C.S(mpa) for 28 days
1	FC0	7500	7600	380	515	15.95	22.7
		7345	7500	338	495		
		7600	7450	360	526		
2	FC10	7500	7500	360	517	16.43	23.5
		7500	7600	370	533		
		7450	7400	382	540		
3	FC20	7550	7500	380	550	16.7	24.43
		7650	7500	362	540		
		7600	7400	383	550		
4	FC30	7340	7360	344	447	15.36	19.67
		7200	7200	355	425		
		7345	7390	340	460		
5	FC40	7200	7350	324	378	14.43	16.6
		7300	7300	336	360		
		7100	7200	315	382		

At the 21th days , the compressive strength of concrete produced with 10% of filter cake is increased by 16.43 MPa, adding 20% of filter cake is more increased by 16.7 MPa , and adding more than 20% of filter cake shows a decreased compressive strength value and also in the age of 28th the value shows there is a higher compressive strength in the adding of 20% of filter cake to cement. compressive.

In general, the compressive strength value shows adding more than 20% of filter cake as a partial replacement of cement gives a lower compressive strength than adding less amount of filter cake in to cement and also a compressive strength without the replacement of filter cake shows greater value than adding more than 20% of filter cake as a partial replacement of cement.

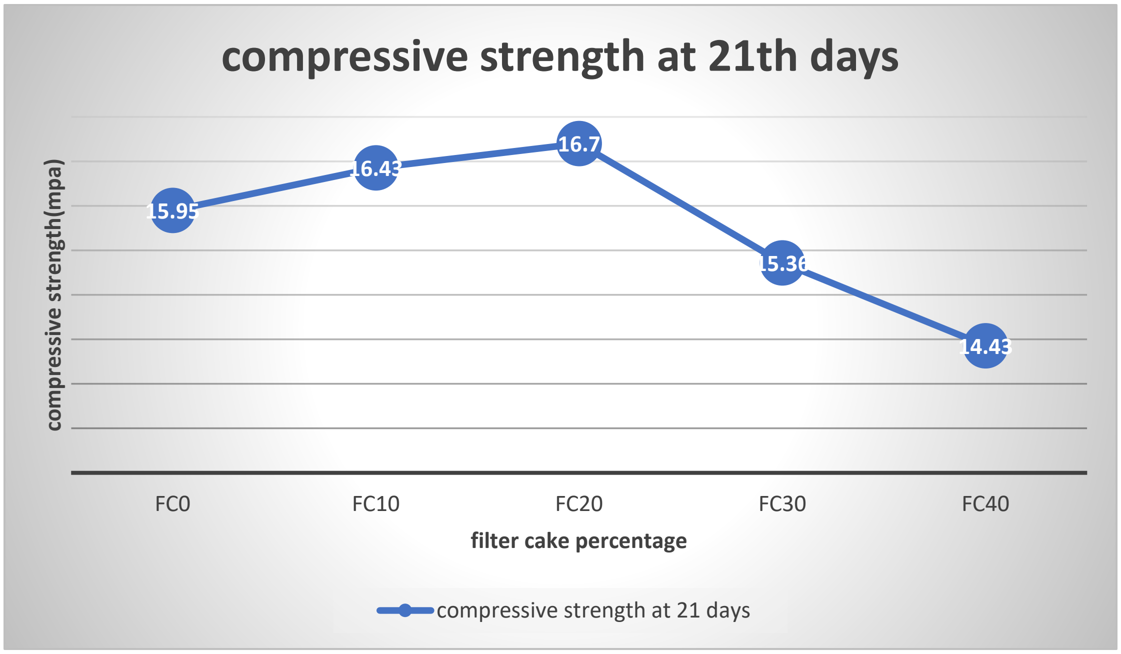

Figure 4.5 compressive strength at the age of 21th days

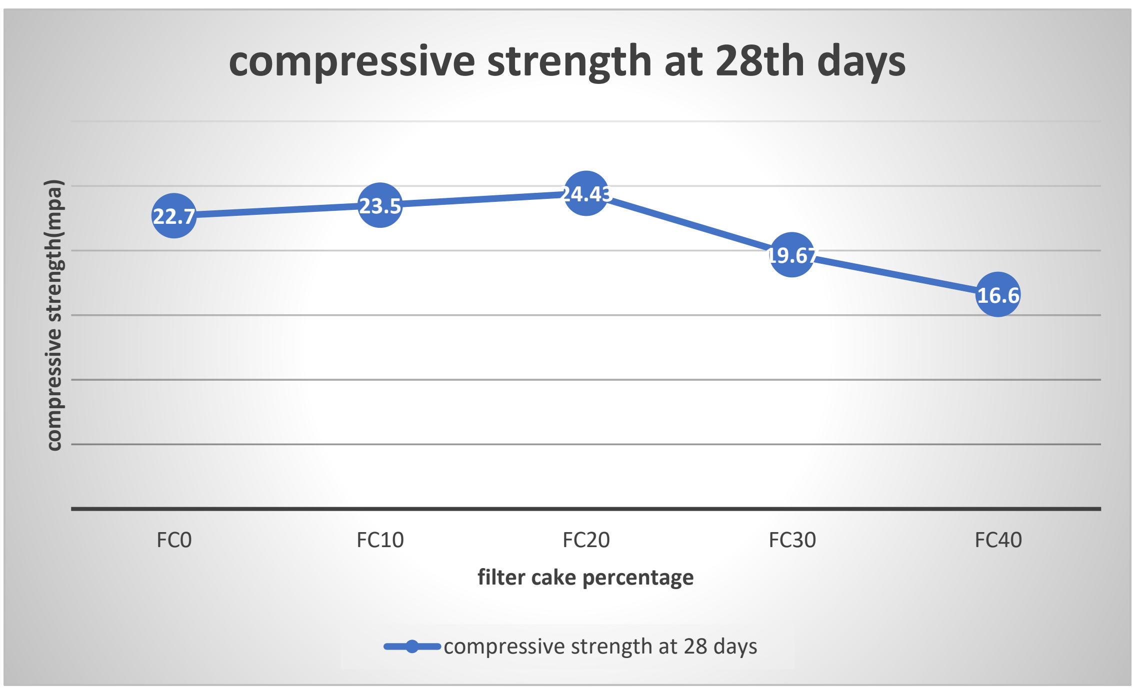

Figure 4.6 compressive strength at the age of 28th days

4.5 Cost Analysis

Let's calculate the cost analysis for a scenario where different percentage of filter cake is replaced in the concrete mix.

The cost of cement currently is 13 birrs per 1kg and the cost of filter cake is currently almost 1.5 birr per 1kg. so, for 1m cubic sample of concrete I used 1.075kg cement,2.83kg sand, 5.182kg aggregate and 0.5375 lit water from the mix design. The table below shows the total cost in 1m3 sample concrete.

Table 4.11 Production cost for 1m3 cube concrete without replacement of filter cake

Inputs	Quantity(kg) needed	Price(birr) per kg	Cost(birr)
Cement	1.075	13	13.91
Sand	2.83	0.02	0.01
Aggregate	5.182	0.77	3.99
Water	0.5375	1.11	3.14
Total Cost			21.05

When different percentage of filter cake replaced in to cement there is a cost different to produce 1m3 sample concrete as shown in the table below.

Table 4.12 Production cost for 1m3 cube concrete with replacement of filter cake

	Cement (90%)	**FC (10%)**	**Cement (80%)**	**FC (20%)**	**Cement (70%)**	**FC (30%)**	**Cement (60%)**	**FC (40%)**
Quantity(kg)	0.963	0.107	0.86	0.21	0.749	0.321	0.642	0.428
Price (birr per kg)	13	1.5	13	1.5	13	1.5	13	1.5
Cost(birr)	12.519	0.1605	11.13	0.32	9.73	0.48	8.346	0.642
Total cost	12.6795		11.45		10.22		8.98	
Net cost benefit	0.3205		1.5		2.78		4.01	
Cost-Benefit ratio	2.5%		12%		21.4%		30.9%	

Table 4.13 Cost – Benefit analysis

	Filter cake replacement ratio			
	10%	20%	30%	40%
Production cost(birr)	20.7295	19.499	18.2685	17.031
Net cost benefit ratio(birr)	0.3205	1.551	2.7815	4.012
Cost-Benefit ratio	1.5%	7.4%	13.21%	19.1%

The total cost without the replacement of filter cake in to cement is 21.05 birr to produce 1m3 sample concrete. When 10% of filter cake replaced in to cement the cost will be 20.7295 birr. so, from this the net cost benefit ratio will be 0.3205 birr. Adding more and more percentage of filter cake in to cement will show a greater cost benefit ratio.

In general, the replacement of filter cake as a partial replacement of cement shows a cost saving to produce concrete.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

- All individual components exhibit desirable properties suggests that they are suitable choices for concrete production. This proves that the chosen materials satisfy the required requirements for durability, strength, and other performance parameters. Based on my observations, the materials used for this thesis had favorable qualities that made them work well together in the concrete mixture. In order to maintain appropriate bonding and cohesiveness within the concrete matrix, which adds to the structure's overall strength and integrity, compatibility is necessary.
- By combining waste materials, filter cake and cement can have a synergistic impact that improves the workability of the concrete mixture, and may even lower its total carbon footprint. so, combining less than 20% of filter cake and Dangote cement gives more strength, more durability and reduce the overall carbon footprint. It gives also a good synergistic effect.
- As demonstrated from the results the workability of the concrete will reduce with the addition of filter cake absorption of water. when more amount of filter cake was added the workability of concrete was reduced.
- From the test results; At the 28th day, the compressive strength of concrete produced with 20% of filter cake is increased by 23.3 MPa, on the other hand adding 40% of filter cake in to cement is decreased by 16.6 MPa, it indicates that Dangote brand cement with the addition of 20% filter cake produced greater compressive strength than the other percentage of filter cake. Also, at 7,14 and 21 ages the compressive strength produced with 10% and 20% is greater but produced with 30% and 40% is less. From the result, using 20% of filter cake as a partial replacement of cement is better mix proportion than without the replacement of filter cake in to cement to produce a greater compressive strength.
- Filter cake is by-product material; it used as a cement replacement material to reduces costs. The Concrete produced in this research is cost effective concrete, because by substituting filter cake partially with cement we can produce low-cost concrete.

5.2 Recommendation

- The use of waste products is not only a partial solution to environmental and ecological problems; it also improves the microstructure and, as a result, the durability properties of concrete, which are difficult to achieve with pure Portland cement. Therefore, wastes likefilter cake should be more used in concrete production.
- To improve durability, there is a growing need for a deeper comprehension of material attributes and improved management of the microstructure that forms in building materials. The ecological and environmental issues will be partially resolved by combining various binders and modifiers to create more affordable and long-lasting building materials.
- The project demonstrated that filter cake can be used as a partial cement replacement material with both technical and environmental advantages. Concerned stakeholders, suchas aluminum sulfate factories, cement industries, and relevant government institution, should be made aware of this potential cement replacement material and encouraged tostandardize its production and use in order to easily reduce environmental problems.
- Further research is recommended, such as the presence of acidic property in filter cake andits degree of effect on concrete quality.

RESEARCH FUND ACKNOWLEDGMENT

This research project is funded by Adama science and technology university under the grant number ASTU/SM-R/1082/24, Adama, Ethiopia.

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