REPUBLIQUE DU Mali
Un peuple- Un but- Une foi
****
Ministère de l'Enseignements
Supérieur et de la Recherche Scientifique
Direction Générale de l'Enseignement Supérieur et de la Recherche Scientifique
Université Privée Africaine Franco-Arabe

REPUBLIC OF Mali
One people- One Goal- One faith
****
Ministry of Higher Learning and Scientific Research
General Directorate of Higher Education and Scientific Research
Private African Franco-Arab University

DEPARTMENT OF CIVIL ENGINEERING

CONSTRUCTION TECHNOLOGY

ASSESSMENT USE OF PEAT COAL FLY ASH AS PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

Submitted in partial fulfillment of the requirements for the award of Bachelor's Degree in Civil Engineering, Construction Technology

Author's Name: MUCYO Alliance
REG N^{O} FSAN-7083
Email: mucyalliance@gmail.com

Supervisor: Eng. Joves NZABONIMPA

Bamako, March 2025

DECLARATION

I, AllianceMUCYO declare that this research project called**"Assessment use of peat coal fly ash as partial replacement of cement in concrete"**is my original work and has never been submitted to any University or other Institutions of Higher Learning.

Date: 7^{th} March, 2025

Signature:

MUCYO Alliance (FSAN - 7083)

APPROVAL

I, Joves NZABONIMPAapprove that this project work called**"Assessment use of peat coal fly ash as partial replacement of cement in concrete"**was done by Alliance MUCYO (FSAN - 7083) under my supervision and it is ready to be submitted to university with my due approval.

Date: 7th March, 2025

Signature:……………………………………….

Eng. Joves NZABONIMPA

DEDICATION

This Report is dedicated to the following persons who without them the project could not be successfully completed, materially, intellectually, physically and financially contributed to make the project success.

- Almighty God who enables in my studies,
- My dearest parents who encourage and support me in all my studies,
- My beloved brothers, sisters and relatives,
- My friends and colleagues,
- My supervisor Eng. Joves NZABONIMPA, who guides me a lot,

You are the sun that lightens my lives. For you, I dedicate this work.

ACKNOWLEDGEMENT

I thank almighty GOD, who protects me in this whole life, all civil engineering lecturers for teaching me in all courses which took me to this wonderful level of final year. I would like to deliver my gratitude to UPAFA institution for its sustainable education they provide to their students. Also, I am particularly thanking my family members, Classmates and my friends for their daily assistance and I know they are able to help me at any cost.

ABSTRACT

Construction industry is one of the main fields making the worldwide development today and it is also developing fast the same case to Rwanda my country. And the use of concrete has been common in this period of that development in construction should suit the economy for people.To achieve this, materials to be used in construction is the main issue to be addressed. That brought me to think about the assessment use of locally available material, peat coal fly ash to be used as partial replacement of cement in concrete which does not yet have a perfect application.This project intends to reduce the cost of construction projects by taking into account the appropriate technology of maximizing the use of residue material. The project was carried out by doing various tests to get optimum peat coal fly ash percentage to be used. Concrete compressive strength test and slump test to assess some necessary properties of material used and result were presented and interpreted in this project work. This report summarized the study on Assessment use of peat coal fly ash as partial replacement of Ordinary Portland cement (OPC) in concrete. OPC was replaced with PFA by weight at 5%, 10% and 15%. 0% of PFA used as reference. Compressive strength test was carried out on 150mm x 150mm x 150mm steel mould after 3,7 and 14 days curing in water bath.

KEY WORDS

- Cement,
- Peat coal fly ash,
- concrete,
- fine aggregate, and
- coarse aggregate

LIST OF FIGURES

LIST OF TABLES

LIST OF ABREVIATIONS AND SYMBOLS

OPC: Ordinary Portland cement

ASTM: American Standard for Testing and Materials

WOPC: White Ordinary Portland cement

PCC: Portland cement Concrete

LOI: Loss on Ignition

LT: Low temperature

HT: High temperature

PA: Pond Ash

UCS: Unconfined Compression Strength

FA: Fly Ash

PFA: Peat coal Fly Ash

BS: British Standard

%:Percentage

UPAFA: UNIVERSITE' PRIVEE AFRICAINE FRANCO-ARABE

TABLE OF CONTENT

CHAPTER ONE: GENERAL INTRODUCTION

1.1. Background of study

Concrete is by far the most widely used construction material nowadays. Concrete has attained the status of a major building material in all branches of modern construction because of reasons. It is possible to control the properties of cement concrete within a wide range by using appropriate ingredients and applying special processing technical, mechanical, chemical and physical. It is possible to mechanize completely its preparation and placing process (Neville, 1987).

It possesses adequate plasticity for mechanical working. Concrete is by far the best material of choice where strength, durability, permeability, fire resistance and abrasion resistance are found.

In the present world, inflation is one of the main problems faced by every country. It has become essential to lower the construction cost without much compromise as far as strength and durability of the structure is concerned. The lowering of cost can be brought about in number of ways. Among all the methods available the most optimum at our disposal is the use of waste materials as substitute. The cement concrete is well-known building material and has occupied an indispensable place in construction work. The strength of concrete depends upon the components such as aggregate, quality of cement, water-cement ratio, and normal consistency of mix, proportion and age of curing of concrete. New building materials are used to accelerate the construction work, in which the mixture plays as important role in characteristics of concrete (Neville, 1987).

Normally, concrete contains four basic ingredients: water, cement, fine aggregate (sand) and coarse aggregate. The production of national concrete using Portland cement releases big amount of greenhouse gases such as carbon dioxide. In this case some alternative materials will be added or used to replace certain amounts of the traditional concrete ingredients.Using alternative materials such as fly ash reduces greenhouse gases in their production, reserves natural resources, and are locally available to decrease transportation costs, or improve material performance during their life cycles (Neville, 1987).

1.2. Problem statement

The construction industry is rapidly growing around the world including Rwanda and the technologies have emerged to face various difficulties in the construction. The manufacturing cement companies are main contributor to release carbon dioxide in the environment (Van Oss, 2003), approximately 0.9 ton of cement produced emit one ton of carbon dioxide and it is responsible for global warming added that about every year 1.89 billion tons of cement (which is a major component of concrete) has been manufactured around the world (Verma, 2021). Around 10% of total world carbon dioxide emission comes from the cement manufacturing process in cement factories. Based on these statistical facts, there is need to conduct this study to examine whether if use of fly ash is environmental protection more than normal cement concrete as used in construction (Verma, 2021).

During the concrete manufacturing, cement is the expensive material which leads to the increase in its cost; according our project I saw that the use of peat coal ash can help in minimizing the cost and quantity of cement to be used in concrete.

1.3. Objectives

The study has both Main objectives and specific objectives which are based on to conduct research those objectives are as following:

1.3.1. Main objectives

The main objective is to assess the use of peat coal fly ash as partial replacement of cement in concrete.

1.3.2. Specific objectives

1. To compare the compressive strength of concrete when using peat coal fly ash against normal concrete used in construction.
2. To assess how the use of peat coal fly ash in concrete is economical rather than normal concrete in construction purpose.

1.4. Research questions

- What is the optimal percentage of peat coal fly ash that can be used as partial cement replacement to achieve comparable or improved compressive strength in concrete?

- How does the peat coal fly ash affect the permeability of the concrete?
- To what extend does the use of peat coal fly ash as a cement replacement reduce the carbon footprint of concrete production?

1.5. Choice of the project

- Cement production is a major contributor to greenhouse gas emissions, particularly carbon dioxide. Replacing a portion of cement with industrial byproducts like peat coal fly ash can significantly reduce this environmental impact.
- It addresses the issue of waste disposal by finding a productive use for peat coal fly ash, which might otherwise end up in landfills.
- This project is in line with the growing global emphasis on sustainable construction practices and the circular economy.

1.6. Interest of the project

This project will have the benefits to Social, Academic and Personal interest

1.6.1. Social interest

- Reducing the amount of coal fly ash that ends up in landfills decreases the risk of soil and groundwater contamination. This directly benefits communities by protecting their access to clean water and healthy environments.

- Lowering cement production reduces greenhouse gas emissions, contributing to mitigating climate change, which has far-reaching social consequences.

- Reducing pollution from cement production and fly ash disposal can improve air quality, leading to better respiratory health in communities.

- By promoting sustainable construction practices, the project can enhance the long-term economic stability of communities.

1.6.2. Academic interest

This document will be published in UPAFA library and serve as reference for further reading to students pursuing their studies, and any other that could benefit their uses in construction field.

1.6.3. Personal interest

- The project will be beneficial to construction field personal involved in project planning, estimation and production of that kind of concrete once proved successful.

- The researchenabled me to be familiarized with carrying out such kinds of researchers in civil engineering field and another related researchers as this is the first one I have ever done. It further allowed me to improve my capacity in manipulating concrete and improving its properties.

1.7. Scope of study

1.7.1. Content scope

This study focused on use of fly ash (peat coal) as partial replacement of cement in normal concrete as economic and environmental friendly materials by conducting slump test and compressive strength test, but it was recommended for split tensile test and cube density to be carried out to check the sustainability of using fly ash (peat coal) which are not part of scope.

1.7.2. Time scope

There are key Time Considerations which are:

- **Curing Time:** Concrete strength development is a time-dependent process, so tests at later ages require extended curing periods.
- **Durability Tests:** Durability tests, such as sulfate resistance and freeze-thaw, can take several months to complete.
- **Data Analysis:** Thorough data analysis and interpretation are crucial and require sufficient time.

1. **Initial Phase: Material Characterization and Mix Design (3 weeks)**
   - **Material Acquisition and Preparation:** Gathering and preparing the peat coal fly ash, cement, and aggregates.
   - **Mix Design Development:** Determining the various mix proportions for concrete samples.
2. **Experimental Phase: Concrete Preparation and Curing (2 weeks)**
   - **Sample Preparation:**
     - Mixing and casting concrete specimens.
     - Implementing controlled curing conditions.
   - **Early-Age Testing:** Conducting setting time tests.

3. **Testing and Analysis Phase: Mechanical and Durability Testing (3 weeks)**
    - **Mechanical Properties Testing:** Conducting compressive strength test at various curing ages 3, 7, 14 and 28 days.

4. **Data Analysis and Reporting Phase (2 weeks)**
    - **Data Analysis:**
        - Analyzing the results of all tests.
        - Performing statistical analysis.
    - **Report Writing:** Compiling the findings into a comprehensive report.

1.8. Organization of the project

Chapter One: General introduction, serves as a foundation for understanding the project, outlining its context, objectives, and significance.

Chapter Two: Literature review provides a comprehensive overview of existing research and knowledge relevant to the use of peat coal fly ash in concrete. It establishes the theoretical framework and identifies the gaps that this project aims to address.

Chapter Three: Materials and Methods, details the experimental procedures and materials used in the research, ensuring reproducibility and transparency. It outlines the methodology for material characterization, mix design, sample preparation, testing, and data analysis.

Chapter Four: data analysis and results, discussion was focused on performance of concrete where peat coal fly ash has been used as partial replacement. All the tests method adopted were described in previous chapter. The results presented in this chapter are regarding the compressive strength test and slump test for different trial mixes of concrete.

Chapter five: conclusion and recommendations, consolidates the findings of the research, draws definitive conclusions regarding the use of peat coal fly ash as a partial cement replacement, and provides practical recommendations for future applications and research.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

This chapter provides a review of existing research on peat coal fly ash (PCFA) as a partial substitute for cement in concrete. It covers the historical context of the topic, the production process of PCFA, its benefits, and previously used materials in concrete mixtures, including various studies.

2.2. Definition of key words

2.2.1. Concrete

Concrete is a composite material consisting of cement, aggregates (coarse and fine), water, and possibly admixtures. Key operations include batching, mixing, transporting, placing, compacting, and surface finishing. Concrete can be categorized as reinforced (which includes steel reinforcement to enhance tensile strength) or plain concrete, which lacks such reinforcements.

Operations on Fresh Concrete:

- **Batching:** Measuring ingredients by volume or mass, with current specifications favoring mass.Traditionally batching is done by volume but most specifications require that batching be done by mass rather than volume.
- **Mixing:** Ensuring uniform distribution of materials.The mixing operation consists of rotation or stirring, the objective being to coat the surface the all aggregate particles with cement paste, and to blind all the ingredients of theConcrete into a uniform mass; this uniformity must not be disturbed by the process of discharging from the mixer.
- **Transporting:** Moving concrete from the mixing plant to the site.
- **Placing:** Ensuring the workspace is clean and the concrete is placed close to its final position.
- **Compacting:** Eliminating air voids to enhance density.Once the concrete has been placed, it is ready to be compacted. The purpose of compaction is to get rid of the air voids that are trapped in loose concrete.
- **Surface Finishing:** Creating a smooth surface using tools like screeds and trowels. The most basic type of concrete finish is a smooth surface created through the use of screeds and trowels. Immediately after concrete has been placed in forms, concrete finishers utilize a screed to level out the concrete surface.

In concrete we have reinforced concrete and plain concrete.
The reinforced concrete is a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength or ductility. The reinforcement is usually, though not necessarily, steel reinforcing bars (bar) and is usually embedded passively in the concrete before the concrete sets.

The plain concrete is used to describe any concrete mass used without any strengthening materials. The physical properties of plain concrete are very similar to stone and include the ability to withstand great pressure. Concrete is a combination construction material made of cement, ash, gravel, limestone and granite. Plain concrete is combined with water and then hardens in place after being poured. This process is known as hydration. The cement reacts with water, creating a new chemical bond between the different materials in the concrete mix. As the water dries, cement cured into a stone- like material (Geek, 2003)

Some of the followings are properties of concrete:

- Setting of concrete
- Workability
- Bleeding and segregation
- Hydration
- Air entrainment

❖ **Setting of concrete**: is the hardening of concrete before its hydration, it is also known as setting of concrete, OR Is the transition process of changing of concrete from plastic state to hardened state. Setting of concrete is based or related to the setting of cement plaster. Thus cement properties greatly affect the setting time.

Factors affecting setting

- Water-cement ratio
- Cement content
- Type of cement
- Fineness of cement
- Relative Humidity

- Admixtures
- Type and amount of Aggregate

- **Workability of concrete:**

Workability is often referred to as the ease with which a concrete can be transported, placed and consolidated without excessive bleeding or segregation.

Factors affecting concrete workability:

- Water-Cement ratio
- Amount and type of Aggregate
- Amount and type of Cement
- Weather conditions
- Temperature
- Wind
- Chemical Admixtures
- Sand to Aggregate ratio

- **Concrete bleeding**: Bleeding in concrete is sometimes referred as water gain. It is a particular form of segregation, in which some of the water from the concrete comes out to the surface of the concrete, being of the lowest specific gravity among all the ingredients of concrete.

- **Concrete segregation**: Segregation can be defined as the separation of the constituent materials of concrete. A good concrete is one in which all the ingredients are properly distributed to make a homogeneous mixture.

- **Hydration in concrete**: Concrete derives its strength by the hydration of cement particles. The hydration of cement is not a momentary action but a process continuing for long time.

2.2.2. Aggregate

Aggregates play a crucial role in concrete, categorized as coarse particles larger than 4.75 mm and fine particles that pass through a 4.75 mm sieve(Kemper, 1965). Coarse aggregates contribute to economy in mix design, while fine aggregates enhance strength and stability. For optimal concrete, aggregates must be clean and strong.

2.2.2.1. Coarse aggregates:

Coarse-grained aggregates will not pass through a sieve with 4.75mm openings.

Those particles that are predominantly retained on the 4.75 mm sieve and will pass through 3- inch screen are called **coarse aggregate.** The coarser the aggregate is; the more economical the mix. Larger pieces offer less surface area of the particles than an equivalent volume of small pieces. Use of the largest permissible maximum size of coarse aggregate permits a reduction in cement and water requirements (Kemper, 1965).

Figure 1: Course aggregates (Wasnik, 2022)

Using aggregates larger than the maximum size of coarse aggregates permitted can result in interlock and form arches or obstructions within a concrete form. That allows the area below to become a void, or at best, to become filled with finer particles of sand and cement only and results in a weakened area.

Following are properties of coarse aggregate:

- Strength
- Hardness
- Toughness
- Durability
- Shape of aggregates
- Adhesion with bitumen

2.2.2.2. Fine aggregate:

Fine aggregate is the essential ingredient in concrete that consist of naturals and or crushed stone. It is the granular material used to produce concrete or mortar and when the particles of the granular material are so fine, they pass through a 4.75mm sieve .

Figure 2:fine aggregate(Wasnik, 2022)

For a good concrete mix, aggregates need to be clean, hard, strong, particles free of absorbed chemicals and other fine materials that could cause deterioration of concrete. Aggregates which account for 60 or 75 percent of total volume of concrete for both fine and coarse aggregates (Verma, 2021)

Fine aggregate is needed in concrete mix cause:

- Fine aggregates provide dimensional stability to the mixture
- The elastic modulus and abrasion resistance of concrete can be influenced with fine aggregate
- Fine aggregates quality also influences the mixture proportions and hardening properties
- The properties of fine aggregates also have a significant impact on shrinkage of concrete
- Fine aggregates increase the volume of concrete, thus it is a cost saving material

The following are properties of fine aggregate:

- **Void content**: how much amount of cement paste will be required for the mix eventually depends on the empty spaces between the aggregate particles.
- **Shape and texture:** size and shape greatly influence the quality of concrete mix, for the preparation of economical concrete mix; you should know that rough textured, angular and elongated particles require more water for the formula. However, We need less water to produce workable concrete when the aggregates are smooth, rounded compact aggregate.
- **Absorption and surface moisture**: the fine aggregate depends on inside

solid material and void content, thus you need to measure the absorption rate prior to ensure how much water will be required in concrete mixture.

- **Abrasion and skid resistance**: in order to minimize the wear in high traffic areas, such as heavy-duty floors and pavements you can consider the relative measure when the fine aggregate is rotated in a cylinder along with some abrasive charge.

For a good concrete mix, aggregates need to be clean, hard, strong, particles free of absorbed chemicals and other fine materials that could cause deterioration of concrete. Aggregates which account for 60 or 75 percent of total volume of concrete for both fine and coarse aggregates (Verma, 2021)

2.2.3. Cementitious Material

- **Cement** is a binder, substance used for construction that sets, hardens to other materials to bind them together. Cement is seldom used on its own, but rather to bind aggregate together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete.
- **Portland cement** is the product obtained by pulverizing clinker, consisting of hydraulic calcium silicates to which some calcium silicates to which some calcium sulfate has usually been provided as an interground addition. It is the most type of cement around the world as basic ingredient of concrete, mortar and non-specialty grout. Materials that contain appropriate amounts of calcium compounds, silica, alumina and iron oxide are crushed, screened and placed in a rotating cement kiln. Ingredients used in this process are typically materials such as limestone, sandstone, marl, shale, iron, clay and fly ash (Rouhi, 2018).

2.2.4. Fly Ash (Peat Coal)

2.2.4.1. Definition and Production

Coal is a flammable black or brownish-black sedimentary rock, which is usually formed in litho strata or veins known as coal beds or coal seams. Sedimentary rocks are exposed to rising Temperature and pressure to form hard forms of coal that are considered metamorphic rocks, such as anthracite. Coal is believed to be formed by the transformation of ancient plant remains buried under the ground through: **peat→ lignite→ bituminous coal→ anthracite** and anthracite can be further converted into **graphite**. (Tilton, 2010)

Figure 3:Coal(Shaffer)

Production of peat coal fly ash

Where does fly ash come from**?** Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue. Boiler tubes extract heat from the boiler, cooling the flue gas and causing the molten mineral residue to harden and form ash. Coarse ash particles, referred to as bottom ash or slag, fall to the bottom of the combustion chamber, while the lighter fine ash particles, termed fly ash, remain suspended in the flue gas. Prior to exhausting the flue gas, fly ash is removed by particulate emission control devices, such as electrostatic precipitators or filter fabric bag houses. (Holtz, 1998).

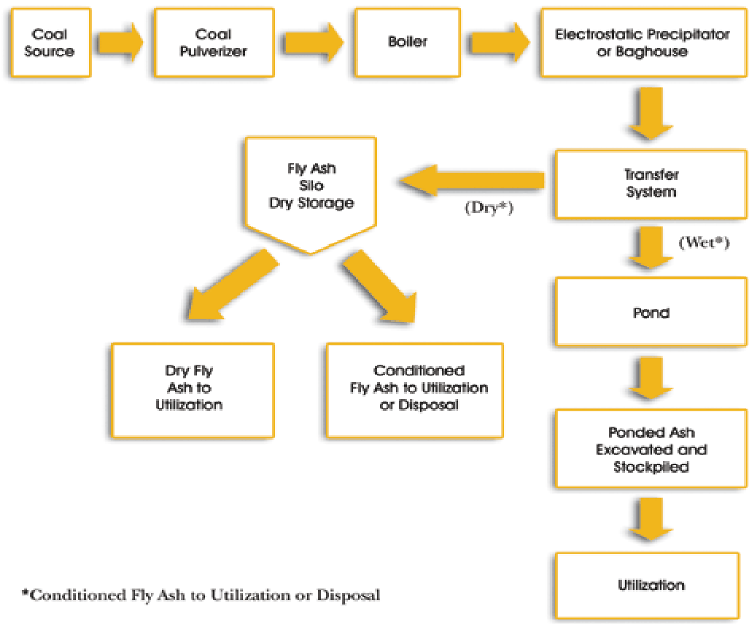

Figure 4: Conditioned fly ash to utilization or disposal(Holtz, 1998)

2.2.4.2. Types of Coal

According to the different carbonization degree of coal, coal is divided into peat, lignite (brown lignite, black lignite), sub bituminous coal, bituminous coal (raw coal) and anthracite. The carbonization degree of anthracite is the highest and that of peat is the lowest. (Tilton, 2010)

Figure 5: different types of coal(Shaffer)

Since many years, fly ash is being used in the concrete. According to "M.S. Shetty" (Author of Concrete Technology Theory and Practice), that the first large scale use of fly ash was in the construction of Hungry Horse dam and later, Canyon Ferry dam in

United States of America. The amount of fly ash used was about 30% by weight of cement. In India, earliest use of fly ash was in the construction of Rihand dam and its quantity was 15% by weight of the cement used. (Shetty, 2021)

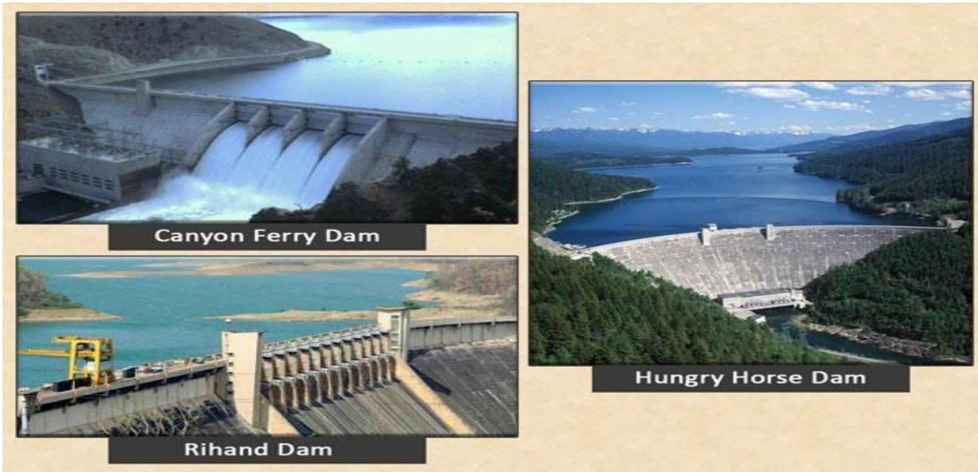

Figure 6: use of fly ash in various dams (Shetty, 2021)

Fly ash is the residue that is left from burning coal, and this is formed when the gaseous releases of the coal are efficiently cooled. It is somewhat like a glass powder that is fine in nature. However, the chemical constituents of this residue might vary from one other. ((Rodriguez, 2019)

Fly ash has several industrial applications and is widely found in power plant chimneys. The material is also used as substitute cement by mixing it with lime and water. The material is embedded with many beneficial features and so is being utilized as a significant building material for the construction purposes. This type of concrete is much smooth. (Rodriguez, 2019)

Figure 7: Cement vs. fly ash (Rodriguez, 2019)

2.2.4.3. Advantages of Fly Ash

The advantages of using fly ash in concrete include the followings:

Fly ash in the concrete mix efficiently replaces Portland cement that in turn can aid in making big savings in concrete material prices.

- It is cost-effective substitute for Portland cement.
- Fly ash is a by-product or a waste product hence use of fly ash concrete reduces CO_2 and is thus is environmentally friendly.
- It has good cold weather resistance.
- It is a non-shrink material.
- Pulverized fuel ash also produces dense concrete/brick with smooth surface and sharp detail.
- Fly ash concrete has great workability as well and allows for a lower water-cement ratio for similar slumps compared to the ordinary concrete. Fly ash is different from other Pozzolanic materials which usually increase the water requirement of concrete mix.
- It reduces the problems of cracks, permeability, bleeding etc.
- It also reduces the heat of hydration.

2.2.5. Tests on Concrete

Quality tests on concrete are performed as a part of quality control of concrete structures. Different quality tests on concrete such as compressive strength tests, slump tests, permeability tests etc. are used to assure the quality of the concrete that is supplied for a given specification. (Bustillo Revuelta, 2021).

2.2.5.1. Tests done on fresh concrete

1. Slump test
2. Compacting factor test
3. Vebe test (Vee Bee test)
4. Flow table test

2.2.5.1.1. Slump test

Slump test is a laboratory or at site test used to measure the consistency of concrete. Slump test shows an indication of the uniformity of concrete in different batches. The shape of the concrete slumps shows the information on the workability and quality of concrete. The characteristics of concrete with respect to the tendency of segregation can be also judged by making a few tamping or blows by tapping rod on the base plate. This test continues using since 1922 due to the simplicity of apparatus and simple procedure. The shape of the Slump cone shows the workability of concrete.

Principle of Slump test

The slump value of concrete is just a principle of gravity flow of surface of the concrete cone that indicates the amount of water added to it, which means how much this concrete mix is in workable condition.

Figure 8: Slump test apparatus

Apparatus for Slump test

Followings apparatus are used in the slump test of concrete:

- Metallic mould in the shape of a frustum of cone having bottom diameter 20cm (8 in), top diameter 10 cm (4 inch) and height 30 cm (12 inch),
- Steel tamping rod having 16 mm (5/8 inch) diameter, 0.6 m (2 ft) long with bullet end.

Procedure of Slump test

During Slump test following steps are followed:

- First of all, the internal surface of the mould is cleaned and free from moisture and free from other old sets of concrete.
- Then place the mould on the smooth horizontal, rigid, and non-absorbent surface.
- The mould is then filled with fresh concrete in four layers with taping each layer 25times by taping rod, and level the top surface with a trowel.

- Then the mould is slowly pulled in vertical and removed from concrete, so as not to disturb the concrete cone.
- This free concrete deforms the entire surface to **subside** due to the effect of **gravity**.
- That subsidence of concrete in the periphery is a **SLUMP** of concrete.
- The height difference between the height of subsidence concrete and mould cone in mm is **'slump value of concrete'**. (Cement concrete.org, Slump Test of Concrete, slump cone for Workability – Procedure, Apparatus, 2019).

Recorded slump value of a sample is = **………mm**

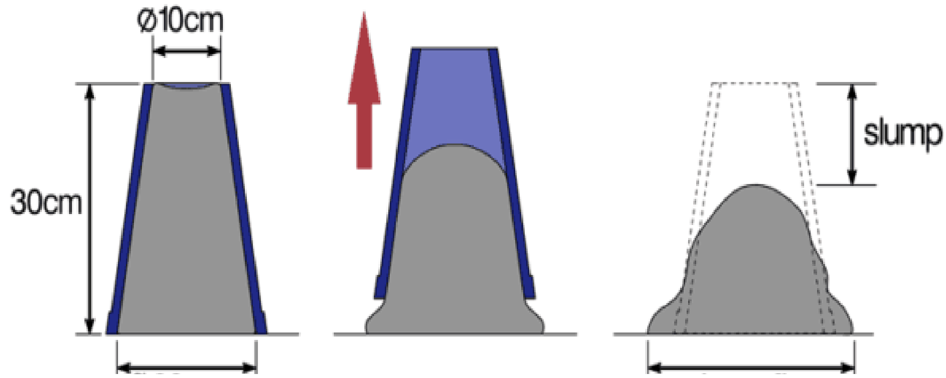

Figure 9: Slump test of concrete (Institution, 1983)

2.2.5.2. Tests done on hard concrete

Once concrete has hardened, it can be subjected to a wide range of tests to prove its ability to perform as planned or to discover its characteristics if its history is unknown.

For new concrete, this usually involves casting specimens from fresh concrete and testing them for various properties as the concrete matures. The "concrete cube test" is the most familiar test and is used as the standard method of measuring compressive strength for quality control purposes. Concrete beam specimens are cast to test for flexural strength and cast cylinders can be used for tensile strength. Specimens for many other tests can be made at the same time to assess other properties, e.g.: drying shrinkage, thermal coefficient, modulus of elasticity (Neville, 1987).


Figure 10: hardened concrete (Metha, 2006)

Tests performed on hardened concrete are:

- Compressive strength test (most common)
- Modulus of Elasticity
- Split-tension test
- Flexural strength test
- Rebound hammer test
- Penetration resistance test
- Ultrasonic pulse velocity test
- Maturity test

2.2.5.2.1. Compressive strength test

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, and quality control during the production of concrete, etc.

Test for compressive strength is carried out either on a cube or cylinder. Various standard codes recommend a concrete cylinder or concrete cube as the standard specimen for the test. American Society for Testing Materials ASTM C39/C39M provides Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to which withstands loads tending to elongate. In other words, compressive strength resists being pushed together, whereas tensile strength resists tension (being pulled apart). In the study of strength of materials, tensile strength, compressive strength, and shear strength can be analyzed independently. (Neville, 1987)

For cube test two types of specimens either cubes of 15cm ×15cm × 15cm or 10cm ×10cm × 10cm depending upon the size of aggregate are used. For most of the works cubical moulds of sizes 15cm*15cm*15cm are commonly used.

This concrete is poured in the mould and tampered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of the specimens should make even and smooth. This is done putting cement paste and spreading smoothly on whole area of specimen.

These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm^2 per minute till the specimen fails.

Load at the failure divided by area of specimen gives the compressive strength of concrete. (Neville, 1987)

Figure 11: Concrete cubes specimens and compressive machine

Table 1: Concrete mix ratio based on concrete grade(Shetty, 2021)

GRADE	MIXRATIO
M5	1 : 5 : 10
M7.5	1 : 4 : 8
M10	1 : 3 : 6
M15	1 : 2 : 4
M20	1 : 1.5 : 3

Ordinary concrete with grade up to M20 can be designed by nominal mix concrete procedure. Standard and high strength concrete should be designed by standardized prescribed mix design procedure.

In most cases, the ratio of fine aggregate to coarse is to 1:2, but based on the size difference it shall be between 1: 1.5 and 1: 2.5.

Table 2: Compressive strength of grades of concrete at 7 and 28 days

Grade of concrete	**Minimum compressive strength N/mm^2 at 7 days**	**Specified characteristic compressive strength N/mm^2 at 28 days**
M15	10	15
M20	13.5	20
M25	17	25
M30	20	30
M35	23.5	35
M40	27	40
M45	30	45

Finally, this literature has been reported some recommendations for future research in this area. These include the following:

Need to test strength of concrete that contains higher percentages of peat coal fly ash and cost of peat coal fly ash as partial replacement of cement in concrete.

CHAPTER THREE: MATERIALS AND METHODS

3.0. Introduction

Analysis and confirmation of building and construction materials require practical tests usually carried on material samples. Those tests differ from each other depending on the material and property in need to be examined. There are number of tests mostly on concrete, to be carried in this study as described below. Concrete mixes and materials containing portions of peat coal will be tested and analyzed.

3.1. Research Design

The Percentage of peat coal fly ash to be used as a replacement for cement is 5%, 10%, 15%, 20%.

The problems that I will face in this study are:

- High cost of transport and shelter in sample preparation procedures,
- High cost of paying test in laboratory.

3.2. Sampling methods and techniques

These following materials will be used to carry out tests or experiments that reflected their use on the project, each of the ingredients for the concrete will be measured by weight using a balance or by size using sieve. These materials are peat coal fly ash, cement, fine aggregates, coarse aggregates and water.

3.3. Data collection techniques and instruments

3.3.1. Concrete mix design:

The concrete mix designation (M) followed by its numbering consecutively and its description alongside.

The concrete to be used in this study will be made using binder, sand and gravel. The concrete mix proportion will be 1:1.5:3 targeting the M20 grade and used in accordance with weight as explained in the previous chapter and in table showing data used while mixing the concrete(Neville, 1987).

3.3.2. Concrete Casting:

- Concrete samples will be cast in standard steel mold of 150mm x 150mm x 150mm for compressive strength testing
- The samples will be mixed thoroughly using a mechanical mixer to achieve uniform consistency and proper dispersion of materials.

3.3.3. Curing:

- ❖ The specimens will be cured in a standard curing tank at 23°C for up to 14 days, following standard curing procedures outlined in ASTM C192 to ensure proper hydration.

3.3.4. Testing:

- ❖ Compressive Strength: The compressive strength of concrete cubes will be tested at 3, 7, and 14 days using a hydraulic compression testing machine (ASTM C39).

3.4. Data Interpretation

- ❖ The results will be compared with those of the control mix (0% fly ash) to evaluate the effectiveness of peat coal fly ash as a partial replacement for cement. Improvements or reductions in compressive strength, workability, and durability will be analyzed to determine the optimal fly ash percentage for enhancing concrete properties.

3.5. Tools and Equipments to be used

Tools, items or things used to mix the concrete. Each tool will have its role:

3.5.1. Balance

It was used to determine the computed weights of mix proportion of samples and also used to get dry and wet masses of sand and PFA sand- cement blocks, as shown on figure.

Figure 12: Balance

3.5.2. Steel mould

In this study, steel moulds were used while operating the tests. This was used for cubes manufacturing as they were made by using a simple cube-making operated manually. The mould was initially oiled before placing the concrete in it in order to prevent the concrete to stick on the side of the mould as shown on figure.

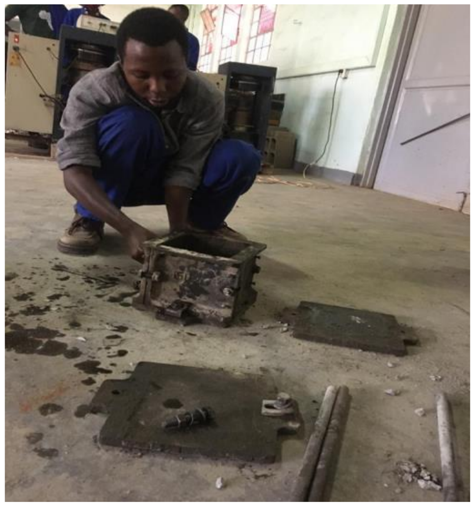

Figure 13: Steel mould preparation for concrete

3.5.3. Tamping rod

Tamping rod was used to eliminate air voids in the concrete mix. The concrete was placed in the mould in layers and each layer was compacted using a tamping rod as shown on figure

Figure 14: Tamping rod

3.6. Data Analysis Techniques

The analysis method was a proven practice for making the tests following various steps including batching and mixing of materials, concrete mix design, casting of specimens, and curing of specimens. Strategies followed in this study were to achieve the targets or aims of the study successfully and were described in this chapter.

Tests carried out in this study were slump test and compressive strength tests and taking references on two variables which were curing time and PFA percentages as shown on the diagrams below, where 7, 14 and 21 days stand for curing time on each PFA percentage.

3.4.1. Preparation of testing specimens

Tests were performed on concrete specimens to evaluate and analyse the purpose of the compressive strength and cube density tests; these tests require steps as shown below;

3.4.1.1. Batching and mixing of materials

Batching of materials was done by weight. The percentage replacements of Ordinary Portland Cement (OPC) by Peat coal Fly Ash (PFA) were 5%, 10%, 15% and 20%. The 0% sample was done to serve as control for other samples, in order to compare with the other percentages.

The concrete was mixed manually, in such a manner as to avoid loss of water or other materials. The cement and fine aggregates were mixed dry until the mixture was thoroughly blended and uniform in color. The coarse aggregate was then added and mixed with the cement and fine aggregate until the coarse aggregate was uniformly distributed throughout the batch and water was then added and the entire batch mixed until the concrete appeared to be homogenous and had the desired consistency

3.4.1.2. Concrete Mix Design

The concrete mix design as shown on the table, shows the mix designation (M) followed by its numbering consecutively and its description alongside.

The concrete used in this study was made using binder, sand and gravel. The concrete mix proportion was 1:1.5:3 targeting the M20 grade and used in accordance with weight as explained in the previous chapter and in table showing data used while mixing the concrete.

Table 3: Mix Portion for different percentages of PFA

Mix Destination	Description
Trial 1	Control concrete
Trial 2	5% PFA + 95% Cement
Trial 3	10% PFA + 90% Cement
Trial 4	15% PFA + 85% Cement
Trial 5	20% PFA + 80% Cement

3.4.1.3. Casting of specimens

Cubic iron moulds specimens of concrete with size 150*150*150 mm were cast for determination of all measurements. The moulds were cleaned by applying mineral oil on all sides before concrete was poured into the moulds in order to avoid the concrete from sticking to the bottom and sides of the steel mould. The concrete was poured into the moulds in three layers by tamping using a tamping rod, after filling up the moulds a trowel was used to produce a smooth, hard and dense surface. The moulds were removed after 24hours and kept in a curing tank for 3, 7, 14 and 21 days as required. The casting of test specimens was as shown on figure.

3.4.1.4. Curing of specimens

After casting the specimens, these were marked for identification using the two variables taking in consideration their PFA percentage and their curing time, after this, all specimens were removed from and placed in water for curing.

Figure 15: Curing specimens

3.4.2. Tests conducted

These were different tests conducted to determine the compressive strength and consistence in terms of water ratio and evaluate if they satisfied the study successfully.

3.4.2.1. Slump test

❖ **Objective**

The concrete slump test is an empirical test done to measure the workability of fresh concrete or the overall energy required to work with this concrete mixture. The test measures consistency of concrete in that specific batch and it determines the amount of energy required for the concrete work at a certain water cement ratio.

❖ **Test equipment**

1. The slump cone at standard dimensions (100 mm top diameter x 200 mm bottom diameter x 300 mm high)
2. Long bullet nosed metal rod (600 mm) long, diameter (16 mm)
3. Measuring graduated and readable ruler.

- **Test procedure**

1. Clean the internal surface of the slump cone and apply oil.
2. Place the mould on a smooth horizontal non- porous (nonabsorbent) base plate.
3. Fill the mould with the prepared concrete mix in 3 approximately equal layers.
4. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers, the tamping should penetrate into the underlying layer.
5. Remove the excess concrete and level the surface with a trowel.
6. Clean away the mortar or water leaked out between the mould and the base plate.
7. Raise the mould from the concrete immediately and slowly in vertical direction
8. Measure the slump as the difference between the height of the mould and that of height point of the specimen being tested.

Manual code used are (ASTM C 143) or (AASHTO T 119) and BS EN 12350-2:2009 – Testing fresh Concrete, Slump Test

Slump value = cone height – sample height

The recommended range for slump value depends on the work condition and requirements for a concrete batch. Note that the slump value depends on water cement ratio the mix ratio, admixtures, temperature, the nature and properties of materials used.

Figure 16: Slump test

3.4.2.2. Compressive strength test

The specimens were tested by compression testing machine after 3, 7, 14 and 21 days curing. The load was applied gradually till the specimens failed. Load at the failure divided by area of specimens gave the compressive strength of concrete.

- **Objectives**

Compressive strength test was carried out to determine the load bearing capacity of cubes. A compressive strength test was been undertaken in accordance to (BS: 516-1959) with a testing machine at the curing ages of 3, 7, 14 and 21 days. Two cubes were crushed in each day of the above stated days for each mix of both materials (sand- cement and PFA sand-cement cubes) respectively and the average compressive strength was measured for each cubes mix specifications

- **Apparatus used**

Compressive testing machine was used to determine how the cube reacts when compressed or crushed by measuring the specimen's behavior under a compressive load as shown on the figure

- **Procedures**

Specimens were tested with the centroid of their bearing surfaces aligned vertically with the center of thrust of the spherically seated steel bearing cubes of the testing machine. The load up to one-half of the expected maximum load was applied at any convenient rate, after which the control of the machine was adjusted as required to give a uniform rate of travel of the moving head such that the remaining load is applied in lost less than one or more than two minutes.

The compressive strength of a masonry unit (cube) was taken as the maximum load at the specimen failure in Newton divided by the gross sectional area of the unit in square millimeters.

Figure 17 and 17: Compressive strength test

CHAPTER FOUR: DATA ANALYSIS AND RESULTS

4.1. Introduction

In this chapter, discussion was focused on performance of concrete where peat coal fly ash has been used as partial replacement. All the tests method adopted were described in previous chapter. The results presented in this chapter are regarding the compressive strength test and slump test for different trial mixes of concrete.

4.2. Specimen preparation and curing

The concrete cubes (control specimens) of size **150mm**x**150mm** x**150mm** were cast by using conventional aggregates. This was labeled as concrete.

There was another batch of concrete cubes, made from a concrete mixture where cement was partially replaced by different percentages of peat coal fly ash respectively. This was called concrete.
For each mix, 150mm size cubes were cast to determine the compressive strength at the age of 3 days. The same cubes used for compressive strength. Here after 3 days of curing in water bath specimen must be tested.

4.3. Slump test

For each mix, the workability (in terms of slump) of the fresh concrete was measured. The slump test was carried out in accordance with BS 1881: Part 102: 2011.
The water to cement ratio was kept 0.5 for concrete. With different mixtures in concrete, the proportions of peat coal fly ash which partially replaced cement in proportions of **0%**, **5%**,**15%** and **20%** of peat coal fly ash and cement respectively. The slumps of these concretes were as follows:

Table 4: Slump of concrete mixtures:

SN	Designation	Slump in mm
1	Normal concrete	**130**
2	Concrete with 5% peat coal fly ash and 95% of cement	**125**
3	Concrete with 10% peat coal fly ash and 90% of cement	**95**
4	Concrete with 15% peat coal fly ash and 85% of cement	**70**
5	Concrete with 20% peat coal fly ash and 80% of cement	**45**

The amount of water used was kept the same for all mixtures. It could be observed that, with a partial replacement of cement by peat coal fly ash, the increase in peat coal fly ash, the slump was also decreased. As the quantity of peat coal fly ash, the slump was decreasing progressively, yet the amount of the water was kept the same W/C=0.5.

4.4. Casting concrete specimens

All specimens were cast in two layers and compacted by the use of a steel rod. Vibration could stop when air bubbles appear on the surface. They were left in the mould in the laboratory at 20^0 to 25^0C respectively. The specimens were tested immediately after removing from the water bath in 3 days.

4.5. Test of compressive strength

At the age of 3days the compressive strength was determined by crushing 150mm cubes in accordance with BS 1881: Part 116: 2011 and an average of three values was obtained, prior to the compressive strength at the age of 3days.
The compressive strength of concrete is the most critical parameter. It indicates where the specific concrete would be used. The resulting compressive strength is directly in relation with the percentage of ingredients (materials) used, but also their properties. The percentage of peat coal fly ash and cement ratio were the variables during the mixing process. Tables show the compressive strength at 3 days for each mixture.

Table 5: Compressive strength of normal weight concrete

	3 days	
Area (mm^2)	Force (N)	Strength (MPa)
22500	**394,400**	**17.528**

Table 6: Compressive strength of concrete with 5% replacement

	3 days	
Area (mm^2)	Force (N)	Strength (MPa)
22500	**401,200**	**17.831**

Table 7: Compressive strength of concrete with 10% replacement

	3 days	
Area (mm^2)	Force (N)	Strength (MPa)
22500	**406,200**	**18.053**

Table 8: Compressive strength of concrete with 15% replacement

	3 days	
Area (mm^2)	Force (N)	Strength (MPa)
22500	**374,700**	**16.653**

Table 9: Compressive strength of concrete with 20% replacement

	3 days	
Area (mm^2)	Force (N)	Strength (MPa)
22500	**373,200**	**16.586**

The general observation about these results were that,

Table 10: Comparison of compressive strength of all concrete grades

Designation	**Compressive strength (MPa)**
	3days
Normal concrete	**17.528**
Concrete with 5% of peat coal fly ash and 95% of cement	**17.831**
Concrete with 10% of peat coal fly ash and 90% of cement	**18.053**
Concrete with 15% of peat coal fly ash and 85% of cement	**16.653**
Concrete with 20% of peat coal fly ash and 80% of cement	**16.586**

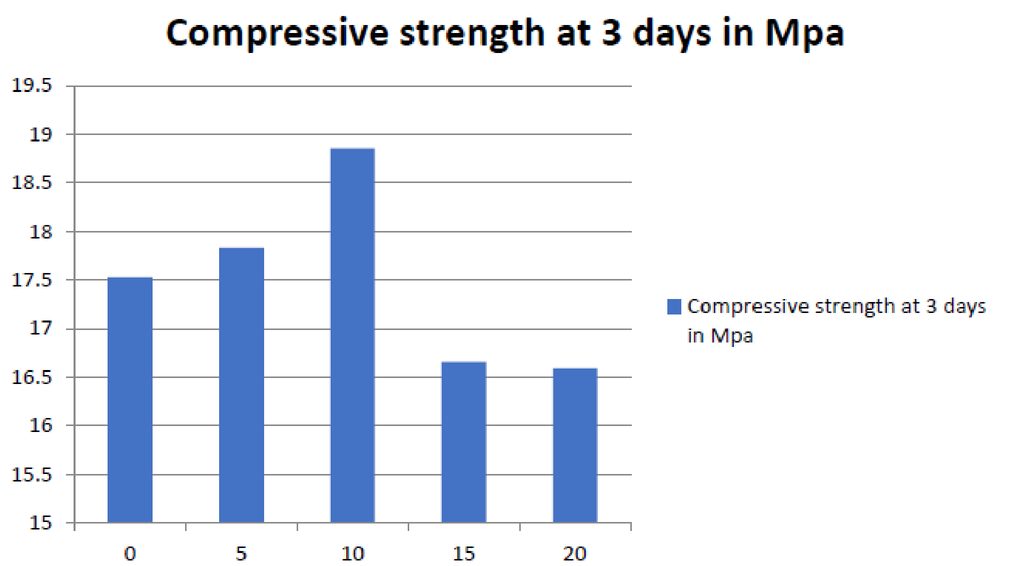

Figure 18: Comparison of Compressive strength to identify optimum percentage of peat coal fly ash

Based on figure representation, Compressive strength presents Y-axis and Percentages of peat coal fly ash presents X-axis.

With normal concrete, the compressive strength was **17.528Mpa** at 3 days respectively. With **5%** replacement, the compressive strength values **17.831Mpa** were at the age of 3days respectively. With **10%** replacement, the compressive strength values **18.053Mpa** were at the age of 3 days, with **15%** replacement, the compressive strength values **16.653Mpa** also this were at 3 days and with **20%** replacement, the compressive strength values **16.586Mpa.**

This concludes, based on our experiments **10%** of peat coal fly ash is optimum percentage while replacing cement in concrete by peat coal fly ash.

4.6. Pricing and cost estimation of concrete

With the aim of this project to try a reduction of cost with concrete work to make it affordable, the process of estimating the cost of concrete and its respective reduction when there is a partial replacement of cement by another binder known as peat coal fly ash. There contains limiting the approximation mainly the required strength of concrete. Costs in this thesis were estimated based on the best and appropriate estimates and assumptions.

Cost of concrete without PFA = **350,000rwf**

Reduction on concrete made by 10% of peat coal fly ash and 90% of cement

- $1m^3$ of concrete has 8 bags of cement which is equal to **400kg**
- 1 bag of cement of 50kg values 11000frw, the amount for 8bags is **88,000frw**
- 5% of peat coal fly ash in concrete replace cement = 400x10/100= **40kg**
- One bag of peat coal fly ash of 50kg values **2000frw**
- 20kg of peat coal fly ash cost = 2000x40/50 = **1600frw**
- Amount of money that will be saved = 88,000-1,600=**86,400frw**

This means, at 10% of peat coal fly cost that will be saved is equal to **1,600frw.**

While the peat coal fly ash is a waste material that can be used to replace partially cement in concrete, it reduces the cost of cement which makes it easy for low and middle income earners to Own their houses.

CHAPTER FIVE: CONCLUSION AND RECOMMANDATIONS

5.1. Conclusion

Based on experimental study concerning compressive strength and slump test of concrete with peat coal fly ash as partial replacement of cement, I conclude by saying that:
As the peat coal fly ash is a waste material that can be used as partial replacement of cement in concrete, it reduces the cost of cement which makes it easy for low and middle income earners to own their houses.

The results of compressive strength of concrete cubes showed that the compressive strength increase as the percentage of peat coal fly ash increased. However the compressive strength increased as the number of days of curing increased for each percentage peat coal fly ash replacement. This experiment shows us the optimum percentage of peat coal fly ash is **10%** with its respectively compressive strength **18.053Mpa** at 3 days.

The experimental results indicate that the optimum peat coal fly ash that can be used as cement supplement material in construction is that have, this one reduce the cost of 1m3 of concrete from **350,000rwf** to **348,400rwf.**

The objectives of research were achieved by gaining more knowledge, skills and experience in field work of study coming up with a technical helpful material for construction.

5.2. Recommendations

By the end of this project, we recommend people to adopt the peat coal fly ash material in their concrete works because it will be profitable and used.

A better understanding of the properties will allow for maximizing materials. The knowledge acquired would lead to optimum designs that will be cost-effective.

Durability studies of concrete cubes made with peat coal fly ash as partial replacement of cement should be carried out.

The use of local materials like peat coal fly ash as Pozzolana should be encouraged in concrete production.

REFERENCE

BS EN, 196-2:. *BS EN, 196-2:.* 2005.

Bustillo Revuelta, Manuel, and Manuel Bustillo Revuelta. "Construction Materials: Geology, Production and Applications." In *Concrete*, 217-274. 2021.

Geek, Wise. *What is Edutainment.* Chicago, 2003.

Holtz, R., C. Barry, and R. Berg. *Federal Highway Administration.* 1998.

Kemper, W. D., and W. S. Chepil. "Size distribution of aggreagates." In *Methods of soil analysis: Part 1 physical and mineralogical properties, including statistics of measurement and sampling 9*, 499-510. 1965.

Neville, Adam M., and Jeffrey John Brooks. *Concrete technology. .* Vol. Vol. 438. Chicago: Longman Scientific & Technical, 1987.

Rodriguez, Mayra Z., Cesar H. Comin, Dalcimar Casanova, Odemir M. Bruno, Diego R. Amancio, Luciano da F. Costa, and Francisco A. Rodrigues. "Clustering algorithms: A comparative approach." 1. 2019.

Rouhi, Alireza. "analysis and conservation of two structures." In *Historic reinforced concrete in Alberta*. PhD diss., Ph. D. Thesis, University of Calgary, 2018.

Shaffer, Brian N., Paul E. Pierce, Scott A. Kinney, Ricardo A. Olea, and James A. Luppens. "Assessment of coal resources and reserves in the Little Snake River coal field and Red Desert assessment area, Greater Green River Basin, Wyoming." 2019-3053. US.

Shetty, Sahithya S., Shriram Marathe, and I. R. Mithanthaya. "Comparative studies on flexural strength of conventional and alkali-activated masonry elements designed to field mix." In *Trends in Civil Engineering and Challenges for Sustainability: Select Proceedings of CTCS 2019*, 73-84. 2021.

Suhendro, Bambang. "Toward green concrete for better sustainable environment." In *Procedia Engineering, 95*, 305-320. 2014.

Tilton, John E. "assessing the threat of mineral depletion." In *On borrowed time*. Routledge, 2010.

Van Oss, H.G. and Padovani, A.C. "Cement manufacture and the environment part II: environmental challenges and opportunities." *Journal of Industrial ecology,*, 2003: 93-126.

Verma, Louisa. "Cement, Concrete and Research Literature Online Repositories (Portland Cement Association)." In *Issues in Science and Technology Librarianship 98* . 2021.

Wasnik, Sharmili, G. S. Pavan, and Susant Padhi. "In Sustainable Cities and Resilience: Select Proceedings of VCDRR 2021." In *Replacement of River Sand with Coal Bottom Ash as Fine Aggregate in Cement Mortar.*, 129-139. Springer Singapore, 2022.

APPENDIX

Excel sheet and graph shows Compressive strength at 3 days.

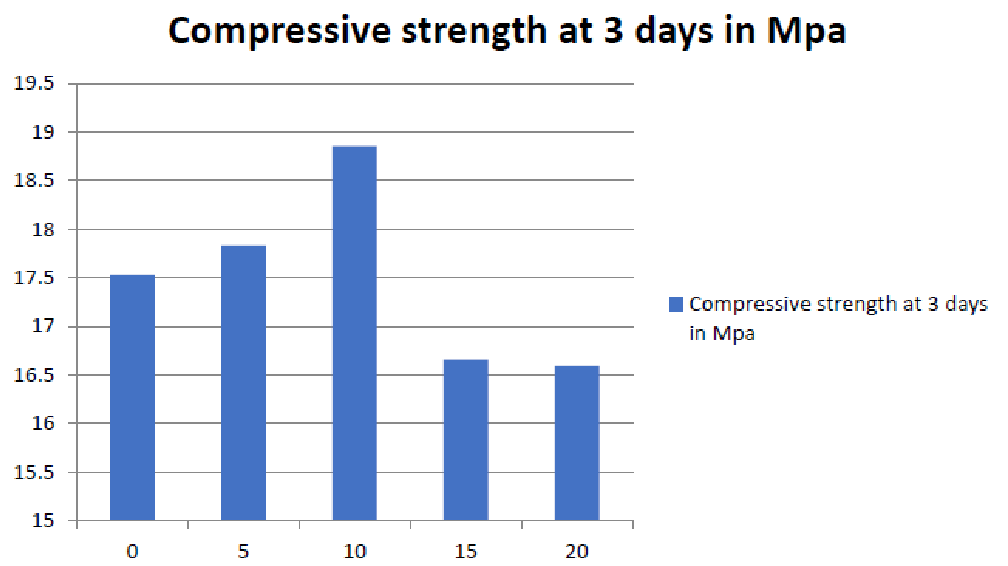

Figure 19: Comparison of Compressive strength to identify optimum percentage of peat coal fly ash

Figure 20: Sample preparation and slump test

Figure 21: Concrete curing and compressive strength test

CONCRETE COMPRESSIVE TEST CONFIRMATION CERTIFICATE

GILAB Ltd
Geo-Impact Laboratory

TIN/VAT: 123125603
Tel: 0785836419/0783306361
Email: gilabltd@gmail.com

TO WHOM IT MAY CONCERN

GILAB Ltd as geotechnical laboratory certify that Mr. MUCYO Alliance a student at UPAFA in department of civil engineering, conducted concrete mixing, concrete casting, concrete curing and concrete compressive strength test in our laboratory for his final dissertation project tests from date 28th February 2025.

We highly recommend her for any position and opportunities that requires knowledge regarding the above concrete testing.

Done at 4th March 2025
HATEGEKIMANA Clément
Managing Director
GILAB LTD