# EFFECT OF CYPRESS TREE EXTRACT ON THE RATE OF STRENGTH DEVELOPMENT OF KENYAN PORT-LAND POZZOLANIC CEMENT CONCRETE

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# Effect of Cypress Tree Extract on the Rate of Strength Development of Kenyan Portland Pozzolanic Cement Concrete

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**A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Construction Engineering and Management of the Jomo Kenyatta University of Agriculture and Technology**

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## DECLARATION

This thesis is my original work, and has not been presented for a degree in any other university

Signature…………………………………………...Date………………………….

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This thesis has been submitted for examination with our approval as the University supervisors.

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## DEDICATION

This work is dedicated to my wife Agnes Oyugi, daughter Gloriah Mich and Sons Billy Geno, Joe Ephraim, Jude Christian and Theo Jeshurun, My Mother Mary Adika and other family Members and Friends for their sacrificial support during my studies.

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First of all, I take this opportunity to glorify the almighty God for the gift of life and good health granted to me during this period of research work. I am heartily thankful to my supervisors, Dr. Eng. Charles Kabubo and Dr. Eng. Victoria Okumu for their sincere guidance, insights, encouragement, and support in developing this research proposal. My gratitude also goes to the Department of SMARTEC and JKUAT institution for the opportunity granted to undertake my studies at the university. Last but not least, I offer my gratitude to all staff in the Department of SMARTEC for their full support in the course of my study.

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **AAS** | Atomic Absorption Spectroscopy |
| **ACI** | American Concrete Institute |
| **ASTM** | American Society for Testing and Materials |
| **BS** | British Standard |
| **BPC** | Blended Portland Cement |
| **DOE Method** | Department of Environment Design Method |
| **HPC** | High Performance Concrete |
| **JKUAT** | Jomo Kenyatta University of Agriculture and Technology |
| **KNBS** | Kenya National Bureau of Statistics |
| **KS** | Kenyan Standard |
| **MPa** | Mega Pascal |
| **NCA** | National Construction Authority |
| **OPC** | Ordinary Portland Cement |
| **PPC** | Portland Pozzolana Cement |
| **RCC** | Reinforced Cement Concrete |
| **SSD** | Saturated Surface Dry |
| XRD | X Ray Diffraction |

## NOTATIONS AND SYMBOLS

| | |
|---|---|
| **$C_3A$** | $3CaO. Al_2O_3$ (Tricalcium Aluminate) |
| **$C_3S$** | $3CaO.SiO_2$ (Tricalcium Silicate) |
| **CAH** | Calcium Aluminate Hydrate |
| **CSH** | Calcium Silicate Hydrate |
| **$C_2S$** | $2CaO.SiO_2$ (Dicalcium Silicate) |
| **$C_4AF$** | Tetracalcium Aluminoferrite |
| **$C_6AS_3H_{32}$** | Ettringite |
| **CH** | Calcium hydroxide |

## ABSTRACT

Concrete is the most widely used construction material in the world. The situation in the country is not an exception as most of the infrastructures in Kenya such as buildings, bridges, drainage among others, are constructed using concrete. Sadly, the failure of buildings and other concrete structures is very common in Kenya. Portland Pozzolanic cement type 32.5 N/mm$^2$ is the most widely used concrete binder material and is found in all parts of the country. Despite blended cement CEM 32.5 being the most commonly used cement type in construction industry in Kenya and most developing countries as a result of its low price and availability locally, its strength gain has been proven to be slower compared to when other types of cement are used due to quantity of pozzolanic material added to the blend. This thesis outlines findings of an experimental investigation on the effect of cypress tree extract as an accelerator to enhance rate of gain of strength on Kenyan Portland pozzolanic cements. Six different blended cement brands locally available were used during the study. Cement chemical analysis was done using X-ray diffraction method while for the cypress extract, Atomic Absorption Spectrometer machine was used. Physical and mechanical properties were checked based on the British standards. The generation of the concrete mix design was done using the British DOE method and concrete was tested for the compressive strength at 7, 14, 21, 28, 56 and 90 days. Cypress tree extract was added at 5%, 10%, 15% and 20% dosage expressed as a mass percentage of cement content. It was observed that 15% dosage gives the most improved compressive strength of concrete: 10.4% at 7 days and 9.5% at 28 days hence the optimum. It was further noted that when Cypress tree extract is used as an accelerator in the mix, the Portland pozzolanic cement concrete achieves the design strength at 27 days saving 10 days of the project duration compared to when no accelerator is used while the ultimate strength was achieved at 67 days. The study therefore recommends the use of the cypress tree bark extract at a dosage of 15% by mass of the cement content as an accelerator when the structure is to be loaded at 28 days and waiting upto 39 days before loading the structure if no accelerator is used for blended cement concrete.

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background Information

Portland pozzolanic cement type 32.5 $N/mm^2$ is the most widely used concrete binder in the construction industry in Kenya and is found in all parts of the country (Kioko, 2014). The total volume of cement Production worldwide amounted to an estimated 4.27 billion tons in 2022. Back in 1995, the total global production of cement amounted to just 1.39 billion tons (KNBS, 2019).In Kenya, the cement production in expanded at an average rate of 11.6% from 2.41 metric tons in 2006 to 4.09 metric tons in 2011 indicating that the consumption of cement is currently increasing all over the world. However, there are differences regarding the types of additives and the quantities used in the blended cement types used in various countries and within the same country (Mbongwe et al., 2014).The requirements of national industry standards and their application varies from country to country. The safety, strength and structural integrity of concrete structures depend largely on the quality of concrete used for construction among other factors. In terms of the strength of reinforced concrete structures, cement, a major binding material in making concrete influences the quality of the concrete so produced with it, the most important quality parameter being 28 days compressive strength. Strength of concrete structures therefore largely depends on the quantity of the cement used and also on the grade or the strength class of concrete among others.

There are six companies producing cement in Kenya which include: Bamburi cement ltd, East African Portland cement ltd, Mombasa cement ltd, National Cement company ltd, Rai cement and Karsan Ramji & sons ltd. Three out of the six companies produce both ordinary Portland cement and blended Portland cement while National Cement Ltd, Rai and Karsan Ramji & Sons Ltd only produce blended Portland cements. Cement industry in Kenya being characterized by very high growth rate, it therefore shows that the blended cement takes the high percentage due to its availability in the local market.

The main aim of structural design is to realize an acceptable probability that the proposed structure will perform satisfactorily during the design period, sustain all the loads and deformations with adequate durability and resistance to the effect of misuse and fire (Adewuyi et al., 2017). Despite the design process of structural element being done, the failure of buildings and other concrete structures has been and is still very common in Kenya to date (Okumu et al., 2022). Concrete is a mixture of water, coarse and fine aggregate, and a binding material which in most cases is cement. Blended Portland cement type 32.5 $N/mm^2$ is found in all parts of the country hence majorly used as a binder for concrete production. Quality assurance of construction materials plays a significant role on structural integrity, serviceability, and durability of constructed infrastructures (Okumu et al., 2017). The properties of construction materials and compliance with design specification becomes the major factor responsible for premature failure of buildings in Kenya. Choice of cement brand used, quantity of cement in the mix and the cement grade are some of the parameters that determine the compressive strength of concrete attained (Adewole et al., 2015).

Prior to the adoption and implementation of the Kenyan blended Portland cement present in the Kenyan Market, the word ordinary Portland cement (OPC) became such a natural part of construction vocabulary that even individuals who very remotely relate to modern construction processes made glib reference to the substance. This is because they were majorly available in the local market and approved for production. OPC which is produced in bagged and in bulk form for open market are available only in major towns. However, the price for OPC cement is almost double compared to other blended cement types. In the local hardware, 32.5 $N/mm^2$ blended cements are mostly available in the stock thus the need to investigate their ultimate strength periods (Shitote et al., 2017).

Currently, the most commonly used cements in Kenya are the 32.5 $N/mm^2$ Portland Pozzolanic cement CEM IV containing between 11-35% natural pozzolanic material and Portland Pozzolanic, Cement (PPC) CEM II containing 21-35% natural pozzolana formulated from Portland clinker and inter-ground with other constituents (mainly natural Pozzolana) according to the requirements of the harmonized East African Standard on cement KS EAS 18-1:2001 (Koteng, 2013).

The comparison of the compressive strength development patterns of concrete using different cement types at 28 days, which is considered as the design strength gain period shows that the ordinary Portland cement have significantly high compressive strength compared to the blended Portland cements. Ordinary Portland cement concrete reach their ultimate compressive strength at 28 days above which the cement types exhibit marginal strength gain while the blended Portland cements continue to gain significant amount of compressive strength between 28 days to 90 days.

Kenyan blended Portland cements locally available in the hardware's may not be suitable for the production of concrete class C 30 and above since none of the cement brands reach the target design strength at a workable slump of ≥30 mm at 28 days and their compressive strength development continue beyond 28 days with the increase in strength of approximately 25% between 28 days to 90 days. Research has shown that none of the blended Portland cement brands achieve the target design strength for >C25 concrete at 28 days  when designed using DOE method (Okumu, 2018).

Concrete strength level and rate of strength gain are dependent on hydration rate and percentage strength level that can be reached sooner when concrete cures at higher temperature or when certain cement/admixture combinations are used. Factors contributing to both strength level and its rate of gain at different ages include cement type, mix compositions, aggregate type and properties, temperature degree, curing time and methods among others.

Despite blended cement CEM 32.5 being the most commonly used cement type in the construction industry in Kenya and most developing countries as a result of its low price and availability, the strength of concrete produced by blended cement have been found to be low compared to when other types of cement are used due to quantity of pozzolanic material added to the cement blend. The chemistry of locally available cement brands dictates the chemistry of concrete (Bhanumathidas & Kalidas, 2003).

An Accelerator is a concrete ingredient used to aid in the development of early strength of concrete at a faster rate than that developed in normal concrete since they help to reduce the amount of curing time required and increase rate of strength gain.

A Cypress tree extract having been proved by other researchers to act as an accelerator have a positive effect on durability of concrete. The plant extract contains chains that react with $Ca^{2+}$ to give calcium silicate hydrate gel, a compound which helps to increase the strength of concrete. Boiled plant extract significantly improves the property of concrete as compared to cold extraction in cold water, therefore, boiling the plant extract was used as a preferred methodology in this research since the method of extraction has an effect on the optimum dosage of the extract (Woldemariam et al., 2014).

The use of boiled cypress extract is a welcome development especially in the developing countries like Kenya due to its sustainability nature and low cost compared to the chemical accelerators. They can be locally obtained and in large quantity using local technology by the local farmers hence improving living standards.

This research therefore evaluated the ultimate compressive strength age of the Kenyan blended Portland cement, the margin by which the strength of the blended Portland cement varies from the target strength at 28 days and accelerating the strength development by adding certain quantity of plant-based accelerator on the concrete to achieve the ultimate compressive strength at 28 days to reduce the project duration.

## 1.2 Problem Statement

From the general assessment of building collapse/failure in Kenya, 90% of the buildings and concrete structures have been collapsing during construction or within three months after the construction completion (Oyawa et al., 2016). Audit carried out by the National construction Authority and published in 2018 by national building inspectorate covering 14,895 buildings revealed that 723 are very dangerous, 10,791 buildings are unsafe and dangerous hence will eventually collapse. The earliest documented case of building collapse in Kenya was in 1990 where the collapse of a multi-story building killed one person and injured others. Over 100 cases of building collapse have been recorded in Kenya since 1990 From the records, a total of 21 collapsed in the year 2015 alone while under construction which was associated to the quality of in-situ concrete and poor workmanship among other factors identified as possible causes of failure (Mbuthia, 2022). The safety, strength and structural integrity of concrete structures depends on the strength of concrete among other factors and since 32.5 $N/mm^2$ Kenyan blended Portland cement are the most available in the Kenyan market and being used by the ordinary people in construction, its quantity and quality become one of the parameters in determination of the 28 days compressive strength of the concrete. Cement paste being the main binder material in concrete plays a major role and dictates the performance and reliability of the concrete structures.

Structural designs are done to achieve their satisfactory performance during the design, construction, and utility period, sustaining all the loads and deformations with adequate durability and resistance. The compressive strength of concrete is usually determined by carrying out compressive tests on 28-day-old cubes which have been prepared using a standard procedure laid down in BS EN 12390-1, 2000. For a reinforced concrete design purpose, BS 8110 allows for the use of the characteristic strength values which is defined as the value below which not more than 5 per cent of the test results fall. These characteristic compressive strength values of concrete identified by the strength class as provided for in the standards are the ones commonly used in reinforced concrete design and hence used to determine the construction guidelines. Sadly, during construction, most of the structures are being loaded before they gain their ultimate compressive strength. This assumption and practice are not true with the blended Portland cement since they develop strength beyond 28 days to achieve their design ultimate strength value and age upon which the structures should be subjected to full load. As the structures are being subjected to construction loads which includes but not limited to materials, personnel and equipment imposed on the structure before achieving their ultimate strength, they are likely to fail since at this time, the strength of the material can not sustain the load being applied. It is therefore important to know the actual ultimate strength curing age so that the study recommends and advice the construction industry not to load the structure before then or proposes usage of accelerators.

Despite blended cement CEM 32.5 being the most commonly used cement type in construction in Kenya, there are fears of compromise in strength at the time of loading, and durability of constructed buildings due to their slower strength gain as compared to the ordinary Portland cement concrete. Since locally blended cement is the main binding material in concrete making in Kenya, its properties influence the quality of concrete so produced by it and therefore its chemistry will dictate the chemistry of concrete. Okumu reports that none of the Kenya blended cement achieve the target design strength at 28 days of age and it continues to gain significant amount of compressive strength even beyond 90 days (Okumu et al., 2017). Hiremath further reported in his study on the early strength development of blended cement concrete that it requires a minimum of 56 to 90 days to attain the desired strength (Hiremath et al., 2019).

The suitability of the Plant extract has been investigated and proved to have a wide range of organic components and materials used as an admixture to alter the properties of cement. Chege recommended the use of pine tree bark extract at a dosage of 20% by mass of the cement content to be used as an admixture (Chege, 2015). Sathya also reported that compressive strength and setting time of cement are influenced by the bio-admixture hydro-extract and bio fine powder of water hyacinth which is one of the common plants in Kenya (Sathya et al., 2014). Thirumalini published a review on the uses of herbs as admixtures in ancient lime mortars (Thirumalini et al., 2011). Athman determined the suitability of blue gum extract as shrinkage reducing admixtures for concrete (Athman et al., 2018). Govin studied the effect of guar gum derivatives on fresh state properties of Portland cement-based mortar such as water retention, rheological behavior, and hydration delay (Govin et al., 2015). Otunyo investigated the palm liquor produce from palm trees as a workability aid and set retarder admixture (Otunyo et al., 2017). Abdeljaleel studied the effect of Acacia tree extract on the workability of fresh concrete and found out that Gum Arabic in liquid state increased workability of fresh concrete (Abdeljaleel et al., 2012). Oyawa studied cypress extract as an eco-friendly admixture in concrete and found that the extract increases the setting time hence act as a retarder (Woldemariam et al., 2014).

The amount of fruitful works done on the use of plant extract in concrete production using Ordinary Portland cement has been meager as compared to the Pozzolanic Portland cement concrete. Therefore, by considering the importance of plant extract in the production of modern, sustainable concrete, and its rising demand in Kenya to meet the expectation of the affordable housing project demands. It is necessary to investigate the effect of plant extract on rate of gain of strength development of pozzolanic cement concrete. With this motivation, a study on cypress tree extract has been done to ascertain its effect on the rate of gain of strength development to save project duration by accelerating the strength development.

This study therefore comparatively assesses the effect of plant base extract on the rate of strength development of the Kenyan Portland pozzolanic cement concrete.

## 1.3 Objectives

### 1.3.1 Main Objectives

To evaluate the rate of gain of compressive strength of blended Portland cement concrete enhanced by use of cypress tree extract.

### 1.3.2 Specific Objectives

1. To establish the properties of the constituent materials for the Kenyan Portland Pozzolanic cements concrete.
2. To establish the Properties of fresh and hardened Kenyan blended Portland Pozzolanic cements concrete utilizing optimum percentage of the plant-based extract as an accelerator on the development of the compressive strength.
3. To develop a mathematical model on the rate of strength development gain for Portland pozzolanic cement concrete mixes containing optimum percentage of cypress tree extract.

## 1.4 Research Questions

1. What is the ultimate compressive strength age of the Kenyan blended Portland cement concrete?
2. What is the effect of plant-based extract at a constant slump as accelerators on the development of the compressive strength of the Kenyan blended cement concrete?
3. What is the simple mathematical model that can help in predicting the compressive strength Portland pozzolanic concrete at any age when plant base accelerator is used.

## 1.5 Justification of the Study

The main aim of structural design is to realize an acceptable probability that proposed structure will perform satisfactorily during the design period, sustain all the loads and deformations with adequate durability and resistance to the effect of misuse and fire, for instance, when the actual strength values and age at which the structure should be practically subjected to full load to guarantee safety is known, then the level of risk on building collapse will reduce. The knowledge on the ultimate strength will help to assess the performance of the building and properly assign loads to the structures when it is properly cured, this will in turn improve on the quality of concrete structures hence reduction in fatality rates and loss of property in Kenya when disaster occurs.

To get the full benefit of pozzolanic material in concrete which includes enhancing impermeability and chemical durability, improving resistant to thermal cracking and resistant to sulfate attack among other benefits, prolonged moist curing beyond the recommended 28 days of the concrete is required because of their slow reaction. Without this type of curing, the pozzolanas simply act as non-cementitious filler (Güney, 2012).

Clear knowledge on the strength development of the Kenyan blended Portland cement will also be significant to the common citizen involved in construction since they will be able to come up with simple safe quality procedures for the concrete structures during construction and after the construction when blended Portland cement is used as a binder material.

When an accelerator is added to the blended cement concrete, it will improve on the setting time hence permit earlier removal of formwork, reduce the required period of curing, and finally advance the time the structure can be placed in service.

## 1.6 Scope and Limitations

### 1.6.1 Scope

The research involved the use of concrete having Class C 20/25 Mpa strength produced using 32.5 $N/mm^2$ blended Portland cement from six manufacturers producing ordinary Portland cements and blended cement in Kenya namely: Bamburi cement ltd, East African Portland cement ltd, Mombasa cement ltd, National cement, Rai cement Ltd and *Ndovu cement.* Since previous researchers have found that none of the locally available blended cement brands achieves the target design strength, this study therefore established the margin from the target strength at 28 days, assessed the effect of boiled cypress tree extract as accelerator to the compressive strength of the blended cement to achieve the ultimate strength at early stage and also developed the compressive strength acceleration rate suitable to meet compliance at 28 days.

The properties of the constituent materials, cement, extract, fresh and hardened properties of concrete was tested in Jomo Kenyatta University Civil Engineering Laboratories, Olkaria IV Laboratory-KenGen and Multimedia University Laboratory.

Microsoft excel was used in the analysis of the results and the output including ultimate compressive strength age of the Kenyan blended cement, compressive strength margin at the standard maturity age of 28 days and the rate of compressive strength acceleration suitable for compliance at 28 days.

### 1.6.2 Limitation

The research limited the compressive strength tests to 90 days of curing age for class 20/25 in blended cement concrete and Ordinary Portland cement was not considered because previous research has proved that it complies to the standard requirements that is meeting design requirement at 28 days of age.

# CHAPTER TWO

# LITERATURE REVIEW.

## 2.1 Introduction

This chapter addresses some of the conventional understanding on concrete and its constituents where cement is the major binder within key theoretical paradigms in order to contextualize the research findings. This section of the research is divided into theoretical review and the conceptual review which leads to the creation of the conceptual framework for the study.

## 2.2 Concrete

Concrete has been defined as a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate, usually a combination of fine aggregate and coarse aggregate (Dixon et al., 1991). Material for concrete production are natural gravels or crushed rocks, natural sand or stone dusts, cement and water, recycled demolition and construction waste concrete, and industrial by products such as ground granulated blast-furnace slag (GGBFS), fly ash (FA) and silica fume (SA) are also in common use as aggregate or cement replacement materials (CRMs). Cement is the most commonly used binder in concrete production in Kenya while the blended materials have varying properties in terms of strength and durability, each material is required to meet specific criterion.

The most important mechanical properties of concrete are its compressive strength, tensile strength, and modulus of elasticity. For concrete, compressive strength is determined by casting and testing of concrete specimens in the laboratory (Thandavamoorthy, 2015). The strength of concrete is grouped into three main types of concrete as: Normal- strength, high-strength and super high-strength concrete with strength ranging from 30 Mpa up to 60 Mpa for normal concrete, $f_{cu}$ between 60 and 100 Mpa for high strength and $f_{cu}$ greater than 100 Mpa for super/high concrete respectively (Ding et al., 2011).

## 2.3 Cement

Cement is a binding material used in the preparation of concrete. It is in a form of fine powder which binds in the coarse aggregate and fine aggregate when it reacts with water. Cement hardens by forming a rigid chemical mineral structure which binds the aggregates together hence giving concrete its strength.

Concrete still remains the building material of choice for most structures and is the single most widely used material throughout the world (Schneider et al., 2011). The consumption of concrete correlates to the economic development; most of the infrastructures in Kenya such as building, bridges, Concrete roads, highway drainages etc. are constructed with concrete. Data from the Kenya Bureau of Statistics released in July 2019 shows that cement production is at 1.46 Mt in the first quarter of 2019 a 6% fall from 1.55 Mt in the same period in 2018. Cement consumption previously grew to 5.9 Mt in 2018 from 5.8 Mt in 2017. For the last decades, Kenya has experienced a remarkable development of small to mega infrastructure projects attracting investors in producing construction materials including cement. Cement Manufacturing has attracted expansion of existing manufacturers and new ones due to existing demand in Kenya which has grown from 154,78 tons in 2005 to 264,000 tons in 2017 and an average of 22% increase per year and is projected to grow steadily until 2026 (Mogire et al.)

Figures 2.1 and 2.2 show the cumulative cement production and growth in production of the country for all brands of cement.

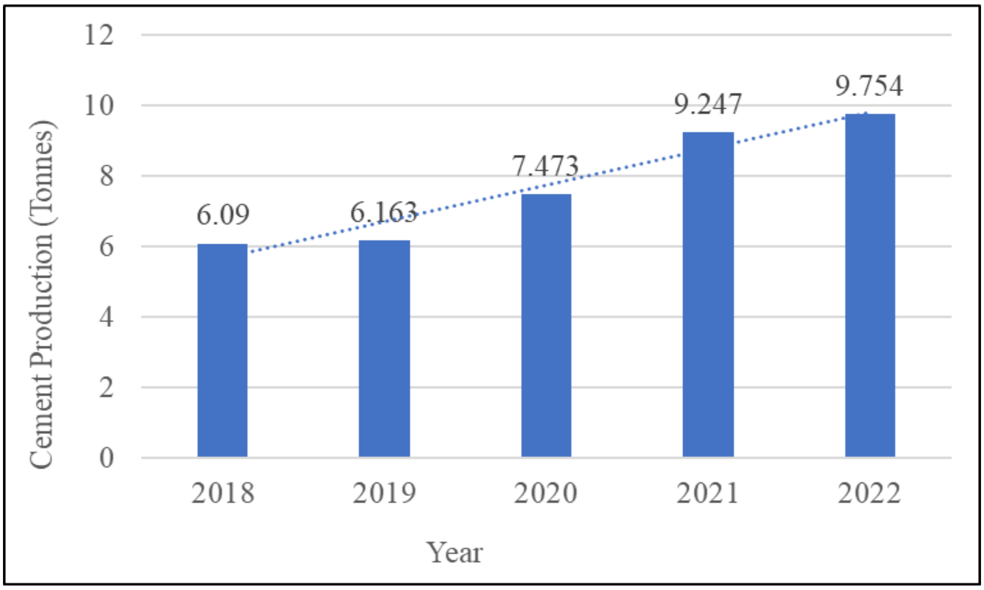


**Figure 2.1:-Cement Production in Kenya Between, 2018-2022.**

(Source: KNBS, 2023).

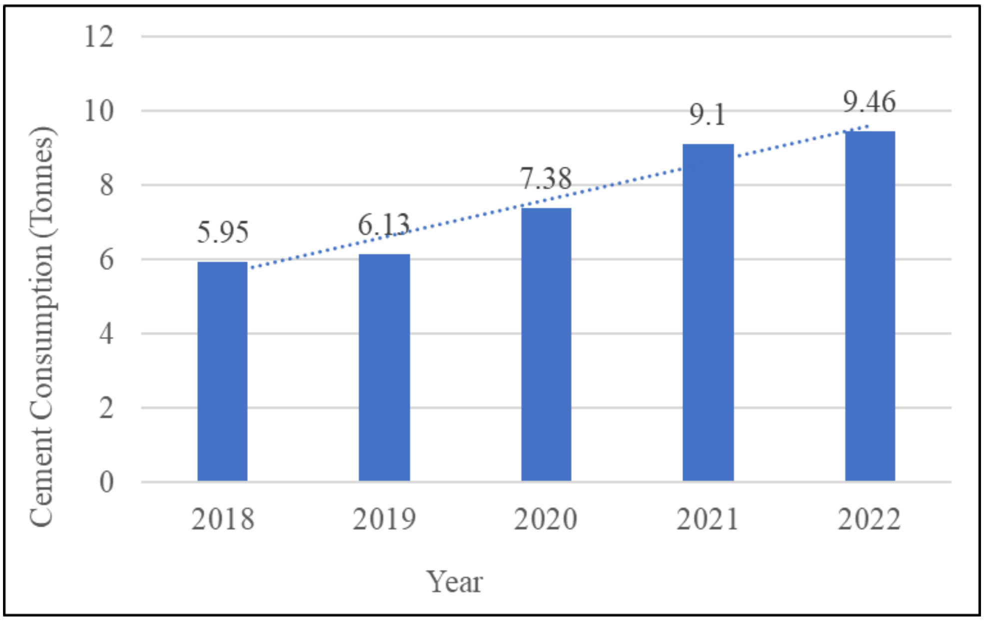


**Figure 2.2: Cement Consumption in Kenya Between, 2018-2022.**

(Source: KNBS, 2023).

Kenyans building and construction sector is one of the most rapidly growing, experiencing an average growth rate of 14.2 percent per year (Mogire et al.). According to the NBS report 2023, it shows that cement production grew by 5.5 per cent from 9,247.7 thousand tonnes in 2021 to 9.754.0 thousand tonnes in 2022. This rise in production was driven by the entry of new cement producers, rise in infrastructure investments by the government, especially in the roads and dams, segment, and extensive capacity expansion by existing players in response to increasing competition. This rise in production led to the consistent oversupply of cement during this period.

In Kenya, six new cement manufacturers came up as shown in the KNBS Survey report (KNBS, 2012; (Mogire et al.)These are: Bamburi Cement-Manufacturing mainly *Nguvu* cement 32.5 N/mm$^2$ , East Africa Portland Cement-Producing mainly the *Blue Triangle* cements 32.5 N/mm$^2$, Mombasa Cement-Producing the *Nyumba* brand cement 32.5 N/mm$^2$, National Cement-Producing the *Simba* cements 32.5 N/mm$^2$, Karsam Ramji and Sons Ltd- Producing the Ndovu brand 32.5 N/mm$^2$ and lastly Rai cements Limited-Producing *Rai* brand 32.5 N/mm$^2$. The most commonly used Cement is Portland pozzolanic cement 32.5 N/mm$^2$ strength class.

In Kenya, blended Portland cements are majorly produced by adding pozzolanic material (Natural and artificial) and sometimes limestone material to the clinker during grinding. The locally available blended cements in the Kenyan market are categorized as: Portland Pozzolanic Cement (PPC) CEM II containing 21-35% natural pozzolana, Pozzolanic Cement (PC) CEM IV with 11-35% pozzolanic material, and Portland Limestone Cement (PLC) CEM II with 6-20% limestone addition (Koteng, 2013)

### 2.3.1 Types of Cement.

The quality of cement may differ from plant to plant due to changes in raw material properties, kiln temperatures, as well as fineness upon grinding. These changes can significantly affect the concrete properties when different cements are used. Cement is classified into two types, namely.

a) Hydraulic cement- This is the type of cement which hardens under water. Its property undergoes chemical change with water (Neville, 2006)

b) Non-hydraulic cement example FAT Lime- They harden or set only when exposed to or in the presence of carbon dioxide (Verma et al., 2019)

Non-hydraulic cement will not set in wet conditions or underwater, rather it sets in dry environment and reacts with carbon dioxide in the air; It can be attacked by some aggressive chemical after setting.

Hydraulic cement such as Portland cement sets and becomes adhesive due to a chemical reaction between the dry ingredients and water. The chemical reaction results in mineral hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack (Kumar et al., 2021)

#### 2.3.1.1 Portland Cement.

Portland cement is powdered substance made with calcium lime and clay as a major ingredient. Clay provides silica, alumina, and iron oxide, while calcium lime basically provides calcium oxide.

Portland cement is made from a combination of calcium rich material including limestone ($CaCO_3$). The process includes grinding the raw material into powder, mixing them, and burning in a large rotary kiln at a temperature of about 1400$^oC$ (Neville, 2010). Iron oxide and aluminum are added during heating to form a flux. This act as a solvent for the silicate forming reactions to lower the sintering temperature and allow the reaction to occur at economically low temperature of the kiln feed. This resulting into the hard ball-like product called clinker. The raw material used include clay, shale, sand, iron ore, bauxite, fly ash and slag.

The quality of a cement clinker is influenced by the nature and composition of the raw material and its thermo-physical treatment to achieve the clinker structure for optimum cement quality. The three main considerations in proportioning raw materials for cement clinker are the potential compound composition, the percentage of liquid phase at clinkering temperature and the burnability of the raw mix. The ratios of the oxide influence the burnability and the clinker composition.

The most commonly used cement at the present time is a hydraulic cement (hardened when water is added) known as Portland cement blends and they are based on basic calcium compounds that are easily hydrated (Gartner, 2011)

The calcination process for typical modern cement clinker is given by Equation (2.1)

$3CaCO_3$ + $SiO_2$ $Ca_3SiO_5$ + $3CO_2$ (2.1)

heat

Calcium carbonate  Silica  Calcium silicate  Carbon dioxide

This powder produced will react with water and change from liquid solution into a solid mass.

Table 2.1 Contain the Recommended Chemical Properties Of The Portland Cements And Their Percentages.

**Table 2.1: Chemical Properties of the Portland Cement**

| **Chemical Constituent** | **Cement Chemistry notation** | **Availability %** |
|---|---|---|
| Lime | $CaO$ | 60-67 |
| Silica | $SiO_2$ | 17-25 |
| Alumina | $Al_2O_3$ | 3-8 |
| Iron Oxide | $Fe_2O_3$ | 0.5-6 |
| Magnesia | $MgO$ | 0.1-4 |
| Sulphur Trioxide | $SO_3$ | 1-3 |
| Soda and /or Potash | $Na_2O+K_2O$ | 0.5-1.3 |

**Source**: (Neville *et al*, 2010)

Table 2.2 shows the typical phase composition in Portland cement where it is worth noting that the Tricalcium silicate and Dicalcium silicate form 70-80% of all the Portland cement and are the most stable, they contribute most of the eventual strength and resistance of the concrete to corrosive salts, alkali, and acid.

**Table 2.2: Typical Phase Composition in Portland Cement**

| Composition of Clinker | Cement chemistry notation | Mass % |
|---|---|---|
| Tricalcium Silicate | $C_3S$ | 20-57 |
| Dicalcium Silicate | $C_2S$ | 20-52 |
| Tricalcium Aluminate | $C_3A$ | 0.5-12 |
| Tetra calcium aluminoferrite | $C_4AF$ | 7-16 |

**Source**: (Neville & Brooks, 1987)

#### 2.3.1.1.1 Classification of Portland Cement.

In Kenya, the applicable cement standard is KS EAS 18-1:2001 which is the adoption of the European Norm BS EN 197:2011 cement Standards. Pozzolans are separated into artificial pozzolans and natural pozzolans.

Artificial pozzolans comprise of fly ash and silica fumes while natural pozzolans composed of calcium, silica, and aluminium compounds.

Table 2.3 below shows the standard classification of cement in terms of mass.

**Table 2.3: The Standard Cement Classification in Terms Of Mass**

| Portland cement | Mass in % |
|---|---|
| Portland cement clinker | 5-100 |
| Blast furnace slag | 6-95 |
| Natural Pozzolan | 6-55 |
| Sulfate (Gypsum) | 0-9 |
| Cement additive | < 1 |

**Source**: (Standard, 2004)

The C 150 standard as was adopted by ASTM recognizes 5 classifications of Portland cement (ASTM, 2012). Table 2.4 contains classification and type of Portland cement according to ATSM.

**Table 2.4: Classification And Type of Portland Cement According To ASTM C150/C150 M.**

| Portland cement | Description |
|---|---|
| Type I and Type 1A | General purpose cement suitable for all uses where the special properties of other types are not required (The original OPC) |
| Type II and Type IIA | Contain no more that 8% tricalcium aluminate for moderate sulfate resistance. |
| Type III and Type IIIA | Chemically and physically similar to type I cement except they are more finely ground to produce higher early strength. |
| Type IV | Used in massive concrete structures where the rate and amount of heat generated from hydration must be minimized. It develops strength more slowly than other cement types. |
| Type V | Contain no more than 5% $Ca_3Al_2O_6$ for high sulfate resistance. |

**Source**: (Kabir et al., 2020)

**a) Ordinary Portland Cement-Type I**

Type I Portland Cement is general purpose cement suitable for all common users and no special requirement necessary (ASTM C 150, 2007). It is used where cement or concrete is not subject to specific exposures, such as sulfate attack from soil or water or to an objectionable temperature rise due to heat generated by hydration. Its uses include pavements and sidewalks, reinforced concrete buildings, bridges, railway structures, tanks, reservoirs, culverts, sewers, water pipes and masonry units (Aïtcin, 2016)

**b) Type II Portland Cement.**

Type II Portland cement is used where precaution against moderate attack is important, as in drainage structures where sulfate concentration in ground water is higher than normal but not unusually severe. This type of cement will usually generate less heat at a lower rate than Type I (Taylor, 1997). With this moderate heat of hydration (an optional requirement), Type II cement can be used in structures of considerable mass, such as large piers, heavy abutments, and heavy retaining walls. Its use will reduce temperature rise especially important when concrete is placed in warm weather.

**c) Type III Rapid Hardening Cement.**

Type III is a high-early strength Portland cement that provides high strength at an early period, usually a week or less. It is used when forms are to be removed as soon as possible, or when the structure must be put into service quickly. In cold weather its use permits a reduction in the controlled curing period. It has similar properties to type I cement, except that the cement particles in type III have been ground finer than in type I and additional calcium sulfate is usually added to control setting time (Roth et al., 2010).

**d) Type IV Low Heat Portland Cement.**

Type IV cement is known for its low heat of hydration. The heat given off by hydration reaction develop at a slower rate resulting into slower rate of concrete strength development. The cement is used for large concrete structures such as large gravity dams, where the temperature rise resulting from heat generated during curing is critical factor.

**e) Type V Cement.**

Cement is used in areas of extreme conditions such as sulfate concentration. This has a potential to chemically react with cement to break it down. The cement is a sulfate-resisting cement used only in concrete exposed to sever sulfate action principally where soils or ground waters have a high sulfate content (Tahwia et al., 2022)

#### 2.3.1.2 Pozzolana.

These are siliceous and aluminous materials which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with lime at ordinary temperature to form compounds possessing cementitious properties (McCarthy & Dyer, 2019)

Portland pozzolan cement gains strength slowly and therefore requires curing over a comparatively longer period, but the long-time strength is high. The pozzolan content is limited to between 15 and 40% of the total mass of the cementitious material. The most common type of pozzolan is siliceous fly ash. BS EN 197-1 recognized two sub classes namely Class IIA which has a fly ash content of 6-30% and class IIB with fly ash content of 21 to 35%.

The use of fly ash particularly improves sulfate resistance and fly ash is widely used with low heat Portland blast furnace cements. Pozzolan may often be cheaper than the Portland cement that they replace but their advantage lies in slow hydration and therefore low rate of heat development this makes them suitable to be used for mass concrete in the construction industry.

Natural materials like volcanic ash are pozzolana in their natural state, but materials such as clay, shales, bauxite waste (artificial pozzolana) have to undergo calcination (heat treatment) before they become pozzolanic. Other materials such as fly ash and ground copper furnace are also pozzolanas (Vakili et al., 2013)

Some of the advantages of pozzolana cement over ordinary Portland cement are that they are cheaper, improve plasticity and have higher resistance to sulfate attack. Pozzolana are known to increase the durability, lower the heat of hydration, increase the resistance to sulphate attack and reduce the energy cost per cement unit (Elsen et al.)

Portland Pozzolana Cement is a type of blended cement which is produced by either inter-grinding of OPC clinker along with gypsum and pozzolanic materials in certain proportions, or grinding the OPC clinker, gypsum and pozzolanic materials separately or thoroughly blending them in certain proportions when producing concrete. Artificial pozzolana materials which comprises of blast furnace slag, silica fume, and fly ashes or natural pozzolana comprises of siliceous or siliceous aluminous materials such as volcanic ash glasses, clays and shale are some of the constituent materials permitted in the manufacturing of blended cements.

In Kenya, lime and natural pozzolanic materials such as volcanic ash, tuffs and diatomaceous earths deposits are commonly used in the manufacture of blended Portland cements. Cement is produced in accordance with KS EAS 18-1: 2001 standard which is an adoption of the European Norm- EN 197 cement standards.

The siliceous and aluminous compounds found in the pozzolans in a finely divided form react with the calcium hydroxide to form highly stable cementitious substances of complex composition involving water, calcium, and silicate. Finely divided pozzolanas and with amorphous silicate gives a better pozzolanic reaction. The principal reaction taking place is given in equation 2.2 (Chengula, 2018)

$$\underset{\text{Silicon oxide}}{2SiO_2} + \underset{\text{Calcium hydroxide}}{3Ca(OH)_2} \longrightarrow \underset{\text{Calcium silicate hydrate compound}}{3CaO.2SiO_2.8H_2O} \tag{2.2}$$

The clay pozzolana is relatively cheap and their production helps protect the environment through reduced carbon dioxide emission (Danner et al., 2020).Because of the worldwide availability of clays and their low carbon content, these calcined clays provide a forward-looking opportunity for producing sustainable concrete (Eshun et al., 2018)

#### 2.3.1.3 Kenyan Portland Pozzolanic Cements.

The Portland pozzolanic cement is a kind of blended cement which is produced by grinding together Ordinary Portland cement clinker and artificial pozzolana (fly ash) with addition of gypsum or calcium sulphate in certain proportion, or grinding the OPC clinker, gypsum and pozzolanic materials separately and thoroughly blending them in certain proportions when producing concrete.

Normal cements are denoted N while rapid strength development cements are denoted R. Table 2.5 gives the properties of local blended cement obtained from the previous researchers for specific cement sample (Okumu et al., 2017). Note that the situation is likely to change when a different sample is used in the experiment.

**Table 2.5: Empirical Physical and Mechanical Properties of Blended Portland Cement.**

| **Blended PC type** | | **Cement fineness** | | **Compressive strength (mpa)** | | | **Consistency and setting time (min)** | | |
|---|---|---|---|---|---|---|---|---|---|
| Cement Type 32.5 | Brand | Residue | Braine (Cm2/g) | 2 Days | 7 Days | 28 Days | Con-sistency | Initial Set T | Final Set T |
| **CEM II/B- R** | A1 | 17.41 | 3856 | 20.2 | 31.4 | 46.9 | 27.6 | 182 | 251 |
| **CEM IV/B -N** | A2 | 16.58 | 3935 | 13.6 | 23.4 | 37.6 | 33.3 | 200 | 295 |
| **CEM IV/B- N** | B | 17.55 | 4471 | 12.1 | 23.9 | 32.6 | 34.9 | 230 | 319 |
| **CEM IV/B- R** | C | 21.98 | 4063 | 21.1 | 35.3 | 45.5 | 31.5 | 197 | 270 |
| **CEM II/B- N** | D1 | 22.98 | 3191 | 13.2 | 26.6 | 43.8 | 29.7 | 251 | 393 |
| **CEM II/B- N** | D2 | 21.86 | 3451 | 13.5 | 28.0 | 39.3 | 30.9 | 208 | 292 |
| **CEM II/B- R** | E | 28.03 | 3034 | 10.3 | 24.9 | 40.1 | 30.56 | 201 | 290 |
| **CEM II/B- N** | F | 27.38 | 3918 | 14.0 | 25.0 | 32.3 | 30.2 | 215 | 319 |

**Source**: (Okumu et al., 2017)

### 2.3.2 Hydration of Cement.

The hydration process of Portland cement refers to a series of chemical reactions taking place within a water cement system which happens when cement comes into contact with water, chemical reactions occur between the various cement compound and water and the process is an exothermic reaction in nature. During this process, the silicate and aluminate present in Portland cement react with water to form hydration products. There are four major mineral compounds present in Portland cement namely $C_3SC_2SC_3A$ and $C_4AF$.

When dicalcium silicate or tricalcium silicate react with water, the microscopic hydrate phase interlocks thus increasing the solid volume (Ramachandran & Feldman, 1996)

$$\underset{\text{dicalcium Silicate}}{2CaSiO_4} + \underset{\text{Water}}{5H_2O} \rightarrow \underset{\text{Phase 2 cement}}{3CaO_2SiO_2} + \underset{\text{Water}}{4H_2O} + \underset{\text{Calcium hydroxide}}{Ca(OH)_2} \quad (2.3)$$

The new solid phase precipitate from a supersaturated aqueous solution to create a significant area of solid-solid bonding interfaces in a volume that was previously filled with liquid water.

**2.4 Accelerators.**

An Accelerator is a concrete ingredient used to fast track the development of early strength of concrete at a faster rate than that developed in normal concrete. Accelerators are used to reduce the amount of time before finishing operations begin by acceleration of hydration which results in shortening the setting time, increased early age strength and reduce curing time.

Calcium Chloride, $CaCl_2$, is the most effective and widely used accelerator globally (ASTM D 98). Calcium chloride accelerates cement hydration and reduces set time for concrete applications, particularly in cold weather. Calcium chloride used decreases water usage and it improve strength. Several alternatives to the use of calcium chloride are available including using high early strength, increasing cement content, curing at higher temperatures, using non-calcium chloride accelerators such as triethanolamine, Sodium thiocyanate, Calcium formate which is a calcium salt of formic acid, or Calcium nitrate (Mamlouk & Zaniewski, 2014)

To improve the setting time of the blended cement concrete, a plant-based accelerator is required to be able to produce concrete with good quality and same time achieve high early strength. The use of chemicals is not sustainable due to the emission of toxic gasses like $CO_2$ to the environment during manufacturing and also high cost of chemicals for the common citizen.

In previous studies, cypress tree extract has been reported to be one of the possible sustainable accelerators that can be manufactured locally. Table 2.6 contains the chemical concentration in ppm of cypress extract.

**Table 2.6: Chemical Concentration in ppm or µg/g.**

| Element | Cypress Extract | Element | Cypress Extract |
|---|---|---|---|
| **Potassium (K)** | 576±14 | Copper (Cu) | 0.070±0.007 |
| **Calcium (Ca)** | 102±3 | Zink (Zn) | 0.428±0.017 |
| **Titanium (Ti)** | 0.199±0.014 | Arsenic (As) | <0.01 |
| **Vanadium (V)** | 0.201±0.020 | Bromine (Br) | 1.26±0.04 |
| **Chromium (Cr)** | 0.241±0.014 | Rubidium (Rb) | 1.49±0.05 |
| **Manganese (Mn)** | 15.3±0.50 | Strontium (Sr) | 1.62±0.04 |
| **Iron (Fe)** | 2.72±0.09 | Yttrium(Y) | 0.074±0.006 |
| **Nickel** | <0.10 | | |

**Source:** (Woldemariam et al., 2014)

The use of boiled cypress extract is a welcome development especially in the developing countries like Kenya due to its sustainability nature and low cost compared to the chemical accelerators. They can be locally obtained and in large quantity using local technology by the local farmers hence improving living standards.

## 2.5 Empirical Review on Blended Cement.

(Okumu et al., 2022) carried out an assessment on effect of material properties on the quality of concrete and made an observation that different brands of Kenyan blended Portland cement have influence on the compressive strength due to the varied composition of pozzolanic materials added to them and the level of fineness. The research concluded that ordinary Portland cement should not be directly replaced by the blended cements in the mix design since when ordinary Portland cement is used, the materials yield compressive strength exceeding the designed target strength, while when Blended Portland cement are used in the same mix, the concrete does not achieve the design or target strengths. In their further studies, they found that different brands of blended cements from the six different manufactures have varying physical and mechanical properties as shown in Table 2.5 which in turns affect the concrete produced. Some brands of blended cement did not meet the characteristic strength of 25 Mpa required for class C25 thus did not achieve the target compressive strength at 28 days. However, the strength increased above 28 days. The study therefore recommended that Kenyan blended cement should not be used to produce concrete of higher strength since it may not be suitable. The author did not determine the ultimate age and rate of gain of strength of the blended cement concrete utilizing plat extract.

(Feng et al., 2019) evaluated the effect of ultrafine granulated copper slag on hydration development and mechanical properties of blended cement mortars. In this study, they observed a reduction on the compressive strength and strength development rate indicating that pozzolanic reacting is a long-term process with contribution to the growth in compressive strength even after 90 days of curing time. This study did not look at the ultimate age in relation to the compressive strength development.

(Hiremath et al., 2019) studied on early-strength development of blended concrete under different curing conditions. In their research where they presented an investigation proposing a new technique for enhancing the early strength development of blended concrete by implementing various thermal curing conditions for blended concrete, blended concrete was produced by incorporating fly ash and ground granulated blast-furnace slag as a partial replacement for ordinary Portland cement. They found that blended cement concrete requires a minimum curing period of 56-90 days for attaining the desired strength.

The study by (Fapohunda et al., 2020) on the effect of changing cement grade on the properties of structural concrete showed that concrete produced with cement grade of 32.5 R and 42.5 R have different strength development pattern and developed different 28-day compressive strength. Therefore, they concluded that the action of changing the cement grade during concreting for the same structural member is not supported by the national code, and will not result in safe and durable concrete.

(V. Sugut 2020) did a market survey to establish the available cement brands focusing on the 32.5 cements because they were general purpose cements and their consumption rates in Eldoret Town as a case study. The research further did a comparative analysis of the properties of concrete made from different cement brands in Eldoret town Kenya. This study established that six brands of blended cement are readily available in Kenya with some significant difference in properties between the local brands of cements.

(Bamigboye et al., 2015) carried out an assessment of compressive strength of concrete produced from five different cement brands in Nigeria-locally manufactured at the time of the study. They investigated the concrete ingredient and tested concrete in terms of setting times and compressive strengths for two different mix ratios concurrently. Their observation was that all brands of cement in Nigeria except one attained the minimum cube strength with a progressive increase in compressive strength from earlier age curing to latest age curing. The study further clearly showed the dynamics of the strength gain for common Nigerian Portland cements.

(Win et al.) performed a comparison between physical properties of three selected brands of Portland cement in Myitkyina City namely crown, Double Rhinos and China. They focused on specific gravity, fineness, soundness, setting time and compressive strengths. Their observation was that while all brands attained values within possible limits, one brand was superior to others in all parameters tested.

(Olonade et al., 2015) carried out a comparative qualitative evaluation of cement brands used in Southwest Nigeria with a view to be comparing their properties. Five brands of the Portland cements were sampled and Fineness, setting times, chemical composition, compressive Strength, and flexural strengths determination done in accordance with the relevant BS and ASTM standards. The study showed that two of the five brands could be adjudged to have met the standard having strength above minimum of 32.5 $N/mm^2$, while others were marginally below the minimum strength. It was concluded that the choice of cement brand to be used should be based on the expected strength requirements.

## 2.6 Empirical Review on Plant Extract as Accelerators.

The use of admixtures in concrete has developed historically across the globe and it is not known when the use of plant-based extract in concrete began but some of the ancient civilization used admixtures. For example, materials like milk and lard were being used by the Romans, eggs during the Middle Ages in Europe: polished glutinous rice paste, lacquer, Tung oil, blackstrap molasses and extracts from elm soaked in water and boiled banana by the Chinese. The Mesoamerica and Peru used cactus juice, latex from rubber plants, bark extracts and other substances as set retarders to keep stucco workable for a long period of time (Dodson, 2013)

Plant extracts have a wide range of organic components and the materials have been used as an admixture to alter the properties of cement. There are many research activities that have been done to improve the quality of concrete among them being the use of pine tree bark extract on the concrete where the researcher recommended the use of pine tree bark extract at a dosage of 20% by mass of the cement content to be used as an alternative to the concrete plasticizing admixtures since at this dosage the strength of concrete increases at all ages (Chege et al., 2014)

Plants, being a natural occurring compound vary in both physical and chemical properties. In Kenya, most of the extracts from plants are being used in traditional applications like bioenergy and Phyto-therapy (BEDADA et al., 2023). Due to their availability, low cost, and eco-friendly nature and many advantages, the plant extracts and Phyto-chemical residues of some commonly available plants and their products have been tried as accelerators in concrete production for impacting and maintain the strength of the structures.

Some plant-based organic admixtures could induce physical effects which modify the bonds connecting particles and could act on the chemical process such as hydration, principally on crystal growth and nucleation. Further study on influence of bio admixtures on mechanical properties of cement and concrete shows that the compressive strength and setting time of cement are influenced by the bio-admixture-hydro extract and bio fine powder of water hyacinth (Kim et al., 2020)

The use of acacia (Hashab: Arabic) tree extract as admixture has been used in concrete at various dosage levels, expressed as a mass percentage of cement content. The research finding where both the powder and liquid forms of the pine tree extract were studied was that 0.4% of the acacia tree extract reduced the compressive strength while increasing slump (Abdeljaleel et al., 2012).

Other studies have been done on tree extracts (Chege, 2015) did a study on coconut plants by extracting its sodium lignin sulphonate from the coir pith. This study recommended its use as plasticizers. (Abdulrahman & Ismail, 2011) also did a study on effectiveness of an extract from Indian Bamboo as a concrete reinforcing steel corrosion inhibitor and found that it is one of the most effective inhibitors of metal corrosion.

Apart from the natural admixtures, chemicals have been majorly used to accelerate the rate of hardening of concrete in large-scale production. Some used chemical accelerators include calcium chloride, other chlorides, triethanolamine, silicates, fluorides, alkali hydroxide, nitrites, formate, bromides, and thiocyanates.

Previous research was carried out on effect of plant based polymetric material on fresh and hardened states properties of cement mortar, where a commonly available vegetable extract (bio admixture) was tested for its feasibility for use as a sustainable bio-admixture in the production of cement based composite materials. This study revealed that the plant-based bio admixture has a potential for use as a low-cost, environmentally friendly and a sustainable admixture for the production of sustainable concrete (Hazarika et al., 2016).

Further studies to determine the suitability of plant extract (cypress tree extract) as an eco-friendly and economical admixture in concrete were carried out and the findings was that the use of cypress plant extract proved to increase compressive strength by increasing the dosage at a constant slump, and also increase workability by reducing the liquid requirement of the wet concrete mix (Woldemariam et al., 2014).

Based on the above findings, considerable research has been done on the compressive strength of the blended Portland cement concrete. The researchers have shown that the blended Portland cement concrete continues to gain significant strength beyond 28 days. The research has however not established the actual ultimate strength age of the concrete. Additionally, research has proven that plant-based extracts can be used to increase the rate of strength gain of concrete. It is however not established to what extent their usage can fast track the compressive strength development of blended Portland cement concrete. This research is therefore aimed at bridging this gap through the use of Cypress plant extract which is locally available and affordable.

## 2.7 Summary of the Findings and the Research Gap .

So far, the work done by previous research (Okumu *et al.* 2017; Famohunda *et al.*,2020 ; Sugut V et al., 2020 ;Yan Feng *et.al.,* 2019; Abraham M *et al.,* 2014*;* Hiremath P.N *et al.,* 2020; Bamigboye G.O.*et al.,* 2015 among others) on Kenyan Portland pozzolanic cement concrete has been mainly on the influence of different brands on compressive strength. Even though, researchers have shown that none of the Kenya blended cement achieve the target design strength at 28 days of age and it continues gain significant amount of compressive strength after 28 curing days, none of the researchers investigated the ultimate strength age of the blended cement concrete and how the plant extract can be used to accelerate the rate of strength gain to meet compliance at 28 days of age to the best of the authors knowledge and also from the literature at the time of this research work.

The suitability of the plant extract has also been investigated by many scholars to ascertain their effect on the fresh and hardened concrete properties. (Chege John *et al*., 2014; Oyawa.W *et al.,* 2014 ; Abdeljaleel,N.S. 2012; Hazarika amrita et al., 2016 ; Sarma, U.S., and Rabindranath, A.D.2003; Sathya A *et al.*, 2014) carried out a study on Pine tree extract, Cypress tree extract, Acacia tree extract, Vegetable extract, Coconut tree extract and hyacinth extract and concluded that plant-based products have elements that affect the properties of fresh and hardened concrete either by decreasing the strength or increasing the strength depending on the level of dosage. Even though many researches have come to a conclusion that addition of plant-based extract either decrease or increase the strength of concrete, from the literature, the plant-based extract has largely been used in Ordinary Portland cement and not blended Portland cement and therefore this research seeks to replace the use of ordinary Portland cement with Kenyan Portland pozzolanic cement and to determine the effect of cypress tree extract on the rate of strength development.

This research study therefore evaluated the effect of Cypress tree extract on the rate of strength gain of Kenyan Portland pozzolanic cement concrete, fresh and hardened properties using optimum percentage of the plant-based extract as an accelerator on the development of the compressive strength and developed a simple mathematical model that can help in predicting the compressive strength of Portland pozzolanic concrete at any age when plant base accelerator is used.

## 2.8 Conceptual Framework.

Concrete is composed of four basic components (Water, cement, fine aggregates, and coarse aggregates) and in this study, boiled cypress extract is an additional component. There were two independent variables to be used in the research namely: Cement brand from different manufacturers and percentage of cypress extract. The response was in terms of wet concrete properties (such as slump) and the hardened properties (such as compressive strength and ultimate compressive strength age). The depended variables were slump (30-40 mm), Compressive strength (25 MPa -30 MPa) and ultimate compressive strength age (7 days- 90 days).

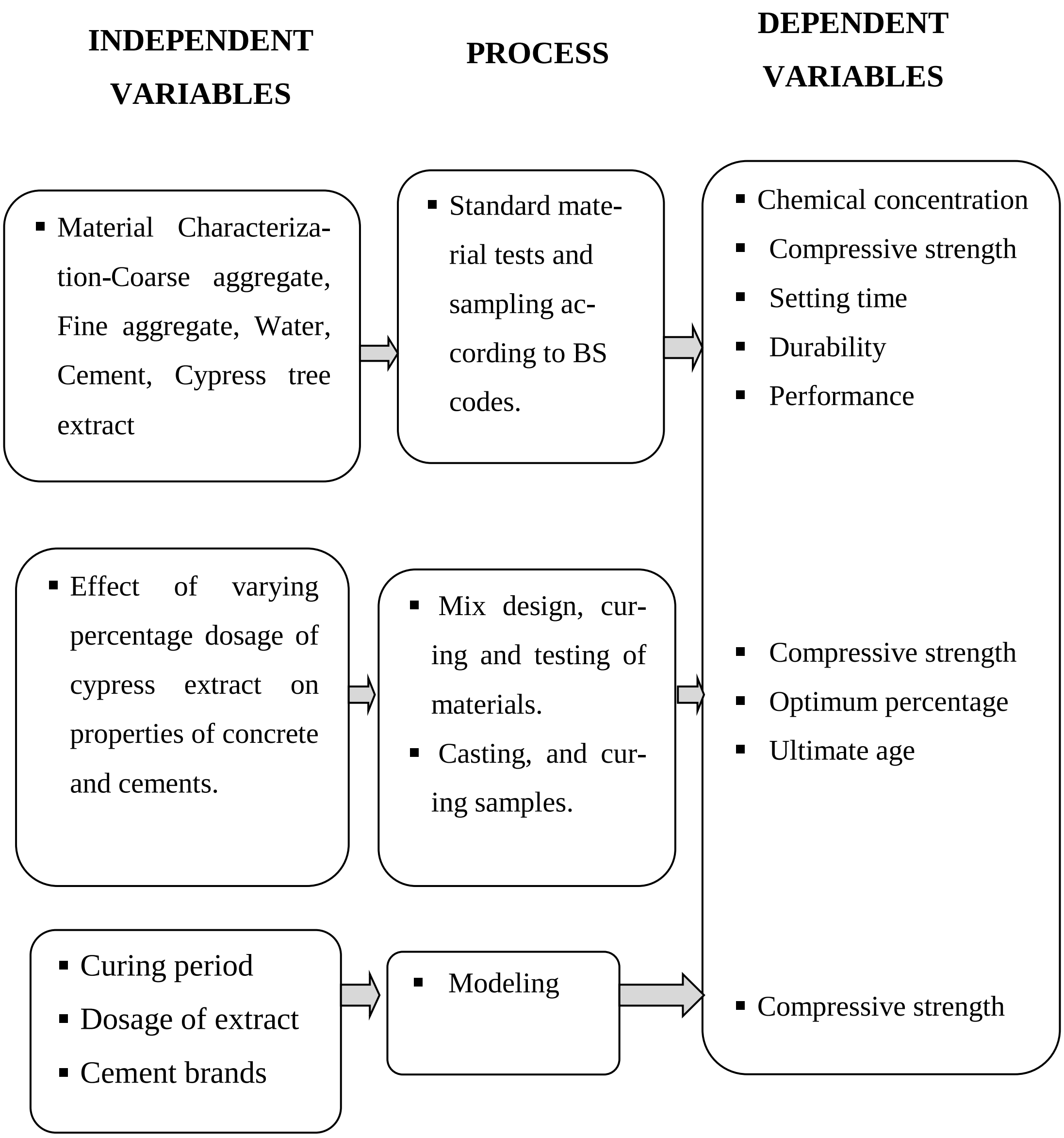


**Figure 2.3: Conceptual Framework of The Study**

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 Introduction

The study aims at using both statistical and experimental tools to achieve the objectives. In this section, the processes and procedures used in achieving the specific objectives are discussed in details and the relevant standards used also stated. The study experiments were conducted in Olkaria Site Laboratory

## 3.2 Properties of Concrete Constituent Materials

All the materials were sourced locally, and the material characterization carried out. Concrete is made by mixing binder with water, coarse and fine aggregates. The constituent materials have varying properties and hence have an effect to the propertied of the final product. To achieve the desired concrete properties in terms of strength and durability, each constituent material is required to meet specific criterion. This portion therefore describes the various material properties that was evaluated on each material and the standards against which they were checked for compliance.

### 3.2.1 Cement

Cement brands were sourced from Naivasha town and made from six different manufactures namely Bamburi, East Africa Portland cement, Mombasa Cement, National cement, Karsan Ranji & Sons ltd and Rai cement Limited.

The properties of the cement brands were evaluated based on BS EN 196-7:2001 which included Chemical analysis/composition of the cements through X-ray Fluorescence (XRF), Cement strength test using BS EN 196 Part 1, Initial and final setting time through BS EN 196 Part 3

#### 3.2.1.1 Setting Time of Cement Pastes

**a) Experimental Setup**

This test was conducted to determine the initial and final setting time of cement paste using Vicat apparatus to BS 4550 Part 3.5-1978. 400 g of the cement was placed in a tray and to it was added 25% water by weight then mix thoroughly to a consistent cement paste within 4 to 5 seconds. The paste was filled on a Vicat mould sitting on a glass plate and made level with the surface of the mould. The assembly was placed under a rod bearing a plunger, the plunger was lowered gently to touch the surface and quickly released to sink into the paste. The depth of penetration was measured and recorded. Trial mixes of varying water content were prepared until a penetration depth of 33 to 35 mm was achieved. The percentage of water by dry weight of cement required to prepare a cement paste of standard consistency was calculated by Equation 3.1

$$P = (W/C)*100$$

Legend: W= Quantity of water added,

C= Quantity of cement used

Samples were prepared by taking 400 g of cement and mixing with water equivalent to 0.85 P above by weight of cement. A stopwatch was started immediately water was added to the sample and time recorded. The Vicat Mould was filled with cement paste and water, followed by mixing to uniformity. Time was counted from the time of adding water to the dry cement.

**b) Data Collection and Analysis Procedure**

Setting time of cement paste was done as described in section 3.5(b) of BS 4550: Part 3.

#### 3.2.1.2 Compressive Strength Test of Cement Paste

**a) Experimental Setup**

Compressive strength test of cement paste was done as described in section 3.4(a) of BS 4550: Part 3.

**b) Data Collection and Analysis Procedure**

Compressive strength test of cement paste was done as described in section 3.4(b) of BS 4550: Part 3.

### 3.2.2 Cypress (L Cupressus: Arabic) Tree Extract

**a) Experimental Setup**

The back of cypress tree plant found within Naivasha was used in the study. The plant extract used was prepared by boiling cypress bark in water instead of soaking in cold water for 24 hours. The bark of cypress was cut into very small pieces and then 1 Kg of the bark was boiled with four litter of water for two hours under pressure at a of 100 °C after which the solution was allowed to cool in the open area after 24 hours, 700 ml/kg of the extract was obtained. Previous studies have shown that when I kg of the bark of the cypress tree is soaked in 1 little of water for 24 hours, 900 ml/kg of extract is obtained. Further, it has shown also that the water-soaked extract is not effective in reducing the water demand as compared to the boiled extract. The boiled one reduced the water demand by double as compared to the soaked extract hence effective. This study therefore adopted the boiling method of extraction (Woldemariam et al., 2014).Also chemical reactions are faster when the extract is boiled.

**b) Data Collection and Analysis Procedure**

The analysis of the cypress tree extract was done using Atomic Absorption Spectroscopy (AAS) of metal concentrations. The concentrations of Magnesium, Zinc, Copper, Iron, Lead, sodium, potassium, and Manganese were determined using AAS-

Shimadzu which was calibrated using certified stock solutions. Dilution of stock solution 1000 mg/l in 0.5M HNO3- with distilled water was applied to make working standard solutions for each metal elements above. This was done in triplicate and mean calculated at its most spectral line assuming no interference. The mean value was calculated after each element's measurement was resolved (in triplicate) at its most sensitive spectral line, assuming that the line was free of interference from other elements in the sample. (Refer to the calibration curves of metal elements in Appendix VI ).

### 3.2.3 Fine and Coarse Aggregate

Crushed stone aggregates from Sinopec quarry in Naivasha was used as coarse aggregate (CA) and fine aggregate (FA) in the manufacture of concrete constituted from size 0-20 mm. Both primary and secondary data sources were used. The suitability of the coarse and fine aggregate for the concrete production was checked in a accordance to the standards.

#### 3.2.3.1 Particle Size Distribution of Aggregates

**a) Experimental Setup**

Particle size distribution was determined as described in section 5(a) of BS 882 - 1992 and BS 812 Part 103.

**b) Data Collection and Analysis Procedure**

Data Collection and analysis was determined as described in section 5(b) of BS 882 - 1992.

#### 3.2.3.2 Specific Gravity and Density of Aggregates

**a) Experimental Setup**

Specific gravity and density of aggregate was determined as described in BS EN 12390-7:2009.

**b) Data Collection and Analysis Procedure**

Data Collection and analysis was determined as described in BS EN 12390-7:2009.

#### 3.2.3.3 Water Absorption and Moisture Content of Aggregates

**a) Experimental Setup**

Water absorption and Moisture content was determined as described in BS 812 part 109:1990 and BS 813 Part 2:1995.

**b) Data Collection and Analysis Procedure**

Data collection and analysis was determined as described in BS 812 part 109:1990 and BS 813 Part 2:1995.

### 3.2.4 Water

Tap water from the Olkaria water treatment plant was used during the study in the mixing of concrete and curing of all the concrete specimens. The water in concrete is used to wet aggregates, precipitate chemical reaction and to lubricate the mixture for easy workability. Contaminants such as silt, sugar, oil or chemicals can be destructive to the setting time and strength development of cement and concrete in general. It is therefore recommended that the quality of water required be as that of drinking water. The Olkaria water met the requirement as per the BS EN 1008 standard requirement for the drinking water.

## 3.3 Effect of Cypress Tree Extract at the Optimum Dosage on the Properties of Fresh and Hardened Kenyan Pozzolanic Cement Concrete.

This is the scientific procedure in which the effect of independent variables was studied on experimental variables. In this section, concrete mix design was generated, and testing of the fresh and hard concrete properties done at varying dosages of the cypress tree extract.

### 3.3.1 Concrete Mix Design

This is the process of choosing suitable ingredients and determining their relative quantities in order to produce an economical concrete mix of certain minimum properties, practical workability, desired Strength, and durability.

The design for characteristic strength class C25 concrete was done based on an assumption that the compressive strength of workable concrete, by and large, governed by the water/cement ratio and not the strength of cement. Also, it is assumed that for a given type, shape, size and grading of aggregate, the amount of water primarily determines the workability. accordance with Department of Environment's Design Method (DOE Method). The quantity of cement, fine and coarse aggregates, and water was generated according to the DOE Method (Refer to the Appendices I and II).

### 3.3.2 Concrete Mixing

In order to determine the compressive strength development of the blended cement concrete, the tested aggregates and six different brands of blended cements from six manufacturers abbreviated as (CEM Type A, B, C, D, E and F) were used to produce concrete without any additives which was then tested for wet and hardened properties. The fine and coarse aggregate were batched in saturated surface dry conditions. In the mixing procedure, the fine aggregate, coarse aggregate, and blended cement were weighed on a weighing scale and mixed on a dry metallic, non-absorbent pan, manually by the use of a spade, till the mix was uniform. Water was then added in two portions as mixing continued until uniformity was achieved. Slump test was carried out to check the workability and fifteen concrete cubes were casted for each blended cement brand. The procedure was repeated for all the six locally manufactured blended cement.

From the 28 days compressive strength test results obtained from the samples with no plant extract in the mix, three brands of blended cement were selected to be used to establish the optimum percentage of the cypress extract on the development of the compressive strength of 32.5 $N/mm^2$ Kenyan pozzolanic cement concrete. Cement concrete showing low, median, and highest compressive strength at 28 days of age for a partial substitution with the cypress bark extract. CEM A or F with the highest compressive strength, CEM E with median strength and CEM B or D with the lowest compressive strength result were selected for the establishment of the optimum percentage of the extract.

In established the optimum percentage of the cypress tree extract on the development of the compressive strength of the blended cement concrete, the tested aggregates and three brands of cement (CEM Type A, D, and E) were used to produce concrete with a varying dosage of cypress tree extract at dosages of 5%, 10%, 15%, and 20% expressed as a mass percentage of the cement content.

Having the optimum percentage dosage of the cypress tree extract, Concrete was then produced using the tested aggregates, each Cement brands with partial replacement of water with an optimum percentage of the Cypress extract in the mix. Concrete was produced and then tested for wet and hardened properties. Compressive strength tests were carried out at the age of 7, 14, 28, 56 and 90 curing days.

### 3.3.3 Concrete Properties

In order to determine the effect of the Cypress tree extract on the strength development rate of kenyan pozzolanic cement concrete, all the locally manufactured brands of cements were used to produce concrete after which the concrete were tested for wet and hardened properties. These tests involved the use of all the different cement types manufactured in Kenya.

Workability test was done on the wet concrete in accordance with BS EN 12350 while compressive strength was done at 7, 14, 28, 56 and 90 curing days according to BS EN 12390-3 and KS EAS 18-1:2008 standards.

### 3.3.4 Data Collection and Analysis Procedure

All data were obtained primarily from the experimental investigation. The analysis and processing of the compressive strength data was done using a statistical method. Excel spreadsheet tool was used to plot the data. Compressive strength verses age curve was plotted for every single set. Results were presented in the form of tables. charts and graphs.

## 3.4 Design of the Test for the Development of the Mathematical Model on Strength Gain Rate

In this research, Ordinary Least Squares (OLS) regressions modeling was used to explain the relationship between the independent (Days, Extract and Cement Brand) and the dependent (Compressive strength) variables when all are brought together.

### 3.4.1 Summary Of the Methodology

This study was designed and executed through laboratory experimentation in five stages namely material collection and characterization, Concrete mix design, mixing and casting, testing of the wet and hard concrete properties, Data analysis and discussions, Research conclusion and recommendations.

Figure 3.1 below shows the flow chart diagram which summarizes the methodology.

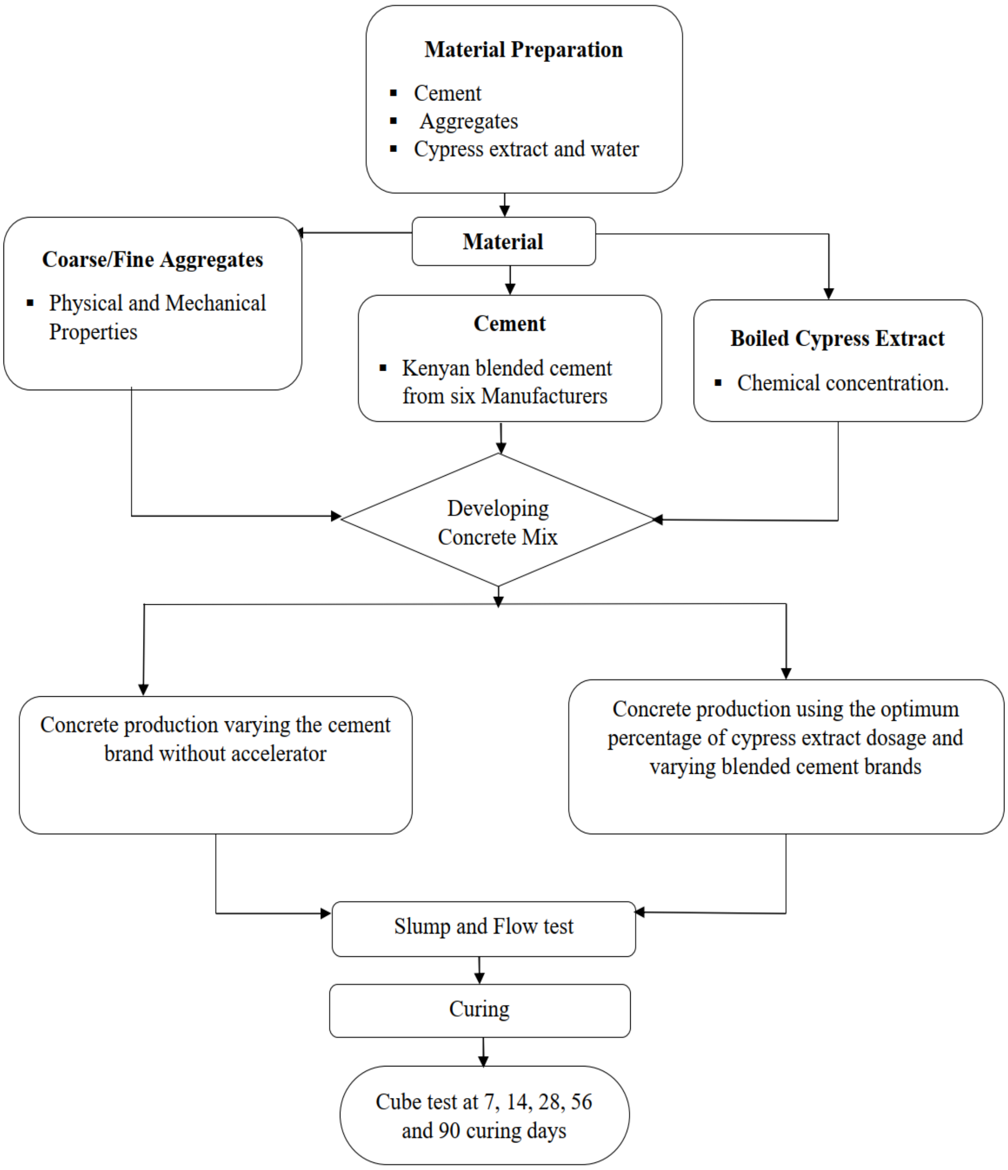


**Figure 3.1: Research flow chart diagram**

# CHAPTER FOUR

# RESULT AND DISCUSSIONS

## 4.1 Material Properties

Fine and coarse aggregates were sourced from the Sinopec quarry in Naivasha. Table 4.1, Table 4.2 shows the properties of the fine and coarse aggregate used during the experiment.

### 4.1.1 Properties of Fine and Coarse Aggregate

Table 4.1 shows the physical properties of the fine aggregate used in the study. The result shows that the fineness modulus was between acceptable limits of 2.3- 3.1, while the silt content was 2%, which is less than the maximum allowable of 5%. The specific gravity of the fine aggregate was 2.55, slightly higher than the acceptable minimum value of 2.5, and the water absorption was 1.89%, which was less than the maximum allowable of 2.0%.

**Table 4.1: Properties of Fine Aggregate Size 0/6 used (BS 882)**

| Aggregate Property | Result from the experiment | Standard Limits | Remarks |
|---|---|---|---|
| **Specifc gravity** | 2.5 | SSD > 2.5 | Compliance |
| **Fine Modulus** | 3.0% | >2.6,<3.1 | Compliance |
| **Silt Content** | 3% | < 5% | Compliance |
| **Water absorption** | 1.8% | < 2% | Compliance |
| **Bulk density** | 1425 $Kg/m^3$ | >1200<1750 | Compliance |
| **Sulphate soundness** | 6.4% | < 15% | Compliance |

The sieve analysis and the percentage fines were also tested, and results as shown in Figure 4.1.

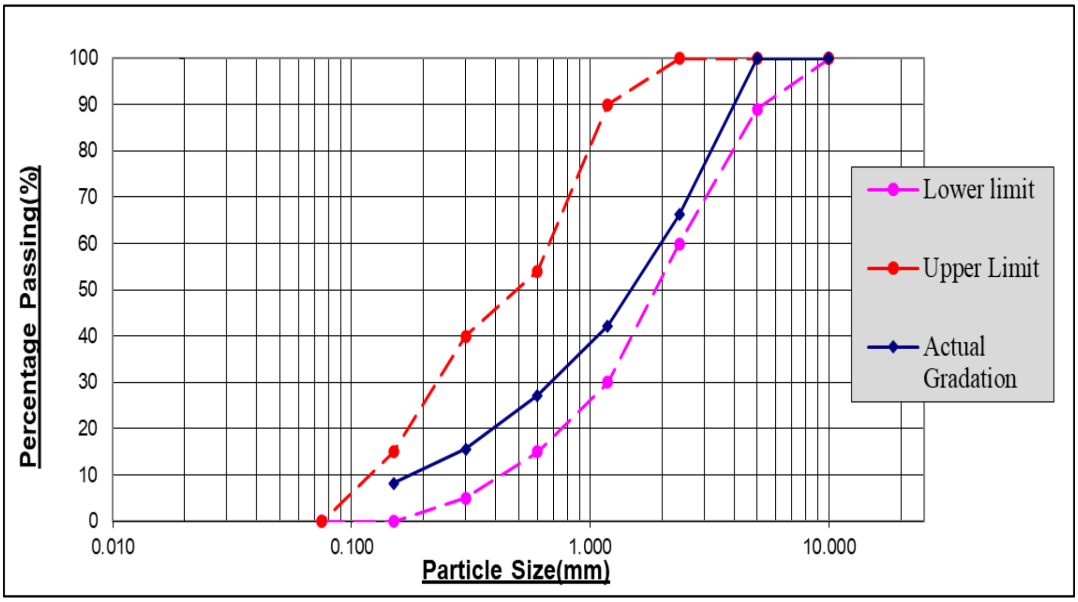


**Figure 4.1: Sieve analysis Results for the fine aggregate 0/6 size**

The results presented in Figure 4.1 shows that the overall grading obtained from the quarry dust (manufactured sand) complies with the specified limits given in the specification and BS. 882 as defined therein. According to the British standards, the recommended level of silt and clay content in a fine aggregate to be used for concrete production should not be more than 4%. Based on this, the fine aggregate had a silt content with the recommended limit hence suitable for use.

**Table 4.2: Properties of Coarse aggregate size 6/10 and 10/20 used (BS. 882)**

| Aggregate Property | Result from the experiment | Standard Limits | Remarks |
|---|---|---|---|
| **Specifc gravity** | 2.5 | SSD > 2.5 | Compliance |
| **Flakines index** | 15.6% | < 25% | Compliance |
| **Elongation Index** | 7.5% | < 25% | Compliance |
| **Water absorption** | 0.8% | < 2% | Compliance |
| **Bulk density** | 1358 $Kg/M^3$ | 1200-1750 | Compliance |
| **Clay Silt content** | 1% | < 3% | Compliance |
| **Sulphate soundness** | 6.4% | < 12% | Compliance |
| **LAA** | 15% | <40% | Compliance |
| **ACV** | 22% | <35% | Compliance |

The sieve analysis and the percentage fines were also tested, and results as shown in the Figure 4.2 and 4.3.

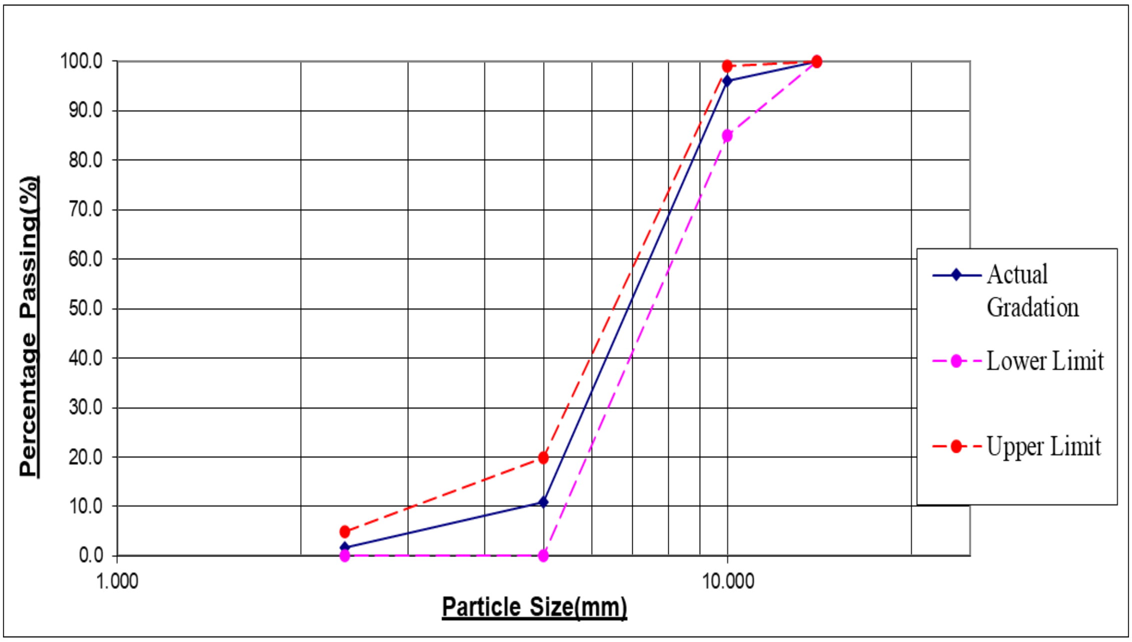


**Figure 4.2: Sieve Analysis Results for the fine Aggregate 6/10 size**

The overall grading obtained on the 6/10 mm concrete aggregate indicates that the sample comply with the specified envelop defined in BS. 882

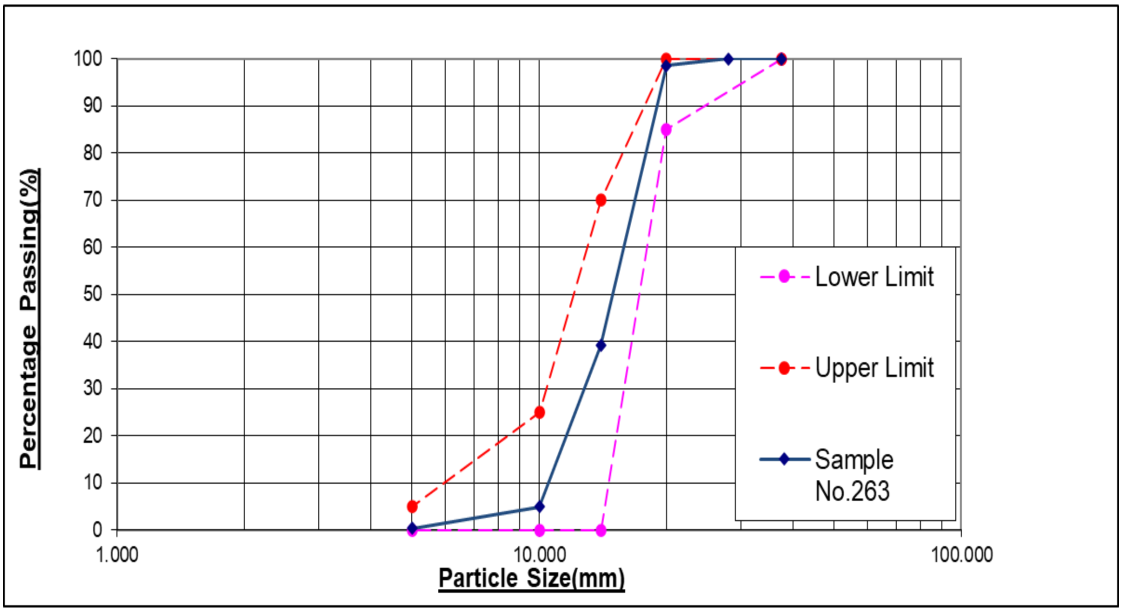


**Figure 4.3: Sieve Analysis Results for the fine Aggregate 10/20 size**

From the envelope presented in Figure 4.3, the 10/20 mm aggregate satisfies the grading specified grading requirements as defined in BS. 882, Thus, it’s concluded that the material is suitable for use in the production of concrete.

### 4.1.2 Properties of the Cypress Tree Extract

The element analysis for boiled plant extract was done and the chemical concentration results are shown in Table 3.1.

**Table 4.3: Chemical Concentration in ppm**

| Element | Cypress extract |
|---|---|
| **Potassium (K)** | 587.4 |
| **Magnesium (Mg)** | 320.4 |
| **Iron (Fe)** | 3.27 |
| **Zinc (Zn)** | 0.367 |
| **Cardium (Cd)** | 0.002 |
| **Copper (Cu)** | 0.113 |
| **Lead (Pb)** | 0.325 |
| **Manganese (Mn)** | 15.63 |

Cypress tree extract contains Magnesium ion which shorten the setting time of cement and increase the compressive strength at earlier curing ages. Magnesium carbonate promotes the formation of Ettringite and the hydration of calcium carbonate in unfavorable to the later hydration of blended cement. Li in his study on effect of Magnesium Carbonate on hydration and hardened properties of Portland cement paste found that magnesium carbonate makes the setting tine of cement paste shorten, and makes the compressive strength of cement paste increase at 1 day and 7 days, but decrease at 28 days (Li *et al.*, 2020).

Iron has various effects on the properties of cement. The addition of irone ions to concrete help to modify the initial hydration product layer and accelerate the hydration process, causing more C-S-H gel generated and dense microstructure. Study done by Change on effect of iron phase on calcination and properties of Barium Calcium Sulfoaluminate Cement revealed that the presence of iron promotes early hydration increases strength and improves the microstructure and composition of the cement (Chang *et al.*, 2021).

The presence of potassium will reduce the temperature emitted due to exothermal reaction of concrete hence making the plant-based extract suitable to be used as an admixture where the temperature and the emitting temperatures place a crucial role in construction and maintenance (Gadgihalli et al., 2017).

### 4.1.3 Properties of the Kenyan Blended Cement

The physical properties of cement which includes setting time and consistency are affected by the cement composition, rate of hydration and ambient temperature among others. The result given in Table 4.4 comparing the consistency and setting time of the different types of brands of blended cement show high values of initial setting time above the standard minimum values which is ≥60 minutes.

The result in the Table 4.4 shows that both Mortar made with CEM B and CEM D had a lower value of compressive strength < 32.5 Mpa. All other cements met the requirements as stated in the KS EAS 18-1:2001 Standard.

**Table 4.4: Physical and Mechanical Properties of the Blended Portland Cement**

| **BLENDED PORTLAND CEMENT TYPE** | | **COMPRESSIVE STRENGTH (Mpa)** | | **CONSISTENCY AND SETTING TIME (MIN), (KS EAS 148-3)** | | |
|---|---|---|---|---|---|---|
| **Cement Type** | **Cement Brand** | **7 days** | **28 Days** | **Consistency** | **Initial Setting** | **Final Setting** |
| **CEM IVB/32.5 N** | CEM A | 23.0 | 33.6 | 33.1 | 105 | 180 |
| **CEM IVB/32.5 N** | CEM B | 18.1 | 31.1 | 29.6 | 105 | 190 |
| **CEM IVB/32.5 R** | CEM C | 23.5 | 38.7 | 34.9 | 115 | 190 |
| **CEM IVB/32.5 N** | CEM D | 18.6 | 31.0 | 30.2 | 105 | 193 |
| **CEM IVB/32.5 N** | CEM E | 23.1 | 36.7 | 31.5 | 105 | 215 |
| **CEM IVB/32.5 N** | CEM F | 26.8 | 37.2 | 27.6 | 106 | 200 |

Chemical composition of the blended cements was done, and the results presented in the Table 4.5. The analysis was done using X-ray diffraction (XRD) method.

The result from the Table 4.5 shows that the amount of CaO ranges between 43.4% and 56.8% which is less than the minimum required value of 60% as recommended by the KS EAS 18-1-2001 for all the tested cement brands. This is a clear indication that none of the blended cement conforms to the standard limits with respect to CaO requirement. Calcium Oxide helps to control the strength gain and soundness of concrete hence the deficiency of CaO in cement reduces strength as well as the setting time of cement. In practice, the lower the resulting quantity of CaO, the higher the Pozzolanicity.

**Table 4.5: Chemical Composition of Kenyan Blended Cement**

| Oxides (%) | CEM A | CEM B | CEM C | CEM D | CEM E | CEM F |
|---|---|---|---|---|---|---|
| **$SiO_2$** | 25.3 | 30.3 | 24.4 | 15.8 | 18.4 | 21.0 |
| **$Al_2O_3$** | 7.0 | 8.6 | 7.6 | 16.9 | 6.1 | 5.7 |
| **$P_2O_5$** | 0.1 | 0.1 | < LOD | 0.2 | 0.2 | < LOD |
| **$SO_3$** | 3.5 | 1.2 | 2.3 | 2.7 | 2.4 | 4.4 |
| **$K_2O$** | 2.3 | 2.5 | 2.9 | 4.2 | 2.4 | 1.7 |
| **CaO** | 50.3 | 43.4 | 47.2 | 46.0 | 56.8 | 56.1 |
| **$TiO_2$** | 0.5 | 0.7 | 0.6 | 0.9 | 0.7 | 0.5 |
| **MnO** | 0.2 | 0.3 | 0.2 | 0.3 | 0.2 | 0.2 |
| **$Fe_2O_3$** | 5.8 | 7.8 | 7.4 | 8.3 | 7.7 | 5.5 |
| **Mg** | < LOD | < LOD | 0.9 | < LOD | < LOD | < LOD |
| **MgO** | < LOD | < LOD | 1.6 | < LOD | < LOD | < LOD |

Both CEM A and CEM B cements had a higher percentage of $SiO_2$ (25.4 % to 30.3%) which exceed the maximum standard limit ranging between 17% to 25% (ASTM). Other cement brands conform in terms of the $SiO_2$ percentage values 24.4%, 15.8%, 18.4% and 21.0% for CEM C, D, E, an F respectively. Silica helps to provide strength to cement. Most result for $Al_2O_3$ shows compliance for all brands of cements except CEM B and CEM D since they are higher than the standard limits of 3-8%. Aluminium oxide is responsible for the quick setting of cement. Excess of aluminium oxide reduces the strength of cement. Ferrous Oxide (Fe2O3) which helps to impart the characteristic grey colour to the cement and also helps in fusing of different materials are higher than the standard limits of 0.5-6% for all cement brands except CEM A and CEM F. The maximum amount of MgO is for CEM C. The amount of MgO which helps to provide hardness conforms to the standard requirement of 0-4% for all the Cement. Sulphur Trioxide ($SO_3$) for all cement brands conforms to the standard limit of 1.3-3% except for CEM A and CEM F which is above the limit (Okumu et al., 2017)

From Table 4.5, CEM B and CEM D cements had the lowest amount of CaO (43.4% and 46.0%) respectively which resulted into the cement having the lowest values of compressive strength. The difference in chemical composition of the various brands and type of cements are as a result of the pozzolanic materials added to blended cements leading to a reduction in the CaO values and are therefore being reflected in the difference in their mechanical properties and qualities of concrete produced.

## 4.2 Properties of the Blended Cement Concrete

### 4.2.1 The Effect of the Cypress Tree Extract on the Workability of Concrete

From the slump test, it was observed that plant extract additions improved concrete workability as shown in Figure 4.4. The plant extract was able to increase the viscosity of the mix and retain water. it was demonstrated in other research that; starch and starch derivatives are capable of reducing the amount of free water and increasing viscosity (Thirumalini & Sekar, 2013). Soft wood plant bark contains lignin (40-45%) (Patural et al., 2011), polysaccharide (30-48%) (Garcia-Perez et al., 2009). Starch is also a polysaccharide that can be fund in plant extract. In addition of increasing the slump, the extract retained water and reduced the fast flow of water or acted as viscous enhancing admixture. Workability increases linearly for the added extract.

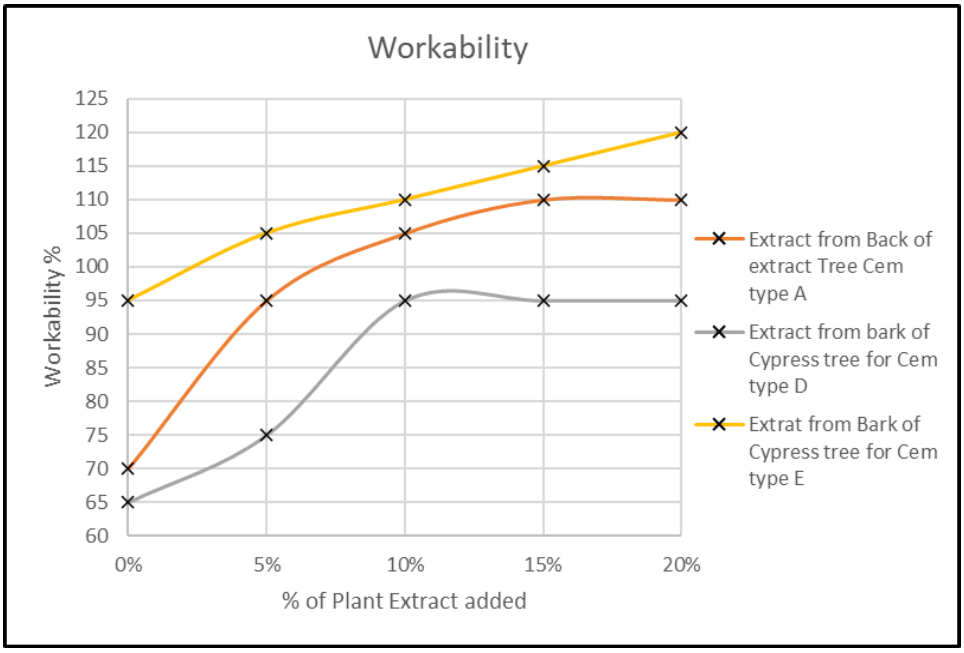


**Figure. 4.4: Effect of Boiled Cypress Bark Etract on Workability.**

The plasticizing properties of the admixture resulted in decreased mix water demand on different blended cement concrete.

### 4.2.2 Compressive Strength Development of the Blended Cement Concrete.

The compressive strength of the blended cements concrete from the local manufactures were evaluated to obtain the optimum compressive strength age and the results shows that different brands have varying compressive strength and for every brand (Refer to Appendix III), the blended Portland cements concrete had a lower compressive strength not meeting the target strength at 28 days age. Figure 4.5 shows the compressive strength development of the Kenyan blended cement with no accelerator added.

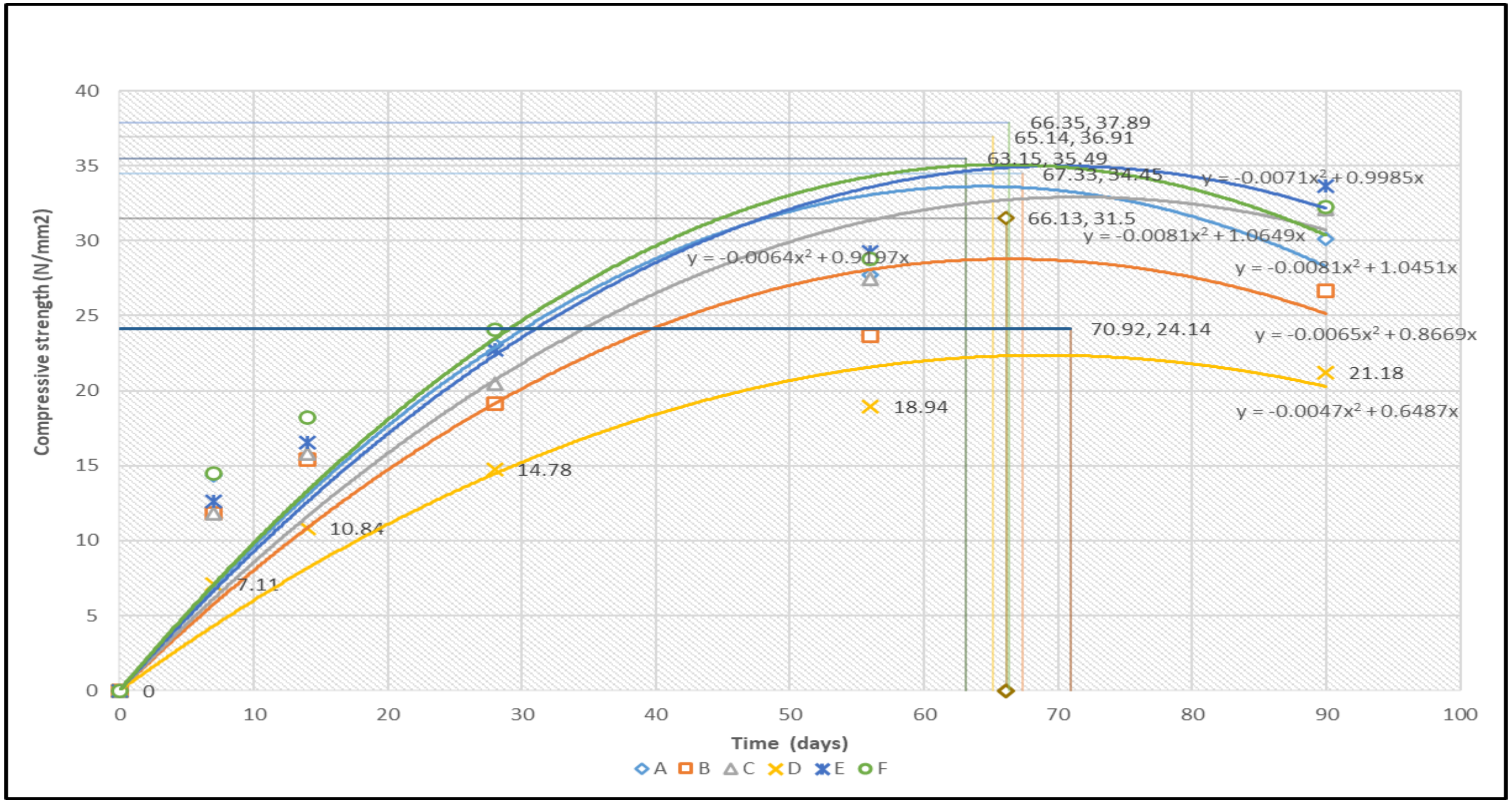


**Figure 4.5: Graph Showing Compressive Strength Development of Kenyan Blended Portland Cement Types**

**Table 4.6: Maximum Values of Compressive Strength and Age from Figure 4.4 when no Extract Added**

| | Maximum points | |
|---|---|---|
| | **X -(Age)** | **Y- (Max Strength)** |
| **A** | 63.15 | 35.49 |
| **B** | 66.13 | 31.5 |
| **C** | 67.33 | 34.45 |
| **D** | 70.92 | 24.14 |
| **E** | 66.35 | 37.89 |
| **F** | 65.14 | 36.91 |

Legend: X- the curing age at which the Maximum/ultimate strength is obtained

Y- The maximum strength referred as ultimate compressive strength.

A, B, C, D, E, F- Blended cement brand

The findings in Figure 4.5 shows that cement brands had different compressive strengths after curing process. All the cement types continued gaining significant amount of compressive strength over the period above 28 days. It was also observed that none of the cement brands reached the design strength at 28 days and that the strength development continued beyond 28 days of age upto the age at which it attained the ultimate strength.

The hydration of $C_2S$ in pozzolana cement does not normally proceed to a significant extent until approximately after 14 days (McCarthy & Dyer, 2019),which delays the release of heat of hydration and thus increase in strength at later days. $C_3S$ phase sets quickly making OPC exhibit a higher compressive strength than pozzolana cements by the 28$^{th}$ day (Karanja, 2013). The hydration of $C_3S$ and $C_2S$ with water gives calcium silicate and calcium hydroxide. $C_2S$ has a very high solubility in water compared to $C_3S$. This makes $C_2S$ to have no cementitious value as it is found as a free lime in the concrete. Thus, this increases porosity lowering the strength of the concrete.

Table 4.6 shows the maximum points from the curves in Figure 4.5. The ultimate compressive strength for the blended cement obtained were CEM A 35.5 Mpa at 64 days age, CEM B 31.5 Mpa at 64 days of age, CEM C 34.5 Mpa at 68 days of age, CEM D 24.1 Mpa at 71 days, CEM E 37.9 Mpa at 67 days of age and CEM F 36.9 Mpa at 66 days. The average ultimate strength age for blended cement with no accelerator was 67 days. The cement types B and D had low ultimate strength due to low amount of CaO in them which had an impact on the compressive strength of the concrete.

In Table 4.7, compressive strength of the blended cement brands at 28 days is lower that then expected design strength. However, at 56 days, CEM A, C, E and F had positive deviation of 2.73 MPa, 2.46 MPa, 4.24 MPa and 3.78 MPa respectively indicating that the Zero deviation was achieved between 28 days of age and 56 days of age. Only CEM B and D had negative deviation of -1.34 MPa and -6.06 MPa respectively. However, at 90 days all the CEM type had positive deviation except CEM D which had the lowest amount of CaO (45.99%) resulting into cement having the least value of 28 and 90-days compressive strength (14.78 Mpa and 21.18 Mpa) respectively and thus giving the lowest values of the concrete compressive strength values.

**Table 4.7: Compression Strength Variation for Difference Concrete Grades Cured at Varied Days.**

| Cement Type | Curing Days of the Blended Cement Concrete | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 7.0 | | 14.0 | | 28.0 | | 56.0 | | 90.0 | |
| | Strength | Var | Strength | Var | Strength | Var | Strength | Var | Strength | Var |
| **A** | 14.4 | -1.9 | 18.2 | -4.3 | 23.1 | -1.9 | 27.7 | 2.7 | 30.1 | 5.1 |
| **B** | 11.8 | -4.4 | 15.4 | -7.1 | 19.2 | -5.8 | 23.7 | -1.3 | 26.7 | 1.7 |
| **C** | 11.8 | -4.4 | 15.8 | -6.7 | 20.5 | -4.5 | 27.5 | 2.5 | 32.1 | 7.1 |
| **D** | 7.1 | -9.1 | 10.8 | -11.7 | 14.8 | -10.2 | 18.9 | -6.1 | 21.2 | -3.8 |
| **E** | 12.6 | -3.7 | 16.5 | -6.0 | 22.7 | -2.3 | 29.2 | 4.2 | 33.7 | 8.7 |
| **F** | 14.5 | -1.8 | 18.2 | -4.3 | 24.1 | -0.9 | 28.8 | 3.8 | 32.3 | 7.3 |

Note- Expected design values at 7 days, 14 days and 28 days are 16.3 N/mm$^2$ , 22.5 N/mm$^2$, 25 N/mm$^2$ respectively.

### 4.3 Optimum Percentage of the Plant-based Extract as an Accelerator on the Development of the Compressive Strength of Blended Cement Concrete.

The compressive strength test of concrete was done when cypress extract was added at a varying dosage of 0%,5%,10%,15% and 20%. The measurement was taken at 7, 14, 28, 56 and 90 days of age. Graphical representation of compressive strength development when extract is added is represented in Figures 4.6, 4.7 and 4.8. (Refer to Appendix IV).

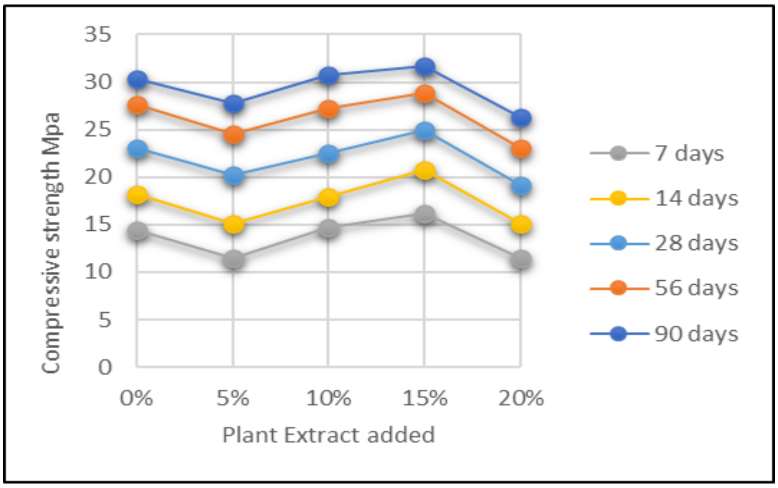


**Figure 4.6: Effect of Cypress Tree Extract on the Compressive Strength for Cement Type A**

From Figures 4.6, it is evident that the compressive strength decreases at 5% followed by an increase at 10% to 15% with a slight decrease at 20%. Figure 4.6 is the graph obtained when CEM D cement is used.

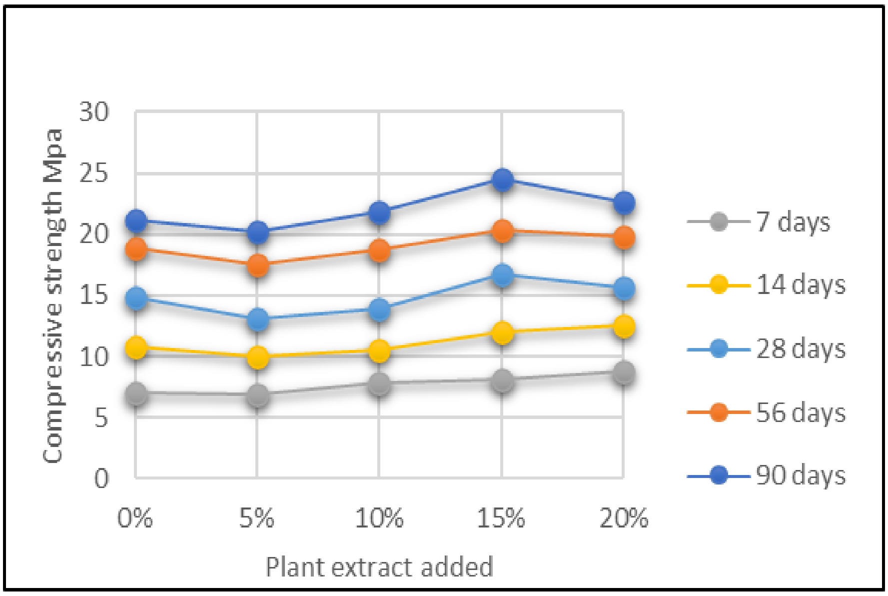


**Figure 4.7: Effect of Plant Extract on the Compressive Strength for Type D Cement**

The Figures 4.7 shows an increase of the compressive strength at 28 days by 3.56 Mpa when 15% of the boiled extract added while when 5% of the dosage is added the compressive strength reduced by 1.57 Mpa. Figure 4.8 is the graph obtained when CEM E is used.

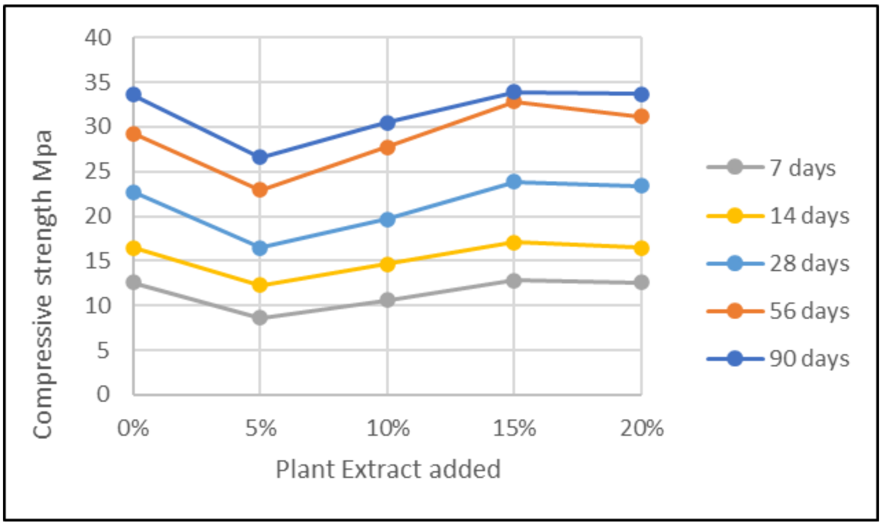


**Figure 4.8: Effect of Plant Extract on the Compressive Strength for Type E Cement**

From the Figure 4.8, the results show that at 28 days, concrete with 15% of dosage of the plant extract increased the compressive strength by 3.25 Mpa while at 5%, the compressive strength reduced by -6.27 Mpa. Based on the study, the highest rate of compressive strength improvement was realized when 15% of the cypress tree extract dosage was added hence being the optimum dosage.

The plant extract has reduced the consistency of cement due to its viscous nature and it has delayed the setting time of cement due to its ability to delay hydration process of cements. Cement contains compounds responsible for setting, early age strength and long-time strength. Tricalcium aluminate ($3CaO.Al_2O_3$) and tetracalcium aluminoferrite ($4CaO.Al_2O_3.Fe_2O_3$) are compounds in cement that react with water to make cement to set very fast (Ahmed et al., 2019). When cement react with water (Cations ($Ca^{2+}$ ) from cement and anions ($OH^-$) from water), calcium hydrate gel ($3CaO_2.SiO_2.H_2O$), Calcium hydroxide ($Ca(OH)_2$) are formed (Taylor, 2013).

Since plant extract contains polysaccharides, it has a carboxyl group that can be grouped with $Ca^{2+}$ ions on the surface of cement particle. In addition, $C_3A$ ($3CaO.Al_2O_3$) react rapidly to form calcium aluminate hydrate if there is sufficient sulfate in solution. The element analysis shows the extract has chains that react with $Ca^{2+}$ to give calcium silicate hydrate gel, a compound which helps to increase the strength of concrete.

The main cement reactions are given in the Equations 4.1 - 4.4 (Taylor, 1997)

$$2(3CaO.SiO_2) + 6H_2O \longrightarrow 3CaO.2SiO_2.3H_2O + 3(CaO.H_2O) \quad (4.1)$$

$$2(2CaO.SiO2) + 4H2O \longrightarrow 3CaO.2SiO2.3H2O + CaO.H2O \quad (4.2)$$

$$3CaO.Al_2O_3 + 6H_2O \longrightarrow 3CaO.Al_2O_3.6H_2O \quad (4.3)$$

$$4CaO.Al_2O_3.Fe_2O_3 + 4(CaO.H_2O) + 22H_2O \longrightarrow 4CaO.Al_2O_3.13H_2O + 4CaO.Fe_2O_3.13H_2O \quad (4.4)$$

The Equation 4.4 proceed so fast with a lot of heat liberation. The presence of sulphate ions causes the $C_3A$ to undergo a different hydration reaction forming ettringite as shown in the Equation 4.5. According to Warner report, the silicate and aluminate hydrates resulting from pozzolana calcium hydroxide reactions have similar properties to Portland cement's hydrates.(Warner, 2012).

$$SO_3.2H_2O + 3CaO.Al_2O_3 + 26H_2O \longrightarrow 6CaO.Al_2O_3.3SO_3.32H_2O \quad (4.5)$$

The plant extract was engaged in complex formation with calcium crosslinking and may be decrease the large amount of heat liberated by Tricalcium aluminate ($3CaO.Al_2O_3$) to delay the setting time hence acting as a retarder at 5% dosage.

The boiled extract act as a plasticizer by reducing the water demand and increasing the strength of concrete hence is comparable to super plasticizer at the optimum level of 15%. Previous researchers shows that super plasticizers such as Sulphonated naphthalene polymer and sulphonated naphthalene formaldehyde among others increased the compressive strength by 22% and 18% respectively. Comparably, this research indicates that cypress tree extracts also increased the compressive strength by 12% at optimum dosage of 15%. Therefore, the cypress tree extract has chains that react with $Ca^{2+}$ to give calcium silicate hydrate gel which increases the strength of concrete. Carboxylic group and other chains present in plant extract increased the strength of concrete by increasing calcium hydrate gel and decreasing calcium hydroxide content (ECO, 2014). Figure 4.9 shows the extent of increase in the compressive strength when 15% of the cypress extract for cement types CEM A, D.

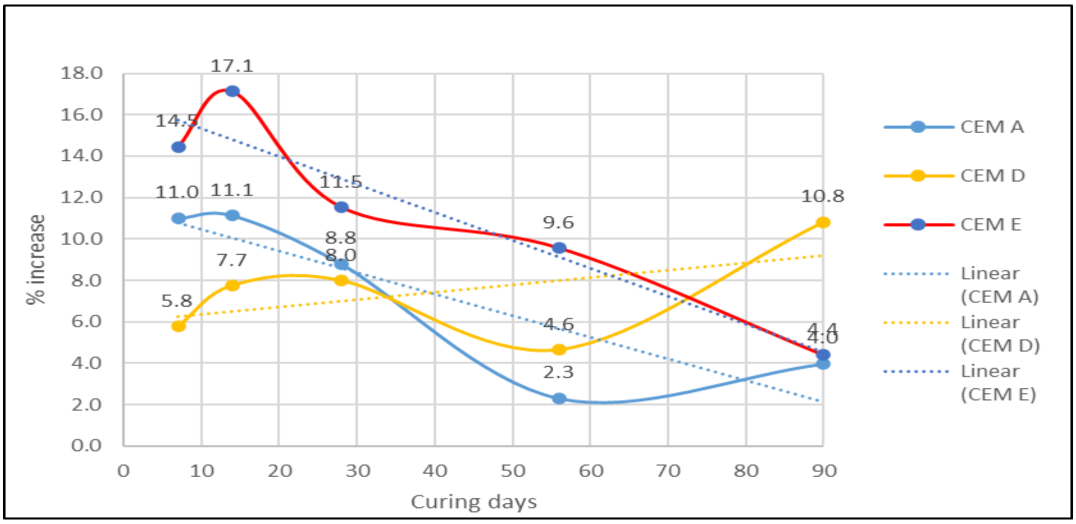


**Figure 4.9: Percentage Increasement on the Compressive Strength for CEM A, D and E with 15% Cypress Extract.**

Figure 4.9 shows that the cypress extract had a higher effect on the early strength development compared to the ultimate strength development. Previous research has shown that accelerators in concrete promotes early strength of concrete with OPC and secure its constructability using additional retarders to control the quick setting of concrete. They promote early strength development of concrete by increasing the hydration rate of the cement composition accelerating the precipitation of hydration products, and speeding up the initial crystallization (Oyawa et al., 2016).

The analysis was done using three brands of cement which were adopted for the objective two, cement concrete showing low, median, and highest compressive strength at 28 days of age respectively. CEM A or F with the highest compressive strength, CEM C or E with median strength, and CEM B or D with the lowest compressive strength. CEM A, D, and E were selected and adopted.

Since the plant extract accelerates the strength of blended concrete at an early stage, the age at which the blended cement will attain its ultimate strength will therefore be lower as compared to when no extract is used.

Figure 4.10-shows the compressive strength development when 15% cypress extract is used. (Refer to Appendix V).

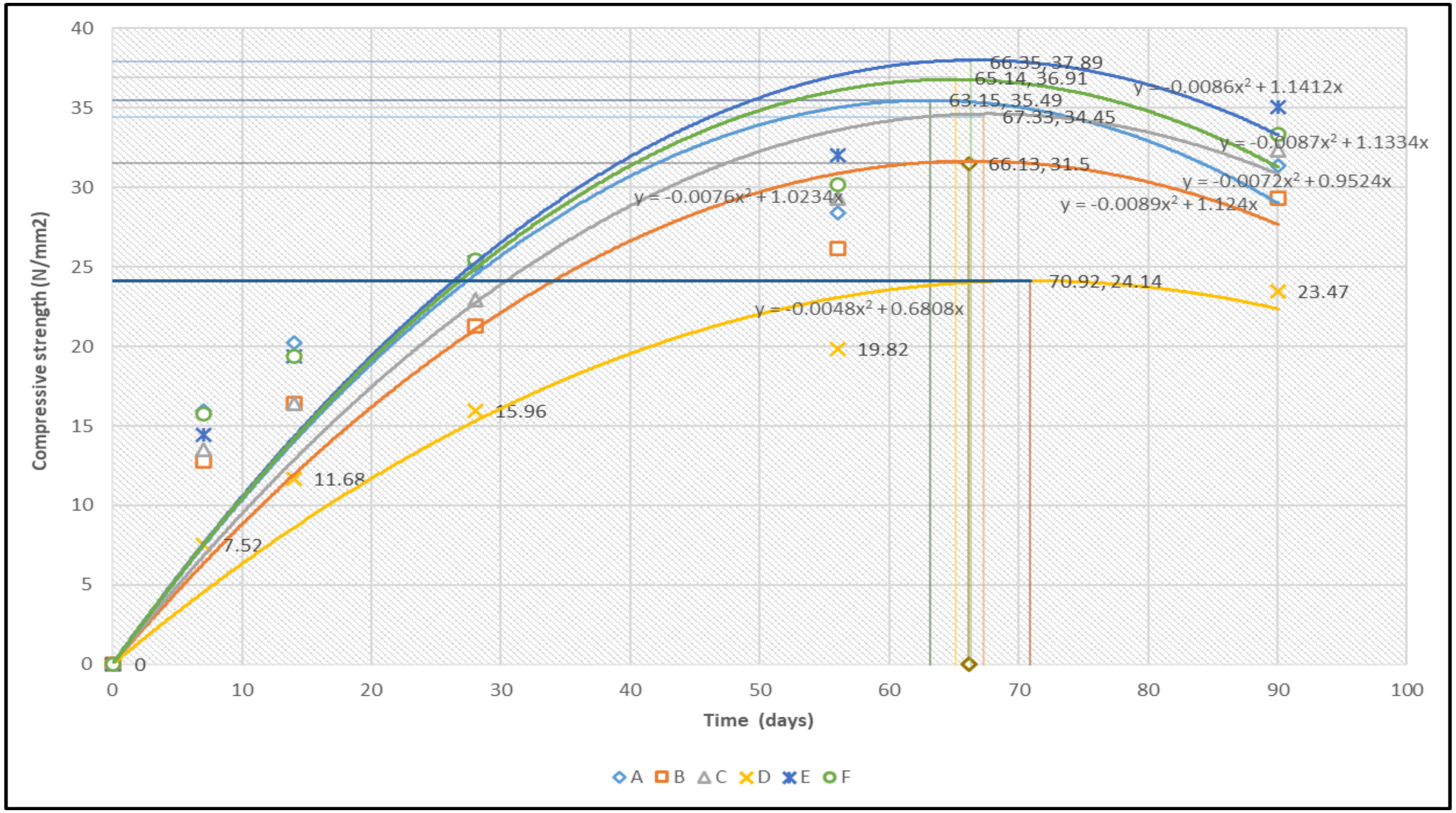


**Figure. 4.10: Compressive Strength Development of the Cement Types with 15% Cypress Tree Extract.**

As indicated in Figure 4.10, when the plant extract was added, concrete achieved its design strength at 28 days for CEM A, 36 days for CEM B, 32 days for CEM C, 26 days for CEM E and 27 days for CEM F while the strength continued to develop up to 67 days where it achieved the ultimate compressive strength. The table 4.8 shows the maximum values of compressive strength for the Kenyan blended cement with an accelerator generated from the graph in Figure 4.9.

From Figure 4.10, it is also evident that the ultimate strength age for the blended cement is at 67 days where the compressive strength gain is minimum for all the Kenyan blended cement.

**Table 4.8: Age at which Blended Cement Concrete Achieve Ultimate and Design Compressive Strength.**

| **Cement type** | **A** | **B** | **C** | **D** | **E** | **F** |
|---|---|---|---|---|---|---|
| Design strength Age when no extract added (Days) | 38 | 70 | 48 | - | 37 | 35 |
| Design strength Age with 15% Cypress tree extract | 28 | 36 | 32 | - | 26 | 27 |
| Ultimate strength age when no extract added | 65 | 67 | 72 | 69 | 71 | 66 |
| Ultimate strength age when 15% dosage of cypress extract added | 64 | 67 | 68 | 71 | 67 | 66 |

From Table 4.8 it is evident that blended cement concrete achieves its design strength at an average of 27 days of age when 15% dosage of extract is used as compared to 37 days of age when no accelerator is used in the mix, a reduction of 10 days curing time. The use of 28 days in the design and determination of the construction guideline limits can only apply when the accelerator is used on the Kenyan blended cement concrete. Cypress tree extract used as an accelerator is a very significant improvement on the setting time hence permitting earlier removal of formwork, reducing the required period of curing the blended cement concrete should take to achieve the design and ultimate compressive strength before being loaded and finally advancing the time the structure can be placed in service safely.

To guarantee safety and reducing the level of risk on building collapse in Kenya when blended cement concrete is used, all structures should therefore be subjected to construction loads at 37 days of age and not 28 days when blended Portland cements are used without any accelerators.

From Table 4.8, the result clearly shows that the number of days for the concrete to achieve the design strength reduces when an accelerator is added but the ultimate strength age remains constant. The ultimate age remained at an average day of 67 when accelerator is added and when not added. This indicates that the plant extract only accelerates the strength development and does not affect the ultimate strength age

## 4.4 Mathematical Model on Strength Gain Rate for the Blended Cement Concrete Considering the Effect of Cypress Tree Extract Dosage at Optimum.

### 4.4.1 Exploratory Data Analysis (EDA)

Table 4.9 indicate the summary statistics (mean, median, standard deviation) for each variable. In addition, visualizations (histograms) have been created to understand the distribution of data.

**Table 4.9a: Summary for Variables; Cement Strength by Categories of: Days**

| Days | N | Mean | sd | Min | Max |
|---|---|---|---|---|---|
| **7 days** | 12 | 12.68 | 2.85 | 7.10 | 15.94 |
| **14 days** | 12 | 16.56 | 2.88 | 10.84 | 20.26 |
| **28 days** | 12 | 21.69 | 3.53 | 14.78 | 25.42 |
| **56 days** | 12 | 26.81 | 4.04 | 18.94 | 32.04 |
| **90 days** | 12 | 30.08 | 4.25 | 21.18 | 35.08 |
| **TOTAL** | 60 | 21.56 | 7.30 | 7.1 | 35.08 |

**Table 4.9b: Summary for variables; Cement Strength by categories of: Cement brand (Cement brands)**

| C_ brand | N | Mean | sd | Min | Max |
|---|---|---|---|---|---|
| **A** | 10 | 23.45 | 6.04 | 14.37 | 31.34 |
| **B** | 10 | 20.27 | 6.13 | 11.81 | 29.33 |
| **C** | 10 | 22.24 | 7.74 | 11.84 | 32.35 |
| **D** | 10 | 15.15 | 5.72 | 7.10 | 23.47 |
| **E** | 10 | 24.09 | 8.23 | 12.58 | 35.08 |
| **F** | 10 | 24.18 | 6.94 | 14.46 | 33.36 |
| **TOTAL** | 60 | 21.56 | 7.30 | 7.1 | 35.08 |

The Table 4.10 indicate the results of a two-sample t-test with equal variances for the two groups being compared labeled as "0% Extract" and "15% Extract." The mean value for the "0%" group is approximately 20.78 while the mean value for the "15%" group is approximately 22.35. The difference in means between the two groups is calculated as -1.58. This difference is not statistically significant, as indicated by the p-values associated with the test (all greater than the typical alpha level of 0.05). Hence, there is no strong evidence to reject the null hypothesis, suggesting that the means of the two groups are not significantly different.

**Table 4.10: Two-Sample Test with Equal Variances**

| Group | Cbs | Mean | Std. Err | Std. Dev. | (95% Conf. Interval) | |
|---|---|---|---|---|---|---|
| 0% | 30 | 20.78 | 1.32 | 7.25 | 18.07 | 23.48 |
| 15% | 30 | 22.35 | 1.35 | 7.39 | 19.59 | 25.11 |
| combined | 60 | 21.56 | 0.94 | 7.30 | 19.68 | 23.45 |
| diff | | -1.58 | 1.89 | | -5.36 | 2.21 |
| diff = mean (0%) - mean (15%) | | | | | | t = -0.83 |
| Ho : diff < 0 | | | | | Degree of freedom = 58 | |
| Ha : diff < 0 | | Ha : diff ! = 0 | | | Ha : diff > 0 | |
| Pr (T < t) = 0.20 | | Pr ( \|T\| > \| t \|) = 0.41 | | | Pr ( T > t ) = 0.80 | |

Most samples exhibit compressive strength between 10 and 20 MPa, with some variation at other strength levels.

### 4.4.2 Regression Modeling

Ordinary Least Squares (OLS) regressions modeling was used to explain the relationship between the independent (Days, Extract and Cement Brand) and the dependent (Compressive strength) variables when all are brought together. The results were as shown in Table 4.11.

**Table 4.11: Linear Regression Model.**

| **Model** | **Standardized Coefficients** | | **Sig.** |
|---|---|---|---|
| | **Beta** | **Std. Error** | |
| **(Constant)** | 13.66 | 0.366 | p<0.001 |
| **A** | 0 | | |
| **B** | -3.181 | 0.424 | p<0.001 |
| **C** | -1.217 | 0.528 | p<0.05 |
| **D** | -8.306 | 0.489 | p<0.001 |
| **E** | 0.635 | 0.613 | p>0.05 |
| **F** | 0.728 | 0.383 | p>0.05 |
| **Extract** | 1.576 | 0.302 | p<0.001 |
| **Days** | 4.505 | 0.118 | p<0.001 |
| **n=60** | | | |
| **R-squared=0.977** | | | |

The linear regression model for the study is specified as

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \cdots + \beta_k x_{ki} + \varepsilon_i$$

Where $y_i$ - Compressive strength

$\beta_0$ - a constant

$\beta_1 x_1$ - Cement Brands

$\beta_2 x_2$ - Extract

$\beta_3 x_3$ - Days

The regression equation for the Extract and Days for the compressive strength (CS) can be modeled as follows:

$$y_i=13.66+4.505\ x_1+1.576x_2$$

This equation accounts for the baseline compressive strength (13.66) and the effects of both days and extract on the strength. This means that keeping all others constant:

a) A unit change in Extract would result into 1.576-unit change in Compressive strength the Cement brands. Additionally, Higher levels of extract are associated with increased compressive strength.
b) A unit change in Days would result into 4.505-unit change in Compressive strength the Cement brands. In other words, As the number of days' increases, the compressive strength also increases significantly.

For both Extract and Days, the significance level is $p<0.001$, indicating high statistical significance. The constant term has a coefficient of 13.66 with a standard error of 0.366 which represents the baseline compressive strength when other factors are zero.

On the other hand, based on the results of the regression analysis, it can be observed that cement brands B, C, and D have significant effects on the compressive strength. Specifically, cement brands B and C have negative effects, while cement brand D has a strong negative effect. On the other hand, variables A, E, and F do not have a significant impact on compressive strength. These findings provide insights into the relationship between different cement brands and their influence on compressive strength, allowing for informed decision-making in the selection and use of cement in construction projects.

Finally, the model has a high goodness of fit (R-squared = 0.977), suggesting that it explains a significant portion of the variation in compressive strength.

### 4.5 Summary Of the Results and Discussions.

The test done on the physical and mechanical properties of the fine and coarse aggregate sourced from Sinopec quarry which included sieve analysis, specific gravity, flakiness index, elongation index, water absorption, bulk density, clay silt content, sulphate soundless, loss angeles abrasion test and aggregate crushing value among others shows values that are within the recommended limits in the respective British standards hence suitable for concrete production. Both the aggregate samples comply to the standards.

Chemical composition of cements shows that none of the blended cement achieve the minimum amount of Cao which is 60% as per the standard. Two out of six blended cement shows higher percentage of silicon dioxide exceeding the standard limits of 18%.  Testing on the physical and mechanical properties proves that the initial setting time for all the blended cement are above the standard minimum values of 60 minutes.

On the compressive strength age development of the blended cement Concrete test, it was observed that none of the cement brands reach the design values at 28 days and the strength development continues up to beyond 70 curing days. The ultimate compressive strength age of the blended cements was found to be at an average of 67 days of curing age.

With the introduction of the cypress tree extract in the concrete mix of blended cement concrete, it was found that 15% of the dosage of the plant extract increased the compressive strength by the highest value hence is the optimum, any dosage above the 15% will reduce the strength hence act as retarder while at 15%, the cypress extract act as an accelerator.

The design strength for the blended cement was achieved at 27 days of age when 15% dosage of extract was added to the blended cement concrete as compared to 37 days when no accelerator was added. The Ultimate strength age of the blended cement concrete was found to remain at 67 days of age with or without accelerator added. This shows that the strength development of the blended cement increases beyond 28 days of age and tends to emerge at the ultimate strength age.

Cement brands B and C have negative effects on the Compressive strength while A, E, and F do not have a significant impact on compressive strength. The rate of compressive strength is achieved using a linear regression model $y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \cdots + \beta_k x_{ki} + \varepsilon_i$ (Where $y_i$ represent the compressive strength, $\beta_0$ is *a* constant, $\beta_1 x_1$ is cement Brands, $\beta_2 x_2$ is extract and $\beta_3 x_3$ is the number of days) while the regression equation for the Extract and Days for the compressive strength (CS) can be modeled as: $y_i = \mathbf{13.66} + \mathbf{4.505}\, x_1 + \mathbf{1.576} x_2$

# CHAPTER FIVE

# CONCLUSIONS AND RECOMMENDATION

## 5.1 Conclusions

Based on the experiments carried out and the result on the effect of the plant-based extract as an accelerator on the blended Portland cement concrete, the following conclusion are made in the order of the objectives:

1. The research revealed that locally produced blended Portland cement from the six different manufacturers have varying chemical, physical and mechanical properties which in turn affect the concrete produced when the different brands of cements are used. None of the Kenyan blended cement met the minimum requirement of the physical and chemical properties as started in the Kenyan standards KS EAS 18-1:2001. All other constituents of the concrete met the standard requirement in terms of their physical and mechanical properties.
2. None of the blended cement concrete reached the design strength at 28 days and the strength development continued upto 67 days where they attain their ultimate compressive strength. The blended Portland cement concrete also achieves their design strength of 25 Mpa at 37 days when no accelerator is added as compared to 27 days when 15% optimum dosage expressed as a mass percentage of the cement content is used in the mix.
3. The linear regression model for the study is specified as $y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \cdots + \beta_k x_{ki} + \varepsilon_i$ (Where $y_i$ represent the compressive strength, $\beta_0$ is *a* constant, $\beta_1 x_1$ is cement Brands, $\beta_2 x_2$ is extract and $\beta_3 x_3$ is the number of days) while the regression equation for the Extract and Days for the compressive strength (CS) can be modeled as: $y_i$=**13.66**+**4.505** $x_1$+**1.576**$x_2$

## 5.2 Recommendations

From the result of the study, the research recommends the following:

### 5.2.1 For Use/Application Purposes

a. The use of cypress tree extract at 15% as an accelerator in Kenyan blended cement concrete.
b. Adoption of 37 days before loading the structures if no accelerator is used for Kenyan blended cement concrete.
c. That the blended Portland cements should not be used to directly replace Ordinary Portland cements in a concrete mix design.

### 5.2.2 Further Studies and Legislative.

a) Further research should be done to establish the influence of the difference in aggregate properties on the quality of blended cement concrete using plant-based extract as an accelerator in Kenya.
b) The construction industry in Kenya should come up with a Policies to ensure that all the structures should be subjected to construction loads at 37 days of age or at 28 days when accelerator is used in the Kenyan blended cement concrete.
c) The use of Blended Portland cement should be regulated to a specific function where it is well designed for. Legal action to be taken on non-compliance especially where people/contractors directly replaced OPC with BPC on the same mix design.

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# APPENDICES

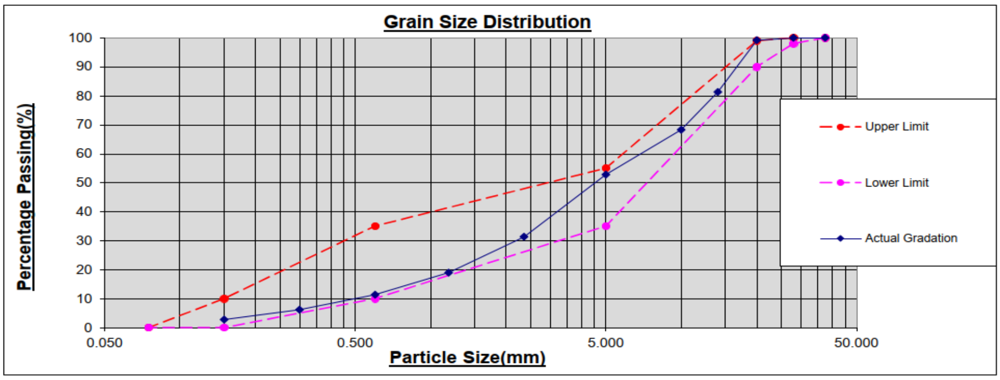
## Appendix I: All In One Aggregate Curve-Actual And Theoretical

**Determination of Particle size distribution for coarse Aggregates**
**BSEN 933-1-2012/BSEN 12620:2002+A1 2008**

**PROJECT: THESIS**

| | | | | |
|---|---|---|---|---|
| **Sample no;** **101** | **Material Description** *All in Aggregates* | **Mat'l Source** *Sinopec Quarry* | **Sampling Date** *7/12/2021* | **Testing Date** *8/5/2021* |
| **Structure ID** N/A | **Max aggregate size** 20mm | **Sampling Location** Aggregate Bin no. 01/02/03/04 | | **Weight before washing (g)** |
| **Project specification:** | | **Sampled by:** *Ambrose/Kevin* | | **Weight after dry (g)** **5000** |

| Sieve Size Standard | Gradation 1 (Mass retained) | Gradation 2 (Mass retained) | Gradation 3 (Mass retained) | Weight Retained Combined | Cumulative Retained(g) | Percentage of Retained(%) | Percentage of Passing(%) | Specification Limits-EN 933-1 | |
|---|---|---|---|---|---|---|---|---|---|
| 37.5mm | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 | 100.0 | 100 | 100 |
| 28.0mm | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 | 100.0 | 98 | 100 |
| 20.0mm | 60 | 36 | 29 | 41.7 | 41.7 | 0.8 | 99.2 | 90 | 99 |
| 14.0 mm | 802 | 915 | 962 | 893.0 | 934.7 | 18.7 | 81.3 | | |
| 10.0 mm | 715 | 666 | 575 | 652.0 | 1586.7 | 31.7 | 68.3 | | |
| 5.0 mm | 793 | 748 | 773 | 771.3 | 2358.0 | 47.2 | 52.8 | 35 | 55 |
| 2.36 mm | 1052 | 1057 | 1115 | 1074.7 | 3432.7 | 68.7 | 31.3 | | |
| 1.18 mm | 610 | 627 | 621 | 619.3 | 4052.0 | 81.0 | 19.0 | | |
| 0.600 mm | 386 | 382 | 378 | 382.0 | 4434.0 | 88.7 | 11.3 | 10 | 35 |
| 0.300mm | 267 | 256 | 253 | 258.7 | 4692.7 | 93.9 | 6.1 | | |
| 0.150mm | 173 | 170 | 158 | 167.0 | 4859.7 | 97.2 | 2.8 | 0 | 10 |
| 0.075mm | 62 | 66 | 60 | 62.7 | 4922.3 | 98.4 | 1.6 | | |
| Pan | | | | 119 | | | | | |




**Remarks:**

Washed quarry sand =**52%** / 6-10mm Aggregates =**15%** / 10-20mm =**33%**

| | Tested By | Reviwed by | Reviewed by: QAQC | E/ER |
|---|---|---|---|---|
| Name: | | | | |
| Sign: | | | | |
| Date: | | | | |

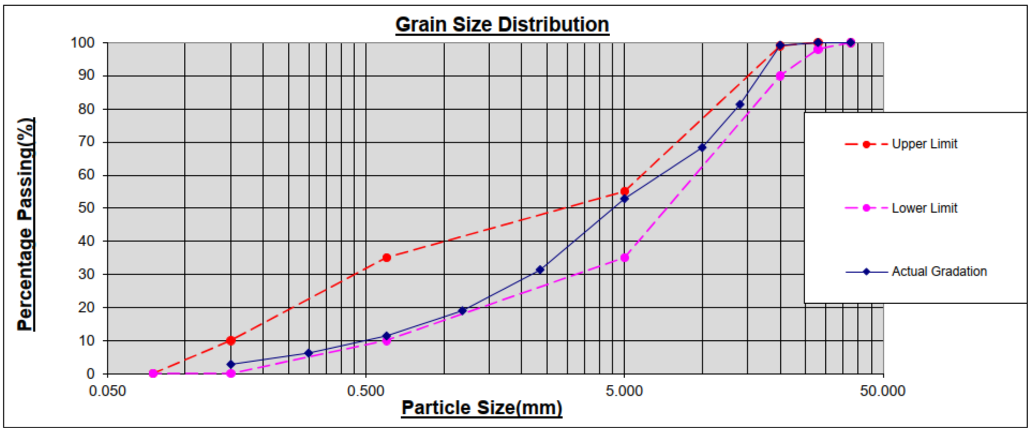
## Determination of Particle size distribution for coarse Aggregates

**BSEN 933-1-2012/BSEN 12620:2002+A1 2008**

**PROJECT: THESIS**

| | | | | |
|---|---|---|---|---|
| **Sample no;** 1,002,003 | **Material Description** *All in Aggregates* | **Mat'l Source** *Sinopec Quarry* | **Sampling Date** *7/12/2021* | **Testing Date** *8/5/2021* |
| **Structure ID** N/A | **Max aggregate size** 20mm | **Sampling Location** Aggregate Bin no. 01/02/03/04 | | **Weight before washing (g)** |
| **Project specification:** | | **Sampled by:** *Ambrose/Kevin* | | **Weight after dry (g)** **5000** |

| Sieve Size Standard | Gradation 1 (Mass retained) | Gradation 2 (Mass retained) | Gradation 3 (Mass retained) | Weight Retained Combined | Cumulative Retained(g) | Percentage of Retained(%) | Percentage of Passing(%) | Specification Limits-EN 933-1 | |
|---|---|---|---|---|---|---|---|---|---|
| 37.5mm | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 | 100.0 | 100 | 100 |
| 28.0mm | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 | 100.0 | 98 | 100 |
| 20.0mm | 60 | 36 | 29 | 41.7 | 41.7 | 0.8 | 99.2 | 90 | 99 |
| 14.0 mm | 802 | 915 | 962 | 893.0 | 934.7 | 18.7 | 81.3 | | |
| 10.0 mm | 715 | 666 | 575 | 652.0 | 1586.7 | 31.7 | 68.3 | | |
| 5.0 mm | 793 | 748 | 773 | 771.3 | 2358.0 | 47.2 | 52.8 | 35 | 55 |
| 2.36 mm | 1052 | 1057 | 1115 | 1074.7 | 3432.7 | 68.7 | 31.3 | | |
| 1.18 mm | 610 | 627 | 621 | 619.3 | 4052.0 | 81.0 | 19.0 | | |
| 0.600 mm | 386 | 382 | 378 | 382.0 | 4434.0 | 88.7 | 11.3 | 10 | 35 |
| 0.300mm | 267 | 256 | 253 | 258.7 | 4692.7 | 93.9 | 6.1 | | |
| 0.150mm | 173 | 170 | 158 | 167.0 | 4859.7 | 97.2 | 2.8 | 0 | 10 |
| 0.075mm | 62 | 66 | 60 | 62.7 | 4922.3 | 98.4 | 1.6 | | |
| Pan | | | | 119 | | | | | |




**Remarks:**

Washed quarry sand =**52%** / 6-10mm Aggregates =**15%** / 10-20mm =**33%**

| | Tested By | Reviwed by | Reviewed by: QAQC | E/ER |
|---|---|---|---|---|
| Name: | | | | |
| Sign: | | | | |
| Date: | | | | |

## Appendix II: Concrete Mix Design

**DESIGN OF NORMAL CONCRETE MIXES**

BS 5338 /BS 8110 / BRE 2nd Ed.

DATE 10/4/2021

| Stage | Item | | Reference or Calculation | Values |
|---|---|---|---|---|
| 1 | 1.1 | Characteristic Strength | Specified | 25 N/mm² at 28 Days; Proportion defective 5.0 Percent |
| | 1.2 | Standard Deviation | | N/mm² or no data 6 N/mm² |
| | 1.3 | Margin | C1 | (k = 1.64) 1.64 x 6 9.84 N/mm² |
| | 1.4 | Target Mean Strength | C2 | 25 + 9.84 34.84 N/mm² |
| | 1.5 | Cement Type | Specified | 32.5/42.5/52.5 |
| | 1.6 | Aggregates type: Coarse<br>Aggregates type: Fine | | Crushed/~~uncrushed~~<br>Crushed/~~uncrushed~~ |
| | 1.7 | Free-water/cement ratio | | 0.5 — use the lower value 0.5 |
| | 1.8 | Maximum free-water/water ratio | Specified | 0.6 |
| 2 | 2.1 | Slump or vebe time | Specified | Slump 60-180 mm vebe time 0-3 s |
| | 2.2 | Maximum aggregte size | Specified | 20 mm |
| | 2.3 | Free-water content | | 180 kg/m³ |
| 3 | 3.1 | Cement content | C3 | 180 / 0.5 = 360 kg/m³ |
| | 3.2 | Maximum Cement content | Specified | 360 kg/m³ |
| | 3.3 | Minimum cement content | Specified | 320 kg/m³ |
| | 3.4 | Modified free-water/cement ratio | | 0.5 kg/m³ |
| 4 | 4.1 | Relative Density of aggregate (SSD) | | 2.5 known/~~assumed~~ |
| | 4.2 | Concrete Density | | 2,320 kg/m³ |
| | 4.3 | Total aggregate content | C4 | 2,320 360 180 = 1,780 kg/m³ |
| 5 | 5.1 | Grading of fine aggregates Retained siebe 0 .6mm | BS 882 | 20.6% |
| | 5.2 | Proportion of fine aggregate | (Adjust to finer in All in aggregates envelope BS 882) | Say 52 % |
| | 5.3 | Fine aggregates content | C5 | 1,780 x 0.52 = 926 kg/m³ |
| | 5.4 | Coarse aggreagtes content | C5 | 1,780 - 926 = 854 kg/m³ |

## DESIGN OF NORMAL CONCRETE MIXES

BS 5338 /BS 8110 / BRE 2nd Ed.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | DATE | 10/4/2021 |
| **Quantities** | **Cement** Kg | **Water** (Litres) | **Admixture** | **Fine Agg. Kg** WQS | **Coarse Aggregates (Kg)** 6/10 mm | | 10/20mm |
| Per $M^3$ (to the nearest 5kg) | 360 | 180 | | 926 | 267.0 | | 587.4 |
| Per trial mix 0.05 $m^3$ | 18.00 | 9.00 | | 46.28 | 13.35 | | 29.4 |

**Correction of Batch Volume** (As per ACI 211.1)

| Material | S.Gravity SSD | Mix design weights ($Kg/M^3$) | | Mix design Volume ($M^3$) | adjustment vol ($M^3$) | | Adjusted Mix Proportions ($Kg/M^3$) |
|---|---|---|---|---|---|---|---|
| Cement | 3.05 | 360 | | 0.118 | 0 | | 360 |
| Water | 1 | 180 | | 0.180 | 0 | | 180 |
| 6/10 | 2.525 | 267.0 | | 0.106 | 0.001 | | 270 |
| 10/20mm | 2.589 | 587.4 | | 0.227 | 0.002 | | 594 |
| WQS | 2.554 | 925.6 | | 0.362 | 0.003 | | 934 |
| | **Total** | **2320** | | **0.99** | **0.01** | | **2338** |

| | **Cement** | **Water** | **0-6mm** | **6/10mm** | **10/20mm** |
|---|---|---|---|---|---|
| **Per trial mix 0.03 $m^3$** | **10.80** | **5.40** | **28.01** | **8.11** | **17.81** |

## Appendix III: Objective 1-Table Of Compressive Strength Test For The Kenyan Blended Cement Concrete Without Cypress Tree Extract

| KENYAN BLENDED CEMENT CONCRETE COMPRESIVE STRENGTH TEST RESULT SUMMARY | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cement Type | Compressive strength of blended kenyan cement concrete without Extract | | | | | | | | | | | | | | | |
| | Slump (mm) | 7 Days Compressive strength | | | 14 Days Compressive strength | | | 28 Days Compressive strength | | | 56 Days Compressive strength | | | 90 Days Compressive strength | | |
| | | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR |
| A | 70.0 | 335.27 | 14.90 | 14.36 | 417.48 | 18.55 | 18.23 | 532.59 | 23.67 | 23.06 | 607.76 | 27.01 | 27.73 | 689.08 | 30.63 | 30.14 |
| | | 312.05 | 13.87 | | 392.57 | 17.45 | | 518.08 | 23.03 | | 626.12 | 27.83 | | 671.23 | 29.83 | |
| | | 322.11 | 14.32 | | 420.64 | 18.70 | | 505.69 | 22.48 | | 638.12 | 28.36 | | 674.38 | 29.97 | |
| B | 95.0 | 271.03 | 12.05 | 11.81 | 339.04 | 15.07 | 15.41 | 413.19 | 18.36 | 19.17 | 573.72 | 25.50 | 23.66 | 592.67 | 26.34 | 26.69 |
| | | 267.09 | 11.87 | | 355.47 | 15.80 | | 423.09 | 18.80 | | 494.50 | 21.98 | | 607.01 | 26.98 | |
| | | 259.01 | 11.51 | | 345.72 | 15.37 | | 457.47 | 20.33 | | 528.89 | 23.51 | | 601.59 | 26.74 | |
| C | 95.0 | 270.50 | 12.02 | 11.84 | 333.35 | 14.82 | 15.82 | 443.59 | 19.72 | 20.49 | 634.51 | 28.20 | 27.46 | 724.65 | 32.21 | 32.11 |
| | | 268.65 | 11.94 | | 336.59 | 14.96 | | 483.09 | 21.47 | | 601.12 | 26.72 | | 729.85 | 32.44 | |
| | | 259.96 | 11.55 | | 397.59 | 17.67 | | 456.18 | 20.27 | | 617.81 | 27.46 | | 712.98 | 31.69 | |
| D | 75.0 | 166.34 | 7.39 | 7.11 | 249.33 | 11.08 | 10.84 | 341.99 | 15.20 | 14.78 | 443.87 | 19.73 | 18.94 | 470.40 | 20.91 | 21.18 |
| | | 160.49 | 7.13 | | 231.98 | 10.31 | | 328.52 | 14.60 | | 437.25 | 19.43 | | 484.29 | 21.52 | |
| | | 152.86 | 6.79 | | 250.15 | 11.12 | | 326.82 | 14.53 | | 397.51 | 17.67 | | 475.03 | 21.11 | |
| E | 100.0 | 294.85 | 13.10 | 12.59 | 370.13 | 16.45 | 16.53 | 499.82 | 22.21 | 22.71 | 672.37 | 29.88 | 29.24 | 779.71 | 34.65 | 33.60 |
| | | 286.65 | 12.74 | | 361.97 | 16.09 | | 523.64 | 23.27 | | 677.37 | 30.11 | | 739.89 | 32.88 | |
| | | 268.01 | 11.91 | | 383.60 | 17.05 | | 509.79 | 22.66 | | 624.19 | 27.74 | | 748.49 | 33.27 | |
| F | 50.0 | 332.48 | 14.78 | 14.46 | 400.88 | 17.82 | 18.18 | 527.83 | 23.46 | 24.06 | 632.45 | 28.11 | 28.78 | 755.50 | 33.58 | 32.27 |
| | | 320.64 | 14.25 | | 406.32 | 18.06 | | 567.50 | 25.22 | | 646.10 | 28.72 | | 708.10 | 31.47 | |
| | | 322.65 | 14.34 | | 420.25 | 18.68 | | 528.76 | 23.50 | | 663.81 | 29.50 | | 714.79 | 31.77 | |

## Appendix IV: Objective 2-Table Of Compressive Strength Test With Varying Percentages Of Cypress Tree Extract

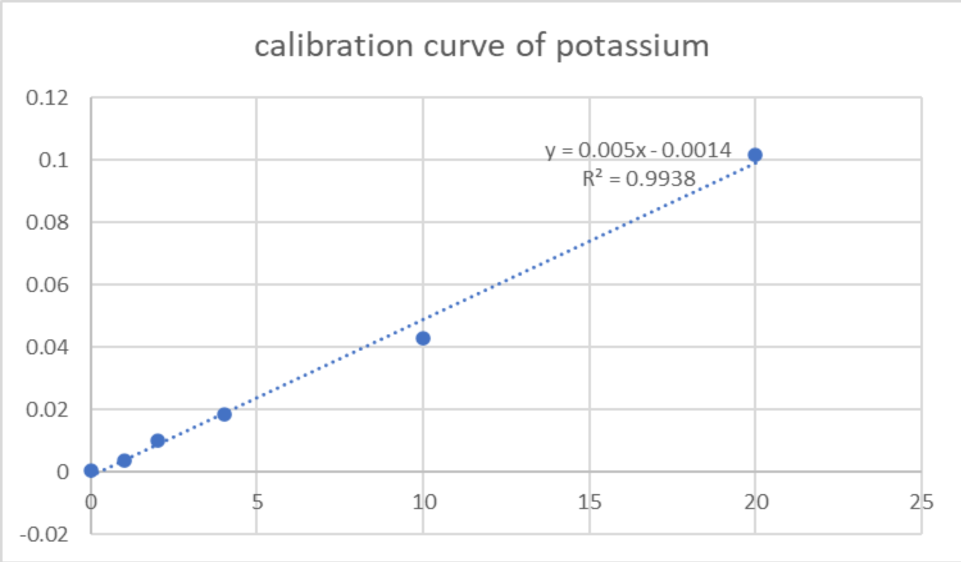
| KENYAN BLENDED CEMENT CONCRETE COMPRESIVE STRENGTH TEST RESULT SUMMARY | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cement Type | % age plant extract added | Effect of Plant extract from Bark of cypress tree on Blended cement compressive strength | | | | | | | | | | | | | | | |
| | | Slump (mm) | 7 Days Compressive strength | | | 14 Days Compressive strength | | | 28 Days Compressive strength | | | 56 Days Compressive strength | | | 90 Days Compressive strength | | |
| | | | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR |
| A | | | 335.27 | 14.90 | | 417.98 | 18.58 | | 532.56 | 23.67 | | 607.76 | 27.01 | | 689.08 | 30.63 | |
| | 0% | 70.0 | 312.05 | 13.87 | 14.36 | 392.57 | 17.45 | 18.24 | 518.08 | 23.03 | 23.06 | 626.12 | 27.83 | 27.73 | 671.23 | 29.83 | 30.14 |
| | | | 322.11 | 14.32 | | 420.64 | 18.70 | | 505.69 | 22.48 | | 638.12 | 28.36 | | 674.38 | 29.97 | |
| | | | 256.25 | 11.39 | | 346.94 | 15.42 | | 451.69 | 20.08 | | 553.76 | 24.61 | | 647.28 | 28.77 | |
| | 5% | 115.0 | 260.76 | 11.59 | 11.54 | 347.84 | 15.46 | 15.10 | 461.40 | 20.51 | 20.20 | 555.69 | 24.70 | 24.62 | 641.10 | 28.49 | 27.82 |
| | | | 261.91 | 11.64 | | 324.77 | 14.43 | | 450.64 | 20.03 | | 552.20 | 24.54 | | 589.69 | 26.21 | |
| | | | 342.11 | 15.20 | | 401.10 | 17.83 | | 522.47 | 23.22 | | 627.66 | 27.90 | | 667.73 | 29.68 | |
| | 10% | 90.0 | 324.81 | 14.44 | 14.72 | 403.84 | 17.95 | 18.03 | 505.28 | 22.46 | 22.54 | 603.37 | 26.82 | 27.19 | 700.96 | 31.15 | 30.70 |
| | | | 326.66 | 14.52 | | 412.29 | 18.32 | | 493.85 | 21.95 | | 604.49 | 26.87 | | 703.35 | 31.26 | |
| | | | 359.70 | 15.99 | | 472.83 | 21.01 | | 563.04 | 25.02 | | 655.08 | 29.11 | | 693.54 | 30.82 | |
| | 15% | 120.0 | 357.87 | 15.91 | 16.16 | 475.11 | 21.12 | 20.80 | 550.12 | 24.45 | 24.89 | 634.06 | 28.18 | 28.80 | 725.93 | 32.26 | 31.66 |
| | | | 373.22 | 16.59 | | 456.40 | 20.28 | | 567.14 | 25.21 | | 654.81 | 29.10 | | 717.56 | 31.89 | |
| | | | 253.81 | 11.28 | | 347.19 | 15.43 | | 434.59 | 19.32 | | 519.26 | 23.08 | | 579.63 | 25.76 | |
| | 20% | 100.0 | 254.60 | 11.32 | 11.39 | 342.13 | 15.21 | 15.13 | 419.67 | 18.65 | 19.24 | 509.61 | 22.65 | 22.97 | 585.64 | 26.03 | 26.33 |
| | | | 260.21 | 11.57 | | 331.79 | 14.75 | | 444.50 | 19.76 | | 521.46 | 23.18 | | 612.17 | 27.21 | |
| D | | | 166.34 | 7.39 | | 247.33 | 10.99 | | 341.99 | 15.20 | | 443.87 | 19.73 | | 470.40 | 20.91 | |
| | 0% | 75.0 | 160.49 | 7.13 | 7.11 | 231.98 | 10.31 | 10.81 | 328.52 | 14.60 | 14.78 | 437.25 | 19.43 | 18.94 | 484.29 | 21.52 | 21.18 |
| | | | 152.86 | 6.79 | | 250.15 | 11.12 | | 326.82 | 14.53 | | 397.51 | 17.67 | | 475.03 | 21.11 | |
| | | | 149.85 | 6.66 | | 229.46 | 10.20 | | 302.87 | 13.46 | | 382.95 | 17.02 | | 494.50 | 21.98 | |
| | 5% | 115.0 | 157.83 | 7.01 | 6.90 | 224.26 | 9.97 | 10.02 | 289.80 | 12.88 | 13.13 | 397.55 | 17.67 | 17.56 | 423.42 | 18.82 | 20.34 |
| | | | 158.26 | 7.03 | | 222.96 | 9.91 | | 293.33 | 13.04 | | 404.58 | 17.98 | | 455.06 | 20.22 | |
| | | | 170.51 | 7.58 | | 238.34 | 10.59 | | 311.65 | 13.85 | | 409.69 | 18.21 | | 457.80 | 20.35 | |

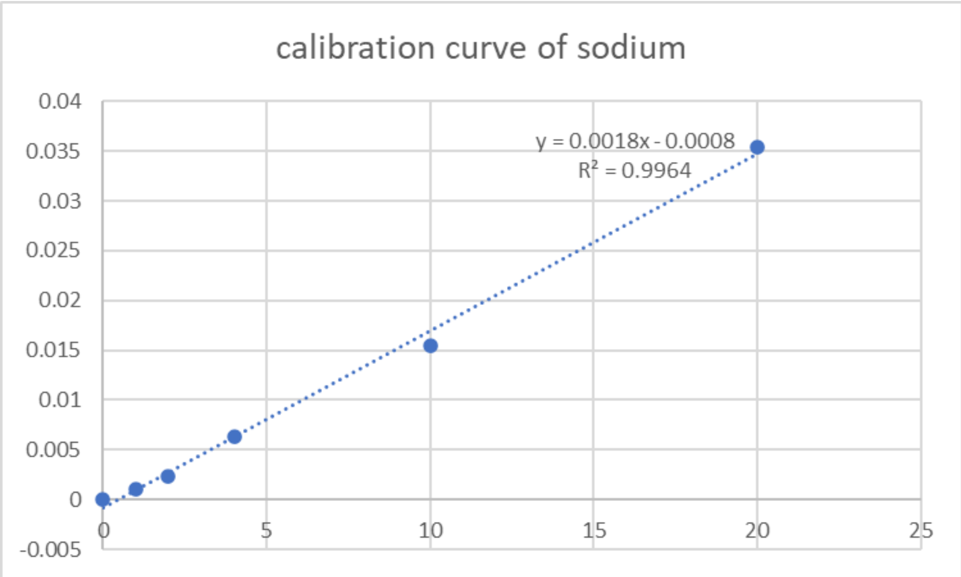
| KENYAN BLENDED CEMENT CONCRETE COMPRESIVE STRENGTH TEST RESULT SUMMARY | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cement Type | % age plant extract added | Effect of Plant extract from Bark of cypress tree on Blended cement compressive strength | | | | | | | | | | | | | | | |
| | | Slump (mm) | 7 Days Compressive strength | | | 14 Days Compressive strength | | | 28 Days Compressive strength | | | 56 Days Compressive strength | | | 90 Days Compressive strength | | |
| | | | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR |
| | 10% | 95.0 | 177.29 | 7.88 | 7.77 | 232.93 | 10.35 | 10.52 | 301.11 | 13.38 | 13.93 | 423.93 | 18.84 | 18.66 | 505.06 | 22.45 | 21.85 |
| | | | 176.94 | 7.86 | | 239.00 | 10.62 | | 327.78 | 14.57 | | 425.62 | 18.92 | | 512.15 | 22.76 | |
| | | | 186.55 | 8.29 | | 270.16 | 12.01 | | 393.35 | 17.48 | | 475.21 | 21.12 | | 551.22 | 24.50 | |
| | 15% | 75.0 | 182.53 | 8.11 | 8.23 | 275.66 | 12.25 | 12.09 | 352.63 | 15.67 | 16.69 | 462.76 | 20.57 | 20.40 | 557.29 | 24.77 | 24.61 |
| | | | 186.33 | 8.28 | | 270.16 | 12.01 | | 380.43 | 16.91 | | 439.20 | 19.52 | | 552.44 | 24.55 | |
| | | | 199.12 | 8.85 | | 284.64 | 12.65 | | 354.27 | 15.75 | | 437.27 | 19.43 | | 479.37 | 21.31 | |
| | 20% | 55.0 | 198.84 | 8.84 | 8.80 | 283.03 | 12.58 | 12.57 | 364.57 | 16.20 | 15.66 | 455.83 | 20.26 | 19.94 | 533.25 | 23.70 | 22.74 |
| | | | 196.06 | 8.71 | | 281.14 | 12.49 | | 338.31 | 15.04 | | 453.03 | 20.13 | | 522.20 | 23.21 | |
| E | | | 294.81 | 13.10 | | 370.13 | 16.45 | | 499.82 | 22.21 | | 672.37 | 29.88 | | 592.67 | 26.34 | |
| | 0% | 110.0 | 286.65 | 12.74 | 12.58 | 361.97 | 16.09 | 16.53 | 523.64 | 23.27 | 22.71 | 677.37 | 30.11 | 29.24 | 607.01 | 26.98 | 26.69 |
| | | | 268.01 | 11.91 | | 383.60 | 17.05 | | 509.79 | 22.66 | | 624.19 | 27.74 | | 601.59 | 26.74 | |
| | | | 194.53 | 8.65 | | 272.45 | 12.11 | | 366.56 | 16.29 | | 515.22 | 22.90 | | 590.38 | 26.24 | |
| | 5% | 125.0 | 186.76 | 8.30 | 8.63 | 275.00 | 12.22 | 12.30 | 372.08 | 16.54 | 16.44 | 520.62 | 23.14 | 22.94 | 590.88 | 26.26 | 26.60 |
| | | | 201.27 | 8.95 | | 283.10 | 12.58 | | 371.37 | 16.51 | | 512.31 | 22.77 | | 614.56 | 27.31 | |
| | | | 229.16 | 10.19 | | 322.43 | 14.33 | | 443.55 | 19.71 | | 594.38 | 26.42 | | 697.53 | 31.00 | |
| | 10% | 95.0 | 243.90 | 10.84 | 10.61 | 333.03 | 14.80 | 14.64 | 457.95 | 20.35 | 19.69 | 653.07 | 29.03 | 27.70 | 675.78 | 30.03 | 30.45 |
| | | | 243.34 | 10.82 | | 332.83 | 14.79 | | 427.73 | 19.01 | | 622.62 | 27.67 | | 681.81 | 30.30 | |
| | | | 269.22 | 11.97 | | 420.68 | 18.70 | | 548.44 | 24.38 | | 751.35 | 33.39 | | 717.93 | 31.91 | |
| | 15% | 105.0 | 277.71 | 12.34 | 12.09 | 363.62 | 16.16 | 17.08 | 527.38 | 23.44 | 23.83 | 736.23 | 32.72 | 32.83 | 822.95 | 36.58 | 33.39 |
| | | | 269.01 | 11.96 | | 368.43 | 16.37 | | 532.98 | 23.69 | | 728.18 | 32.36 | | 712.77 | 31.68 | |
| | | | 285.60 | 12.69 | | 379.81 | 16.88 | | 551.16 | 24.50 | | 697.76 | 31.01 | | 742.01 | 32.98 | |
| | 20% | 120.0 | 287.93 | 12.80 | 12.61 | 368.10 | 16.36 | 16.49 | 522.75 | 23.23 | 23.40 | 717.46 | 31.89 | 31.13 | 755.89 | 33.59 | 33.73 |
| | | | 277.85 | 12.35 | | 365.08 | 16.23 | | 505.65 | 22.47 | | 686.36 | 30.51 | | 779.04 | 34.62 | |

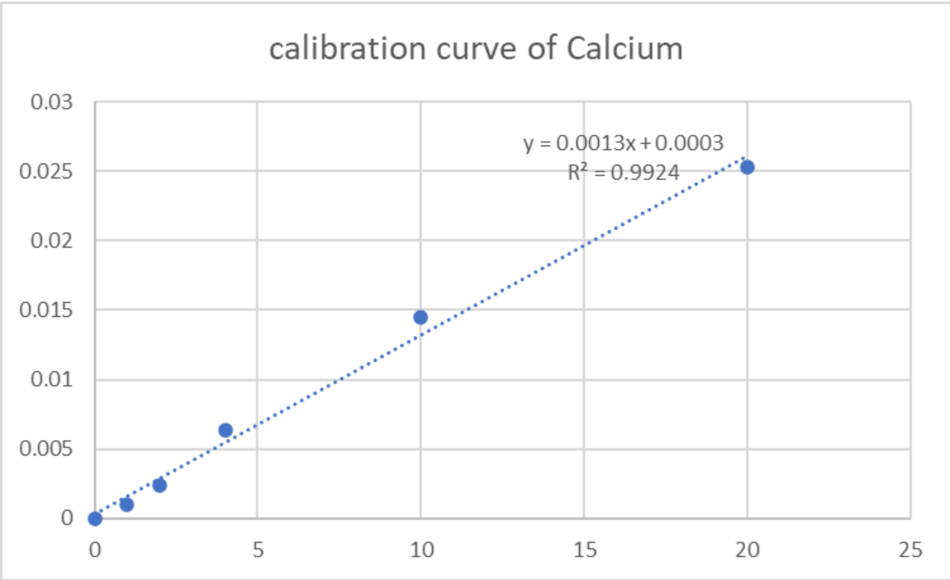
## Appendix V: Objective 3-Table Of Compressive Strength Test For The Kenyan Blended Cement Concrete With 15% Dosage Of Cypress Tree Extract

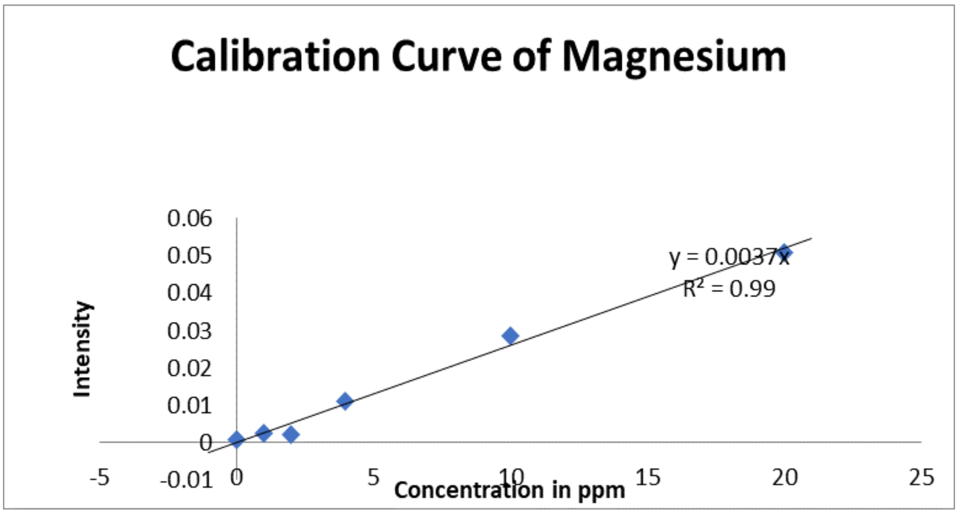
| KENYAN BLENDED CEMENT CONCRETE COMPRESIVE STRENGTH TEST RESULT SUMMARY | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cement Type | Effect of 15% plant extract from Bark of cypress tree on Blended cement compressive strength | | | | | | | | | | | | | | | |
| | Slump (mm) | 7 Days Compressive strength | | | 14 Days Compressive strength | | | 28 Days Compressive strength | | | 56 Days Compressive strength | | | 90 Days Compressive strength | | |
| | | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR | Load (KN) | Strength (Mpa) | AVR |
| A | 120.0 | 362.30 | 16.10 | 15.94 | 456.48 | 20.29 | 20.26 | 566.45 | 25.18 | 25.09 | 648.64 | 28.83 | 28.37 | 703.87 | 31.28 | 31.34 |
| | | 360.96 | 16.04 | | 452.02 | 20.09 | | 567.63 | 25.23 | | 631.58 | 28.07 | | 680.08 | 30.23 | |
| | | 352.61 | 15.67 | | 458.90 | 20.40 | | 559.70 | 24.88 | | 634.83 | 28.21 | | 731.77 | 32.52 | |
| B | 115.0 | 287.18 | 12.76 | 12.78 | 365.06 | 16.22 | 16.41 | 435.05 | 19.34 | 21.27 | 608.04 | 27.02 | 26.19 | 705.71 | 31.36 | 29.33 |
| | | 287.12 | 12.76 | | 375.66 | 16.70 | | 442.55 | 19.67 | | 586.33 | 26.06 | | 636.88 | 28.31 | |
| | | 288.37 | 12.82 | | 366.68 | 16.30 | | 557.86 | 24.79 | | 573.72 | 25.50 | | 637.06 | 28.31 | |
| C | 105.0 | 307.91 | 13.68 | 13.53 | 371.05 | 16.49 | 16.42 | 561.38 | 24.95 | 22.95 | 656.50 | 29.18 | 29.34 | 713.06 | 31.69 | 32.35 |
| | | 303.08 | 13.47 | | 381.32 | 16.95 | | 494.03 | 21.96 | | 679.25 | 30.19 | | 734.19 | 32.63 | |
| | | 302.14 | 13.43 | | 355.75 | 15.81 | | 493.55 | 21.94 | | 644.94 | 28.66 | | 736.33 | 32.73 | |
| D | 115.0 | 166.83 | 7.41 | 7.52 | 259.70 | 11.54 | 11.68 | 355.33 | 15.79 | 15.96 | 445.64 | 19.81 | 19.82 | 522.97 | 23.24 | 23.47 |
| | | 169.96 | 7.55 | | 265.73 | 11.81 | | 358.40 | 15.93 | | 463.08 | 20.58 | | 546.33 | 24.28 | |
| | | 171.10 | 7.60 | | 263.15 | 11.70 | | 363.53 | 16.16 | | 429.37 | 19.08 | | 515.26 | 22.90 | |
| E | 105.0 | 333.36 | 14.82 | 14.41 | 420.21 | 18.68 | 19.36 | 581.77 | 25.86 | 25.33 | 696.78 | 30.97 | 32.04 | 783.73 | 34.83 | 35.08 |
| | | 328.06 | 14.58 | | 442.45 | 19.66 | | 559.00 | 24.84 | | 746.85 | 33.19 | | 764.61 | 33.98 | |
| | | 311.06 | 13.82 | | 444.06 | 19.74 | | 569.32 | 25.30 | | 718.86 | 31.95 | | 819.67 | 36.43 | |
| F | 70.0 | 366.84 | 16.30 | 15.75 | 442.01 | 19.65 | 19.41 | 576.16 | 25.61 | 25.42 | 658.71 | 29.28 | 30.16 | 757.57 | 33.67 | 33.36 |
| | | 356.73 | 15.85 | | 435.57 | 19.36 | | 585.12 | 26.01 | | 698.93 | 31.06 | | 750.87 | 33.37 | |
| | | 339.53 | 15.09 | | 432.42 | 19.22 | | 554.74 | 24.66 | | 678.14 | 30.14 | | 743.57 | 33.05 | |

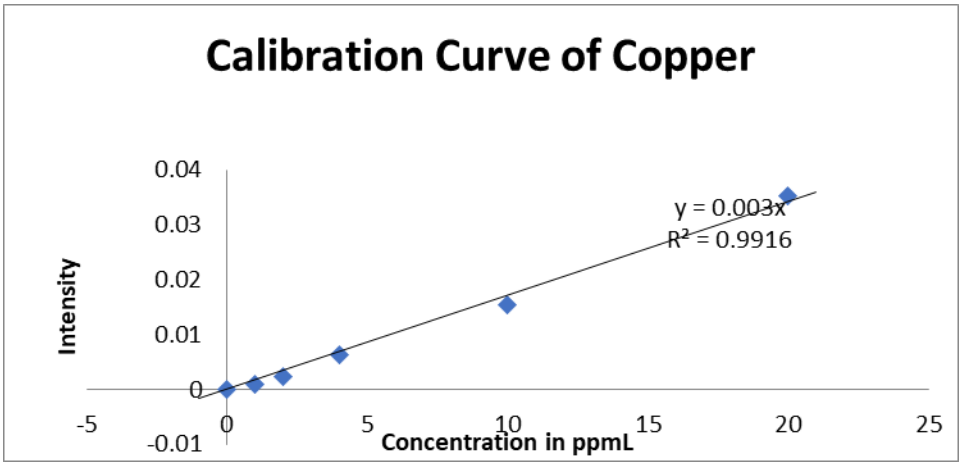
**Appendix VI: Calibration Curve For Analyzing The Extract Using Aas Method**

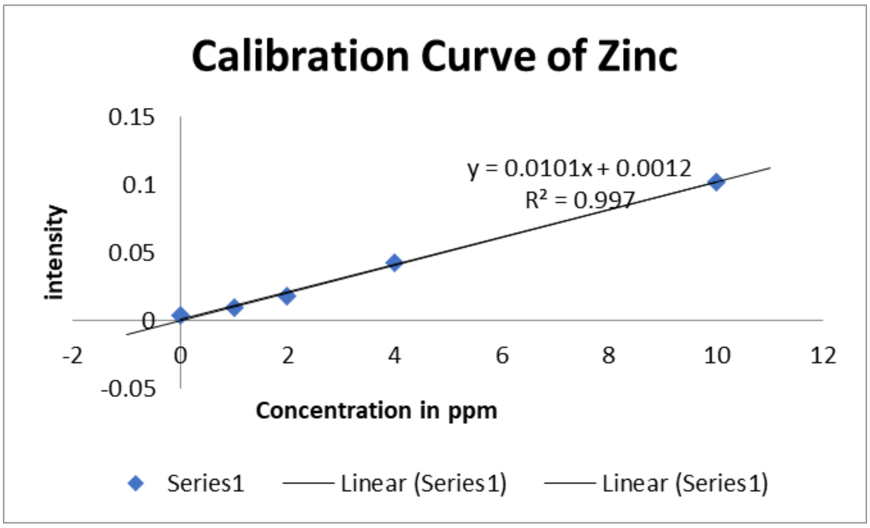


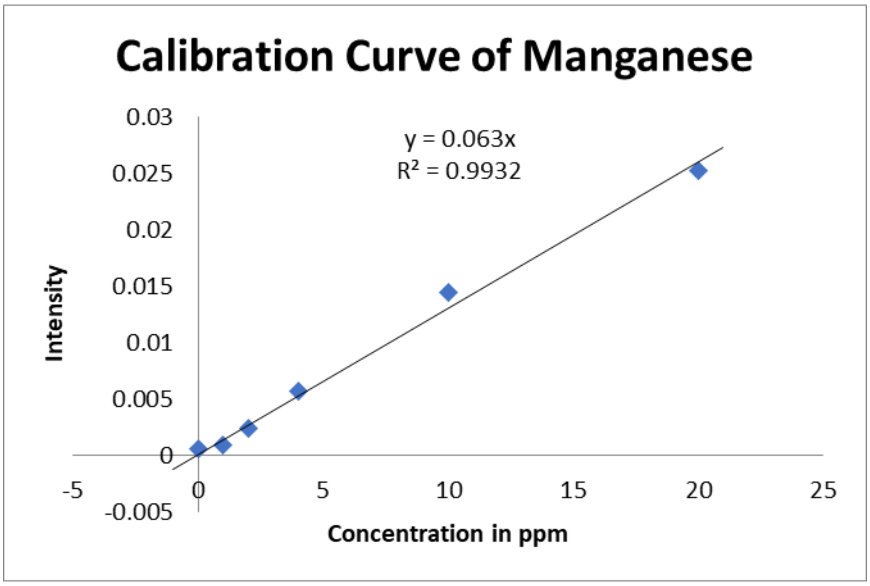



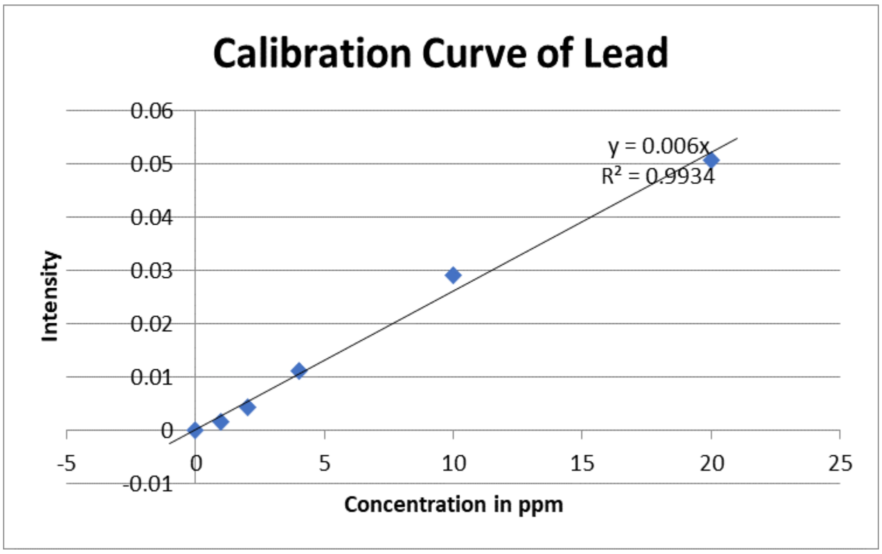

calibration curve of Calcium
y = 0.0013x + 0.0003
R² = 0.9924
0.03
0.025
0.02
0.015
0.01
0.005
0
0
5
10
15
20
25

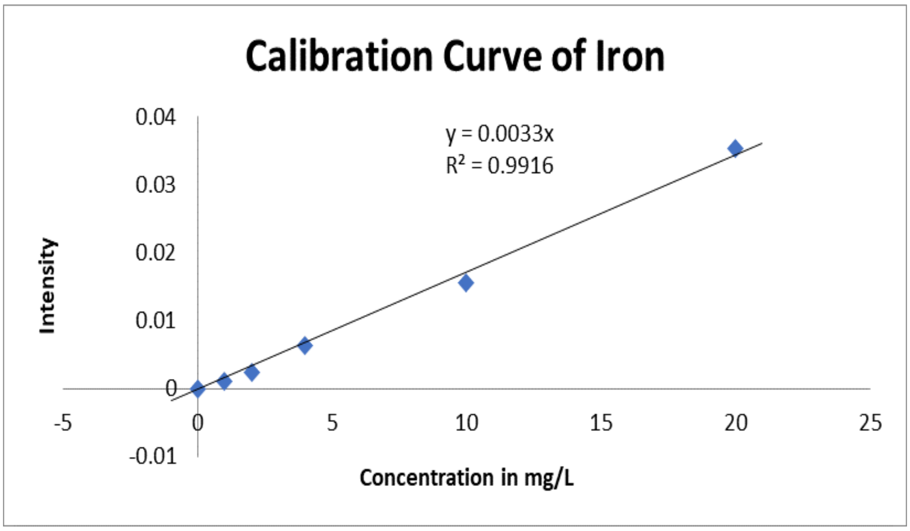

Calibration Curve of Magnesium
Intensity
y = 0.0037x
R² = 0.99
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-5
0
5
10
15
20
25
Concentration in ppm

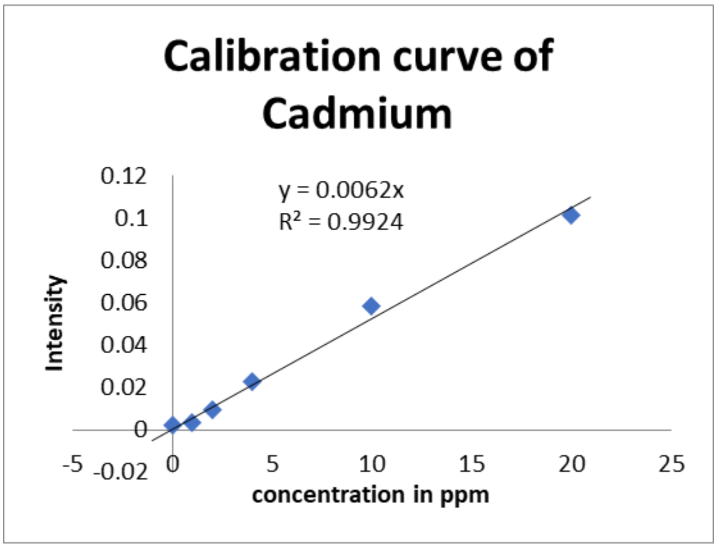

Calibration Curve of Copper
Intensity
y = 0.003x
R² = 0.9916
0.04
0.03
0.02
0.01
0
-0.01
-5
0
5
10
15
20
25
Concentration in ppmL


Calibration Curve of Zinc
y = 0.0101x + 0.0012
R² = 0.997
intensity
Concentration in ppm
0.15
0.1
0.05
0
-0.05
-2
0
2
4
6
8
10
12
Series1
Linear (Series1)
Linear (Series1)


Calibration Curve of Manganese
y = 0.063x
R² = 0.9932
Intensity
Concentration in ppm
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
-5
0
5
10
15
20
25


Calibration Curve of Lead
y = 0.006x
R² = 0.9934
Intensity
Concentration in ppm
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-5
0
5
10
15
20
25


Calibration Curve of Iron
y = 0.0033x
R² = 0.9916
Intensity
0.04
0.03
0.02
0.01
0
-0.01
-5
0
5
10
15
20
25
Concentration in mg/L


Calibration curve of Cadmium
y = 0.0062x
R² = 0.9924
Intensity
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-5
0
5
10
15
20
25
concentration in ppm

## Appendix VI: Photos

| APPENDICES 6<br>PHOTOS -ENC 331/0382/2019 |
|---|

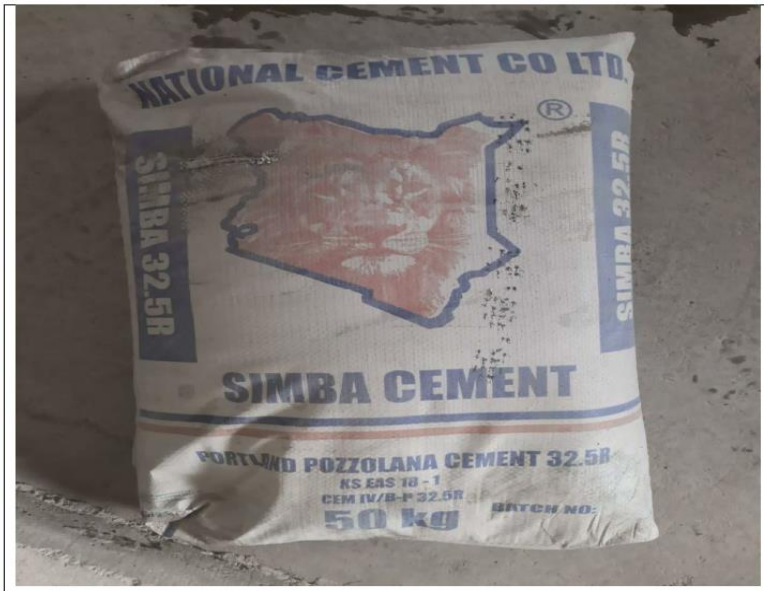



Fig 01: Simba cement- one of the kenyan blended cement


Fig 02: -Blended cement- Nyumba

## APPENDICES 6
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Fig 03: -Rai cement- one of the kenyan Blended cement


Fig 04: Tembo cement from Bamburi

## APPENDICES 6
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Fig 5: - Checking the weight of the cubes in the lab


Fig 6: AAS Machine for testing elements in the extract

## APPENDICES 6
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Fig 7: - Compression test machine at Olkaria Laboratory


Fig 8: - One of the cube test results

## APPENDICES 6
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Fig 9: - Workability test-slump test for wet concrete

Fig 10: -Concrete cubes casted

## APPENDICES 6
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Fig 11: - Curing process of the Concrete cubes ongoing

Fig 12: - Motor beams prism for flexural and compressive strength

**APPENDICES 6**
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Fig- 13-Sulphate soundness check