**PERFORMANCE ANALYSIS OF CASSAVA PEEL ASH IN MITIGATING THE OCCURRENCE OF ALKALI- SILICA REACTION IN CONCRETE**

**BY**

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**[20PGBC000137]**

**BEING A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF ENGINEERING DEGREE [M.ENG] IN CIVIL ENGINEERING.**

**TO THE**

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**COLLEGE OF ENGINEERING, LANDMARK UNIVERSITY, OMU-ARAN, KWARA STATE, NIGERIA**

**JULY, 2022.**

# DECLARATION

I, (Joseph Adeniyi AJAYI), a (Master's Degree) student in the **Department of Civil Engineering,** Landmark University, Omu-Aran, hereby declare that this thesis, titled "**Performance analysis of Cassava Peel Ash in mitigating the occurrence of Alkali Silica reaction in Concrete**," is premised on my original work. Any and all materials taken from other sources, as well as all work done by other people or institutions, have been properly acknowledged.

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Signature & Date

# CERTIFICATION

This is to confirm that this thesis has been examined and accepted as meeting the standards of Landmark University's Department of Civil Engineering in Omu-Aran, Nigeria, for the award of a Master degree in Civil Engineering).

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**DEDICATION**

This project is dedicated to God and my Parents. I also wish to dedicate it to the loving memory of my late brother (Oluwatomisin Ajayi).

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I thank Almighty God, The Most Beneficent, The Most Merciful, for guiding me through this endeavor, my academic difficulties, and my entire life. May his name alone be revered, I say. Amen.

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# ABSTRACT

Concrete is a composite material created by humans that has mechanical properties similar to naturally occurring limestone pebbles. Researchers have become interested in the sustainability of concrete as a result of the increasing harm being done to the environment. As a result, they are looking for partial substitutes for Portland cement in concrete to lessen the alkali-silica reaction. In this investigation, the potential use of cassava peel ash (CPA) to stop ASR in concrete structures is explored. Cassava peels were gathered as waste, sun-dried, and then heated to 850°C in an electric furnace for 90 minutes. Using a mix ratio of 1:1:2 and replacement rates for CPA in the cement of 0, 5, 10, 15, 20, and 30% by weight, concrete samples having water-cement ratios of 0.65 and 0.7 were created. For the test, four distinct set sizes of samples—100 x 150 mm cylindrical sample, 150 x 150 x 150 mm cubic sample, 30 x 30 x 150 mm, and 100 x 100 x 1000 mm—were made and cured in water. X-ray fluorescence (XRF) spectroscopy was used to analyze the elemental makeup of CPA. Workability, compressive strength, split tensile, thermal conductivity, water and acid solubility, and electrical resistivity tests were carried out on accelerated mortar bars at 7, 14, 21, and 28 days. The results demonstrated that using cassava peel ash as a cement substitute in concrete at acceptable concentrations reduced the development of ASR (5, 10, and 15 percent). Because CPA had the greatest effect on alkali-silica reactivity, it can be used to manage alkali-silica reactions in concrete by substituting it for 10% of the cement.

# ABBREVIATION

AASHTO Association of America State of Highway and Transportation Officials

ASTM American Standard of Testing Material

BS British Standard

CPA Cassava Peel Ash

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# CHAPTER ONE

# 1.0 INTRODUCTION

## 1.1 Background of the study

Concrete is a composite manmade material that possesses similar mechanical properties to the naturally derived lime stone rocks. Its major ingredients are fine aggregate, coarse aggregate, water, and cement; and it also developed the required mechanical strength through cement hydration reaction (Shafigh *et al.,* 2014). Concrete’s utilization in the infrastructural development sector is on the increase, especially in developing countries which causes a relative increase in its demand and also results in more consumption of the ingredients. For concrete structures to satisfy their design life, their durability should be optimal and cost implications minimal. The incorporation of waste materials in concrete production helps to solve satisfactorily environmental and waste management challenges (Chimmaobi *et al.*, (2020). This becomes essential because, during the process of production of cement which is an essential ingredient in concrete, a large quantity of CO2 emissions occurs as a result of the fuel combustion and industrial processes which are major drivers of global warming. To tackle these challenges, the use of supplementary cementitious materials to substitute cement use reduces the total construction cost and also achieves environment efficient, environment friendly, and sustainable development in terms of infrastructure (Lothenbach *et al.,* 2011; Onyelowe*,* 2019).

The durability of concrete structures is however impeded by a reaction known as Alkali-Silica Reaction (Santos *et al.,* 2020; Adanikin *et al.,* 2019;Chatterji, 2005**)**.The acidic silanol (Si-OH) groups of the weakly crystalline hydrous silica react with the surrounding hydroxyl ions in the strong alkaline solution in an acid-base reaction. Thomas (2011) claims that some of the siloxane connections (SiO-SI) are also attacked as the reaction progresses and hydroxyl ions progressively penetrate the silicate structure.

Cassava peel is a refuse of the processing of cassava, and these materials are produced on either a home (household) or industrial scale. Particularly when manually peeling, the cassava peel makes up between 20 and 35 percent of the weight of the tuber (Olanbiwoninu & Odunfa 2012). To thermally degrade this agricultural waste into ash with pozzolanic properties, it is heated using a control incinerating system (Salau *et al.,* 2012). The cementitious substances calcium silicates hydrates, calcium sulfo-aluminate hydrates, and calcium aluminate hydrates are thought to be produced when calcium hydroxide and finely split silica and alumina react in the presence of water (Thomas, 2013). Pozzolanic materials have been utilized as building construction ingredients for almost as long as there have been civilizations. They are utilized to improve the properties of lime, and many of these constructions are still standing today as proof of the longevity of pozzolanic-lime concrete mixtures (Ololade & Mohammed, 2019).

## 1.2 Statement of the Problem

Recycling agricultural waste is a huge issue for municipalities all over the world, including Nigeria, where the agricultural waste management is a major difficulty and poses a serious threat to humanity's health (Ezechi *et al,* 2017; Ferronato and Torretta, 2019). The role of Cassava Peel Ash (CPA) during the accelerated ASR performance test is one area where there is a knowledge gap (Rajabipour *et al.,* 2015) and not much has been done. However, this study will examine the effectiveness of agricultural waste (specifically cassava peels) in reducing the impacts of Alkaline Silica Reactions (ASR) in Nigerian concrete structures. Additionally, the study will address the environmental issue brought on by the trash's careless disposal.

## 1.3 Aim and Objectives of the research

The thesis investigates the applicability of cassava peel ash (CPA) as a pozzolan to reduce ASR in concrete. The following precise objectives were established to fulfill this purpose:

1. to estimate composition of cassava peel ash
2. examine how cassava peel ash (CPA) affects the chemical and mechanical characteristics of the final concrete
3. to identify the thermal characteristics of the final concrete
4. to ascertain how Cassava Peel Ash (CPA) affects the ASR of the resulting concrete.

## 1.4 Justification of Research

Cassava peel (CP) is a leftover from the processing of cassava that can be used in both domestic and commercial settings. Adesanya, *et al.,* (2008) claim that when cassava is manually peeled, it might make up 20–35 percent of the weight of the tuber. Approximately 6.8 million tonnes of cassava peel are produced annually, with 12 million tonnes expected to be produced by 2020, according to a 20 percent estimate. Due to blatant underuse and a lack of machinery to recycle them, cassava peels are tossed carelessly, creating a significant problem and a tragedy for the environment. Therefore, finding fresh approaches to reuse them is necessary. Salau and Olonade (2011) examined the pozzolanic potential of CPA and discovered that it showed pozzolanic reactivity following calcination at 7000C for 90 minutes and came to the conclusion that CPA contained more than 70% combined silica, alumina, and ferric oxide at these conditions.

## 1.5 Scope of Study

The study scope consists of three independent examinations, each of which is self-contained in and of itself, but which are intimately intertwined, one complementing the other while providing useful information. These are: (a) determining the chemical properties of cassava peel ash and evaluating the mechanical properties of concrete comprising various percentages of cassava peel ash and cement; (b) assessment of the cassava peel ash's ability to reduce ASR in concrete (c) determining the optimal CPA replacement percentage that will have the most beneficial effect on the concrete using the Electrical Resistivity approach.

## 1.6 Expected Contribution of Research to Knowledge

The CPA has been demonstrated to be pozzolanic in previous research and has been recommended for use in concrete as Supplemental Cementitious Materials (SCM) / natural pozzolan to control ASR. However, it is unknown how CPA reduces ASR (i.e., what mechanisms are involved) and which features of cassava peel ash (CPA) are most important in determining its effectiveness against ASR. To prevent ASR in concrete, more efficient and less expensive SCMs must be developed. According to previous studies on CPA, the chemical composition of CPA should be capable of decreasing ASR. This research will therefore explain the mechanism and optimal percentage replacement required for the use of CPA in reducing ASR in concrete. This study will also be valuable in solving environmental problems associated with cassava peel indiscriminate dumping.

# 

# CHAPTER TWO

# 2.0 LITERATURE REVIEW

## 2.1. Cement

A cementing substance possesses the cohesive and adhesive properties necessary to assemble inert particles into a solid mass with enough tensile and compressive strength. Cement is a key component of concrete that is used all over the world. Although various types of cement are available for specialized applications, the term "cement" normally refers to ordinary Portland Cement (OPC). Various forms of cement have been employed in the construction business in recent years. The selection of correct cement is important based on the requirements of the project site and the grade of concrete. This decision is based on both physical and chemical cement analyses. Cement is primarily made by grinding clinker with gypsum to the proper consistency. Only when cement is combined with water does it gain sticky properties. After blending, cement and water undergo a process known as cement hydration in which chemical reactions take place. The main reason why cement gets stronger is because the silicates in the cement hydrate (Joel & Mpadun, 2016). According to research, temperature has an impact on how quickly concrete strengthens (Soutsos et al., 2018).

### 2.1.1 Types of cement

Around the world, Kalpana and Sudharson (2021) submitted that Portland Cement is the most widely used type of cement as a key component of concrete. Gana *et al*., (2020). Here is a list of the numerous cement varieties that are employed in construction projects.

1. Rapid Hardening Cement is a speedily hardening variety of Portland cement (OPC). The C3S content is greater, and the grinding is finer. As a result, compared to OPC, it promotes early strength development. The strength of this cement over 3 days is virtually comparable to that of OPC after seven days at almost the same water-cement ratio, according to Vengadesh & Soundarya's (2019) research.
2. Low Heat Cement: It is created by increasing the concentration of C2S and decreasing the amounts of C3S and C3A, Jadhav (2021). This cement has a lower reactivity, and it takes longer to build up than OPC. This cement is primarily utilized in the construction of mass concrete structures.
3. Sulphate Resisting Cement: It's manufactured by lowering the content of C3A and C4AF in cement. Cement with this composition is very resistant to sulphate attack. AlSadig and Khalifa (2017). This cement is used to build foundations on soils with significant subsurface sulphate concentrations.

### 2.1.2 Cement in Nigeria

Concrete is the most commonly utilized building material, obute *et al.,* (2021). Nigeria's problem is not unique, as much of the country's infrastructure, such as buildings, bridges, and concrete highways, is made of concrete. In Nigeria, buildings and other concrete constructions frequently fail. The quality of the concrete used for building determines the safety, strength, and structural integrity of the structure.

### 2.1.3 Constituents of cement

Gaharwar *et al.,* (2016) claim that the following components are crushed, ground, and proportioned to create Portland cement:

* 1. Lime
  2. Silica (SiO2).
  3. Alumina, Al2O3
  4. Iron, Fe2O3
  5. Gypsum, CaSO4.2H20: found together with limestone

### 2.1.4 Chemical composition of cement

Silica, lime, alumina, and iron oxide are the primary raw ingredients used in the manufacture of Portland cement (Gaharwar *et al.,* 2016). Within the kiln, a sequence of reactions occurs between each of these raw ingredients, resulting in compounds that are significantly more complicated than the parent components, eventually reaching a state of chemical equilibrium (Gaharwar *et al.,* 2016). The characteristics of cement are affected by the proportions of various oxides.

### Functions of the compounds present in Cement

1. **Tricalcium Silicate**

Due to a higher percentage of this chemical releasing a huge quantity of heat as a result of hydration, it accounts for a faster improvement in strength (Gaharwar *et al.,* 2016). A higher percentage of this compound causes Portland cement's early strength to be stronger. This substance immediately becomes hard and has a significant role in initial setting and early strength.

1. **Dicalcium Silicate**

The process of hardening is slowed. The strength of concrete rises with concrete's age.

1. **Tricalcium Aluminate**

Because it is the first chemical to hydrate, it contributes significantly to the development of concrete strength in the first few days. Contributes to faster growth in strength by allowing the body to expel more heat as a result of hydration. Due to its weak sulfate resistance, it will reduce in bulk when dried.

1. **Tetracalcium Aluminoferrite**

It assists “in the manufacturing of Portland cement” (Sabbie *et al.,* 2019) in the first place. Although it hydrates quickly, it does not contribute to significant levels of strength. Is to responsible for Ordinary Portland Cement's greyish colour. It acts as a filler.

Calcium silicates (3CaO.SiO2 and 2CaO.SiO2) account for at least two-thirds of the mass of Portland cement (Ige, 2013).

### 2.1.6 Setting and Hardening of cement

The mixture of cement and water produces a stiff but sticky paste that, depending on its properties, remains plastic for a certain period (Raheem & Bamigboye, 2013). The plastic nature or plasticity of the cement paste gradually deteriorates over time, causing it to stiffen due to hydration. The setting of cement is a gradual yet fascinating occurrence.

### Testing of cement

Laboratory testing and field testing are the two categories into which cement testing may be separated.

1. **Field testing**

Putting cement through a variety of field testing is a crucial step in ensuring its validity (Aryal, 2019). More frequently than not, field testing is done on cement samples that will be utilized for small-scale projects. The following tests should be carried out when in the field:

1. Visually inspect and evaluate the cement by opening the bag. There should be no lumps evident. The cement should be a greenish-gray colour.
2. Place your hand into the bag of cement. The cement should feel cold to the touch and be free of lumps.
3. Feel the cement between your fingers or in your palm with a pinch or a hand full of it. The cement should be smooth, not gritty or harsh to the touch.
4. **Laboratory testing**

Cement that will be utilized for medium and large-scale projects undergoes laboratory testing. An endless number of factors can compromise the integrity of cement used in a building. Improper storage, poor manner or mode of transportation, and so forth are some of them. A series of laboratory tests can be run to evaluate which cement is suitable for construction (Aryal, 2019).

## 2.2 Concrete

The construction industry is vital to a country's economic and social development, and it is regarded as the backbone of the economy (Sohu *et al.,* 2018). Because it is accessible and long-lasting, concrete has become more popular. Residential homes, skyscrapers, bridges, pavements, and dams are just a few of the buildings made with concrete. But by the early 1800s, it had been demonstrated that concrete exhibited a remarkable strength in compression but a weakness in tension, depriving it of tensile strength, ductility, and crack resistance (Agarwal *et al.,* 2014; Behbahani *et al.,* 2012). When a component fails, it may lose nearly all of its loading capacity, reducing its usability and application. Steel bars were used to strengthen concrete and increase its tensile strength in order to address this weakness. Tensile strength and crack resistance are improved with steel reinforcing bars, but at a price. Because it contains coarse particles, concrete, which is made of cement, sand, coarse aggregates, and water, gives a building its own weight. It has an advantage over other materials because of its growing compressive strength and low cost. Concrete is utilized in the construction of load-bearing elements of buildings, such as staircases, Gana *et al.,* (2020)

### 2.2.1 Water-cement ratio

Although adding water improves workability, it also diminishes the strength of the concrete and raises the risk of segregation during compaction.

### 2.2.2 Grades of Concrete

Ordinary concrete and regulated concrete are the two primary classes or classifications of concrete (Rehan *et al.,* 2016). Ordinary concretes are ones that haven't had any initial testing done to them.

The mix ratios of different grades of concrete mix are all different. These proportions describe how the components (sand, gravel, cement, and water) are blended and are as shown in Tables 2.1.

**Table 2. 1:** **Proportions of different ingredients in a concrete mix**

|  |  |  |  |
| --- | --- | --- | --- |
| **S/No.** | **Grade** | **Concrete Mix** | **Uses** |
| 1 | M10 | 1:3:6 | Piers, abutments, and large reinforced concrete members are all made of mass concrete. |
| 2 | M15 | 1:2:4 | Slabs, columns, beams, walls, and narrow span arches are typical R.C.C. works. |
| 3 | M20 | 1:11/2:3 | Reservoirs, columns, and piles are examples of water-retaining structures. |
| 4 | M25 | 1:1:2 | Arches with long spans and heavily weighted columns. |
| 5 | M30 | Design mix | Foundations made of mass concrete. |
| 6 | M35 | Design mix | Pre-stressed concrete that has been post-tensioned. |
| 7 | M40 | Design mix | Pre-tensioned pre-stressed concrete. |

Source: Khurmi & Gupta, 2008

### 2.2.3 Batching of concrete

Batching is the act of weighing out and mixing the necessary concrete components by volume or weight in accordance with the mix design to produce a homogeneous concrete quality (Opeyemi, *et al*., 2018). To ensure consistency of proportions in subsequent batches, a careful and exact measurement of all materials used in concrete production is required. Until the concrete has a consistent appearance and all of the components are distributed evenly, all of the components should be gently mixed. In addition to being operated at the manufacturer's advised mixing speed, mixers should not be filled above their rated capacities. The additional production should be accomplished with a larger mixer or more mixers rather than speeding up or overloading the current machinery. A mixer's ability to mix will be less effective if its blades become dull or coated in hardened concrete. We should deal with these problems. The density, air content, slump, and coarse-aggregate content of concrete samples taken from different batches should be almost same if the concrete has been correctly mixed. ASTM C 94 specifies the maximum permissible variations for evaluating mixing homogeneity within a batch of ready-mixed concrete (AASHTO M 157).

### 2.2.4 Strength of concrete

The major shortcoming of concrete, which every engineer is aware of, is that, despite its high compressive strength, it is very weak in tension. Because of this lack of tensile strength, reinforcing is required to carry any tensile force present in the structure. Typically, only the behaviour of the material under uniaxial stress is investigated, while the uncertainty introduced into the analysis by the assumption allows it to be examined under different stress circumstances. The rate of increasing strength in concrete is rapid in its early life but slows as it ages, but some concrete continues to grow stronger for many years. For design reasons, the concrete strength at 28 days is usually used, which is around 80% of the strength after one year. Any strength obtained after 28 days can be regarded as an additional contribution to the factor of safety.

### 2.2.5 Factors affecting the compressive strength of concrete

Variations in concrete design strength can be attributable to a variety of factors. Natural (intrinsic) and/or production-related factors may have an impact on design strength (Ebenezer, 2019). These factors include natural influences include basic material qualities, mixed proportions, and age, Compaction, the external environment, curing, and placement are all elements that affect production.

## 2.3 Pozzolans: Meaning, Origin and Classifications

Pozzolans alone don't have much, if any, cementitious value. However, when combined with finely split alkalis and moisture, they will chemically react to produce cementing chemicals.

## 2.4 Mechanism of Pozzolanic Activity

The silica content of pozzolans can range from 22 to 42 percent and from 55 to 22 percent, depending on where they were formed. As a result, the ratio Ca/Si and the quantity of water molecules can change, and the stoichiometry may not be accurate (Chatterji, 2005).

## 2.5 Cassava Production in Nigeria and Uses of Cassava Peels

The South American plant known as cassava is also known as Manihot esculenta, manioc, yucca, and tapioca. A common preparation and high-carbohydrate dietary item is tubers (parts of the root system). It serves as a staple food in numerous impoverished nations throughout the world, including South and Central America, India, and Southeast Asia. Wherever there is uncertain rainfall, cassava can be grown (Food Safety Network, 2005).

South American plants produce cassava. Nigeria produces more cassava than any other country in the world, nearly doubling that of Indonesia and Thailand and accounting for a third of Brazil's production. Other African countries like the Democratic Republic of the Congo, Ghana, Madagascar, Mozambique, Tanzania, and Uganda appear to produce less cassava than Nigeria, which has a sizable output. Sanni *et al.,* (2005) state that the Food and Agriculture Organization of the United Nations (FAO) in Rome calculated that Nigeria produced over 34 million tonnes of cassava in 2002.

In 2002, the Projects Coordinating Unit (PCU) estimated production at 28 million tonnes, which was the most conservative projection. PCU data gathers state-level data from each state's Agricultural Development Program (ADP) offices. The most abundant crop produced in Nigeria is cassava, which is followed by yams (27 million tonnes in 2002), sorghum (7 million tonnes), millet (6 million tonnes), and rice (5 million tonnes). Figure 2.1 shows that practically all of the states in the Federation—aside from those in the northeast—grow cassava.

Currently, annual production is estimated to be 51 million metric tons (Aro *et al.,* 2010). However, according to the International Institute of Tropical Agriculture (IITA, 2004), production will reach 60 million tonnes by 2020.

## 2.6 Cassava Peel and Cassava Peel Ash (CPA)

A by-product of the processing of cassava, cassava peel is used for both domestic and commercial applications. Between 10 and 13 percent of cassava tubers are thought to contain peels, according to Calvosa and Amorriggi's (2009) estimate. From 5% to 15% of the root might be made up of cassava peels (Aro *et al.,* 2010; Olanbiwoninu and Odunfa 2012). The tubers are bought after being mechanically peeled and washed (Aro *et al.,* 2010). According to Tewe (2004) and Adesanya *et al.* (2008), cassava peels make up 20–35 percent of the weight of the tuber, especially when hand peeling is utilized, which is the most popular method in Nigeria. They also contain more cyanogenic glycosides and protein than other tuber sections. Cassava peel production is estimated at over 13 million tonnes per year, with 15 million tonnes anticipated by 2020. Less than 40% of this is used again as ethanol production, animal feed, and other purposes; the remainder is dumped in landfills and burned. There must be recycling because this is such a large amount.

Cassava peels have a dry matter content of 27.9%, a crude protein content of 5.3 percent, and an ether extract content of 1.2 percent. It has a high crude fibre content (20.97%) and ash content (5.93 percent). It has a nitrogen-free extract content of 66.6 percent. It does, however, contain more hydrogen cyanide (HCN) than the pulp (Adesanya *et al.,* 2008). Cassava peel is used as a feed for ruminant animals, pigs, and rabbits, as well as a livestock feed alternative (Iyayi and Tewe, 2009). One disadvantage of utilizing cassava peel only as animal feed is its low protein content, which necessitates supplementing the pellets with other protein sources to suit the nutritional needs of the animals. Another stumbling block is cassava's high cyanogenic glycoside content. Cassava peel is also difficult to digest for all animal species (Calvosa and Amorriggi, 2009).

Cassava peels are also used as a carbon source for Aspergillus niveus to produce Amylolytic enzymes, and efforts have been made to utilise them in the production of ethanol and microbial protein enrichment (Adesanya *et al.,* 2008). However, due to a lack of technology needed to process cassava peels in these numerous ways, as well as the other factors mentioned above, cassava peels are woefully underutilized. As a result, mounds of cassava peel end up in landfills near cassava processing plants. An example of a cassava peel waste site is shown below.

Table 2.2 shows the Production of Cassava and its Peels by Geo-Political Zones in Nigeria in 2002 while the Figure 2.1shows Cassava Production in Nigeria.

Table 2. 2: Production of Cassava and its Peels by Geo-Political Zones in Nigeria in 2002

|  |  |  |  |
| --- | --- | --- | --- |
| **S/N** | **Region** | **a Quantity of Cassava Tubers Produced (Tonnes)** | **b Quantity of Cassava Peels Produced (Tonnes)** |
| 1 | South West | 5 883 805 | 1 470 951 |
| 2 | South South | 6 321 674 | 1 580 419 |
| 3 | South West | 5 846 310 | 1 461 578 |
| 4 | North West | 2 340 000 | 585 000 |
| 5 | North Central | 7 405 640 | 1 851 410 |
| 6 | North East | 140 620 | 35 155 |
| **Total** |  | **27 938 049** | **6 984 512** |

a = (PCU 2003)

b = Cassava peels are 25% by weight of Cassava tubers (Adesanya et. Al, 2008).

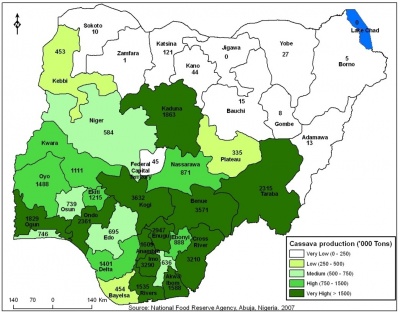


Figure 2. 1: Cassava Production in Nigeria

Source: National Food Research Agency, Abuja, Nigeria. 2007

### 2.8. Review of Literature on SCMs

Some examples of Natural pozzolans that utilized in Portland cement concrete are rice husk ash (RHA), cow bone ash (CBA), cassava peel ash (CPA), sugarcane bagasse ash (SBA), bamboo leaf ash (BLA), and sawdust. The research findings on supplemental cementitious materials (SCMs) utilized in cement concrete are summarized in the following paragraphs.

Falade, *et al.,* (2012) showed that bones that are pulverized have some pozzolanic properties. The

Through his examination, the researcher proved that crushed bones are pozzolanic. The study found that as long as the replacement level doesn't go above 20%, they are perfect for use as a partial replacement for cement in concrete without sacrificing strength.

An experimental examination on the usage of Bamboo Leaf Ash (BLA) as a cement substitute in concrete was conducted by Umoh and Ujene (2014). According to the study, the inclusion of BLA reduced voids and decreased permeability in the concrete. The compressive strength of the concrete was decreased by the addition of BLA, while the tensile splitting strength of BLA mixed cement concrete cubes increased with curing time but decreased as BLA percentage increased.

Abdulfatai and Lawal (2014) worked on “Partial replacement of cement with rice husk ash (RHA) as filler in asphalt concrete design”. Through experimental tests, the researcher was able to prove that the Rice husk ash used in the study is pozzolanic and of class C, with a total concentration of silica, aluminum, and iron oxides of 69.96 percent. According to the Marshall Stability test, a replacement rate of 10% is ideal. The Asphalt Institute's standards were met by this.

According to Arabani *et al.,* (2016), rice husk ash (RHA), a waste byproduct of rice milling, has significant advantages when used in bituminous highways and pavement, including lowering construction costs and conserving natural resources. There isn’t many research on the usage of this component in asphalt mixtures, though.

Olutoge and Oladunmoye (2017) studied “Bamboo Leaf Ash (BLA) as Supplementary Cementitious Material”. The study demonstrated that BLA had pozzolanic qualities and showed that using BLA as a substitute material for OPC at a percentage of 10–20% enhanced the concrete's workability. However, the researcher observed an increase in the concrete's setting time as the amount of BLA used increased. According to the researcher, BLA might be used to reduce the price of concrete and alleviate environmental concerns that could result from the improper disposal of bamboo leaves.

Okeyinka *et al.,* (2018) investigation on the "durability performance of cow bone ash blended cement (CBABC) concrete in a hostile environment." The researcher comes to the conclusion that CBABC, or cow bone ash blended cement, has the most capability for usage in hostile conditions, particularly those that are subject to hydrochloric acid. CBABC has a 10 percent replacement of cow bone ash content. The findings of this study imply that in regions where hydrochloric acid (HCl) is available, the novel 10 percent CBABC concrete mix could be employed as a long-lasting substitute for conventional Grade C25 Concrete mixes.

Ikumapayi and Arum (2019) demonstrated that adding sugarcane bagasse ash to substitute some of the conventional Portland cement produced concrete with better compressive strength and little changes to shrinkage after curing. A 12% mix substitution of sugarcane bagasse ash for ordinary Portland cement was reported to be ideal.

According to Ashraf and Doh (2020), the mixtures with the highest compressive strengths were those containing 5 percent egg shell ponder and 30 percent or 40 percent fly ash, respectively. The study's findings suggest that using green elements in place of cement can produce concrete with great strength while using up to 45 percent less cement overall.

Mohiey *et al* (2020) have produced a report on "The Performance of Hot Asphalt Mixes and the Effect of Rice Husk Ash." The researchers came to the conclusion that adding RHA decreased the amount of rutting that was created in the asphaltic concrete, with a 50% RHA replacement being deemed the best because it developed the highest Marshall Test value. The results showed that RHA addiction improved the dynamic modulus and flow values.

Balogun and Otunola, (2021) worked on using yam peel ash to replace traditional cement in concrete and came to the conclusion that the best compressive strength of the blended concrete was witnessed for a mix ratio of 1:3:6 at 5% yam peel ash (YPA) replacement while the best flexural strength discovered was at a mix ratio of 1:2:4. The outcome also showed that the density of the test specimens of the blended concrete did not significantly change as the percentage of YPA substitution of cement increased.

## 2.9 Summary of Existing Literature

Due to the (Atoyebi *et al.,* 2020) increasing destruction of the present and future environment, academics and engineers have grown interested in concrete sustainability. Various studies have recently been undertaken to improve concrete in order to make it safer and more capable of performing more particular tasks Atoyebi *et al.,* (2020). Cassava peel ash is pozzolanic, and the longevity of concrete structures is always impaired by a reaction known as alkaline silica reaction, according to a study (Santos, *et at.,* 2020; Adanikin *et al*, 2019; Chatterji, 2005). To reduce the likelihood of alkaline silica reactions in concrete, many supplementary cementitious materials have been utilized, including rice husk ash, wood ash, sugar cane bagasse ash, cow bone ash, sawdust ash, egg shell ash, and others. It has also been suggested to use cassava peel ash as SCM in concrete. Foroughi *et al.,* (2012) proposed that replacing a proportion of Portland cement with natural pozzolan in concretes should be explored in minimizing expansion potentials and therefore addressing the occurrence of alkaline silica reactions. More research is needed on ways to avoid Alkaline Silica reactions in concrete utilizing cassava peel ash, as well as the thermal and mechanical qualities of the final concrete. As a result, the current researcher thinks it is crucial to look at how well using cassava peel ash in concrete works to lessen alkaline silica interactions.

# CHAPTER THREE

# 3.0 METHODOLOGY

## 3.1 Description of the study area

Research area is Omu-Aran in Kwara State, which is located in the country's North Central geopolitical zone.

## 3.2 Collection of Materials

Th peel used was sourced as waste from a local processing company in Omuaran, Kwara State, Nigeria, where a variety of conventional cassava food varieties are currently created for consumption (such as gari, fufu, starch, Abacha, and so on). The peels subsequently air dried before being burned at 750°C to ashes. As shown in Plates 3.1 to 3.5, the clinker was grinded and sieved in the lab using a sieve number 200 (0.075mm).

Plate 3. 1: cassava peels Plate 3. 2: Cassava peel ash

Plate 3. 3: Coarse aggregate Plate 3. 4: Bag of cement Plate 3. 5: Fine aggregate

Table 3. 1: Properties of Materials used

|  |  |
| --- | --- |
| **Material** | **Size (mm)** |
| Fine aggregate | <4.75 |
| Coarse aggregate | 5-20 |
| Cement | <0.075 |
| Cassava Peel Ash | <0.075 |
| Water cement ratio | 0.65 & 0.7 |

Table 3. 2: Properties of Dangote 3x 42.5R Portland cement

|  |  |  |
| --- | --- | --- |
| **S/N** | **Properties** | **Characteristic Value** |
| a. | Slump test | 40 mm |
| b. | Compressive Strength:   1. 7 days 2. 14 days 3. 21 days 4. 28 days | 16.89 N/mm2  18.14 N/mm2  21.78 N/mm2  22.06 N/mm2 |

**Source: Bamigboye *et al*. (2015).**

The typical chemical composition of Dangote 3X 42.5R Portland cement which makes it suitable for use in this study is displayed in Table 3.3.

Table 3. 3: Chemical Composition of Dangote 3x 42.5R Portland cement

|  |  |  |
| --- | --- | --- |
| **S/N** | **Chemical Composition** | **Characteristic Value (%)** |
| a. | K2O | - |
| b. | Na2O | - |
| c. | TiO2 | - |
| d. | P2O5 | - |
| e. | MnO | 1.0 |

**Source: Bamigboye *et al.,* (2015)**

## 3.3 Experimental Design

Table 3.4 below provides the study's experiment design.

**Table 3. 4**: Experimental Design (1:1:2 Mix Ratio)

**CODE CPA CEMENT FINE SAND GRAVEL REPLICATES**

**(%) (%)**

B0 0 100 1 2 3

B5 5 95 1 2 3

B10 10 90 1 2 3

B15 15 85 1 2 3

B20 20 80 1 2 3

B30 30 70 1 2 3

## 3.4 **Experimental Methods**

Water and other concrete ingredients were weighed out in accordance with the 1:1:2 mix ratio. The tests on the concrete control samples were then done. The concrete was then amended by simply substituting some of the cement with Cassava Peel Ash, ranging from 0% to 30% at a 5% interval (CPA). The amended concrete underwent workability (slump), water and acid solubility testing, split tensile tests, compressive strength - cube tests, and thermal property tests. Table 3.5 lists the numerous laboratory tests performed as well as the standards used in this investigation.

Table 3. 5: Laboratory Tests Conducted on materials used

|  |  |
| --- | --- |
| **Material/ Combination** | **Laboratory Test – Standard** |
| Materials used | * Sieve Analysis (Sand only) - BS 812 (1985) * Fineness test (Cement and CPA) * Initial and final setting time (Cement only) * Chemical Analysis (CPA and Cement) * Specific Gravity (Cement, CPA, sand, and coarse aggregate) * Moisture content test (fine aggregate only) * Silt content test (fine aggregate only) |
| Control Sample | * Workability (Slump test) * Water absorption test * Compressive Strength, cube tests (7th, 14th, 21st, and 28thdays) – BS 1881 (2016) * Thermal properties test, (28th days) - ASTM C78M (2018) * Electrical Resistivity - ASTM C1760 (2012) * Water and Acid Solubility - ASTM C1152 (2012) * Accelerated Mortar Bar Test (AMBT) - ASTM C1260 (2009) * Scanning Electron Microscopy (SEM) – ASTM C1723 (2016) |

**Table 3.5: Laboratory Tests Conducted on materials used Continues**

|  |  |
| --- | --- |
| Resulting concrete | * Workability (Slump test) * Compressive Strength, cube tests (7th, 14th, 21st, and 28th days) – BS 1881 (2016) * Thermal properties test, (28th days) - ASTM C78M (2018) * Electrical Resistivity - ASTM C1760 (2012) * Water and Acid Solubility - ASTM C1152 (2012) * Accelerated Mortar Bar Test (AMBT) - ASTM C1260 (2009) * Scanning Electron Microscopy (SEM) – ASTM C1723 (2016) |

## 3.5 Sample Production

The coarse aggregate was then introduced and mixed using manual method until a thoroughly dispersed mixture with the fine sand and cement in the mixing pan were obtained. Finding the weights of 5%, 10%, 15%, 20%, and 30% and combining them appropriately to produce concrete samples. A specific amount of water added to the item that had already been blended. In total, 180 samples with labels were created. Three samples were tested from each mix design after 7, 14, 21, and 28 days of curing. Cassava Peel Ash was not used in the control group (0%). (CPA). The water-cement ratio is 0.65, which was raised to 0.7 as the percentage of CPA increased, and the mix ratio is 1:1:2. For easy de-moulding, two sets of molds were lightly treated with used motor oil before the slurry was put into them. The initial mould was 150 x 150 x 150mm in size, and It was tested for split tensile strength and compressive strength. A second mould was used to create 18 samples, each measuring 100mm in diameter and 150mm in length, for the thermal conductivity test. With a steel trowel, the concrete was leveled to the top of the molds after the slurry had been compacted with a tamping rod until no air bubbles were visible on its surface.

## 3.6 Chemical Analysis

Chemical research reveals the principal chemical components found in cassava peel ash and cement, along with their percentage abundance. The chemical study demonstrates how the cassava peel ash's elemental composition can turn it into a pozzolana in the presence of water.

## 3.7 Determination of the effect of Cassava Peel Ash (CPA) on the Mechanical and Chemical Properties of the concrete

Samples put through the following tests.

### 3.7.1 Workability using Slump Test

Cleansing the molds inside surface is followed by four equal levels of fresh concrete being poured over a horizontal, non-absorbent surface while the mold is firmly kept in place. Each one is about a quarter of the mold's height. Each layer tampers 25 times with a tamping rod that evenly distributes the strokes across the mold's cross-section. The tamping rod penetrates the underlying layer for the second and succeeding layers. The excess concrete is brushed out above the concrete cone with a tampering rod or a trowel. The vertical height of the cone (h1) is measured, and the cone is removed vertically slowly, and cautiously. As soon as the cone is removed, the concrete starts to sink vertically. The height of the cone (h2) is measured by placing the steel scale horizontally above the top of the settled concrete. The value of slump is calculated as the difference between two heights (h1-h2).

### 3.7.2 Determination of water Absorption test

The samples were shook to eliminate excess water, and then immediately dried with a cloth until no free water was left on the surface. Following that, the specimens were reweighed, and Equation 3.4 was used to calculate the percent water absorption for each specimen.

Percentage water absorption =………………………3.4

### 3.7.3 Determination of bulk density

### The ASTM C29 / C29M - 07 standard was used as a reference when calculating the bulk density.

### 3.7.4 Split Tensile Strength

Three samples were tested in each category, and the average result was recorded. The split tension test was carried out utilizing a digital compression machine with a 2000kN capacity, as shown in Plates 3.6 and 3.7. We used the standard formula in equation 3.5 to get split tensile strength:

Split Tensile strength (MPa) = 2P / π DL …………………………… 3.5

Where, P = Load at failure (kN): D = Diameter of the Sample: L = Length of Sample.

 ****

Plate 3. 6: Cylindrical sample before failure. Plate 3. 7: Split Tensile Test of cylinder sample

### 3.7.5 Compressive Strength - Cube Test

Concrete's compressive strength gauges how well the substance can endure compressive loads (such as traffic). The compressive strength measurements are generally used to assess whether the concrete mixture delivered on-site complies with the task specifications stated in the project's planning. The compressive strength of 150mm concrete cubes was evaluated by applying a 3.0 KN/s compression force following BS 1881: Part 111. (1983). The concrete samples' weight (kg), density (kg/m3), and crushing load (KN) were determined, and the compressive strength (N/mm2) was calculated. Before evaluating the density of each concrete cube, the weight of each cube was determined. This was completed following BS 1881: Part 114: 1983.

Cubic test specimens with dimensions of 150mm x 150mm x 150mm are used. The test specimens were built so that the concrete was completely compressed after mixing, without segregation or undue laitance. Plates 3.8 and 3.9 show the compressive testing machine and the procedure.



Plate 3. 8: Universal Testing Machine (Digital Okhard 2000kN) Used for Testing Concrete Strength



Plate 3. 9: Crushing of Concrete Samples

### 3.7.6 Water and Acid Solubility Test

The test primarily aids in determining how chlorides present in aggregates and cement might be lowered, resulting in structural weakness and concrete's life expectancy being shortened. Additionally, it will assess the conductivity of a concrete sample to evaluate how impermeable the concrete is to chloride ions and how the inclusion of CPA inhibits chloride attacks on the concrete, hence reducing ASR (ASTM C1152). The samples' percentage solubility (the percentage of solute dissolved in the solvent) was calculated using the formula in equation 3.5.

The equipment utilized for the test, as well as the process for performing the water and acid solubility test, are shown in Plates 3.10 to 3.13.

|  |  |  |
| --- | --- | --- |
|  | |  |
| **Plate 3. 10: Dissolution of Concrete Samples in Acid** | | Plate 3. 11: Filtering of Samples |
|  |  | |
| **Plate 3. 12: Weighing of Samples** | Plate 3. 13: Weighing of Samples | |

## 3.8 Thermal Conductivity

The k-value, or thermal conductivity (W/m°C), is among the crucial properties to consider when determining whether a substance may be used as a thermal insulator. Using the guarded hot plate technique, the thermal conductivity of cylindrical block samples was assessed. This technique requires that the guarded hot-plate equipment be used in a steady-state setting (controlled environment).

The test was conducted on the 28th day of curing by vertically stacking the cylindrical block samples (see Plate 3.14), which resulted in a thin wall that could pass through the hot-plate chamber's entrance using the general equation shown in equation 3.6 provided by Fourier's law.

Qo = -kA ----------- 3.6

Qo = Rate of heat transfer

T1 = Temperature of the heating chamber

T2 = Temperature of the sample after 1 hour

K = Thermal conductivity (w/mk)

P = Power supplied to the heating chamber = (watts)

dx = Thickness of sample (m)

A = Cross sectional Area (m2) = 7.85 10-3m2

dT = T1 - T2

R = radius of the cylindrical specimen = 50mm



Plate 3. 14: Arrangement of sample into the guarded hot plate plugged with the stabilizer



Plate 3. 15: Guarded hot plate set up

### 3.8.1 Thermal diffusivity

The quantity of heat that moves over a unit area of a layer with a unit thickness and a unit temperature difference between its faces in a unit amount of time generates a change in temperature in the material's unit volume, which is measured by thermal diffusivity.

A = ……………………… 3.7

### 3.8.2 Specific Heat Capacity

Equation 3.8 was used to estimate the specific heat capacity

Q = mCpT 3.8

Q = Energy (J)

m = mass (kg)

T = Temperature difference

Qo = Rate of heat transfer

Because of this, the specific heat describes how much energy must be delivered to a unit mass in order to boost the temperature by a unit. Thus, it evaluates a material's capability for internal energy storage (thermal energy).

### 3.9 Accelerated Mortar Bar Test (ASTM C1260)

The experiment was conducted by creating three samples for each of the CPA replacement percentages. On the 7th, 14th, and 28th days, dial readings of the elongation were collected and compared to the permitted standards for concrete expansion. Plates 3.15 to 3.20 depict the AMBT test's equipment, experimental setup, and procedure.



Plate 3. 16: Batching of materials for AMBT test at varying % of CPA Addition



Plate 3. 17: Measurement of the Length of Concrete Samples for AMBT

|  |  |  |  |
| --- | --- | --- | --- |
| C:\Users\user\Desktop\20190119_110400.jpg | |  | |
| Plate 3. 18: Weighing of Concrete Samples Before Immersion in 100g of NaOH | | Plate 3. 19: Immersion of Concrete Cubes in 100g of NaOH | |
|  |  | |
| **Plate 3. 20: Samples in Oven at 800C for days** | Plate 3. 21: oven used for the experiment | |

## 3.10 Electrical Resistivity

Concrete's long-term durability can be affected by how quickly pore structures form in it. Additionally, the tensile strength of cementitious materials is weak during a young age, and the substance is vulnerable to cracking. As a result of this initial breach, dangerous substances can enter the matrix. This cracking can be identified using resistivity tests, which helps determine how long concrete will last. Additionally, the concrete's moisture content and the connection of its micropores can be assessed using electrical resistance. This test will employ the Vertical Electrical Sounding (VES) technique and an electrical resistivity meter.

The equipment, experimental setup, and process for the electrical resistivity test are shown in Plates 3.21 to 3.23.



Plate 3. 22: Cast Concrete with electrodes



Plate 3. 23: Experimental setup for electrical resistivity



Plate-3. 24: Experimental setup for Electrical Resistivity

## 3.11 Scanning Electron Microscopy – Secondary Electrons (SEM-SE) Analysis

The SEM-SE is used to identify and image submicroscopic characteristics, as well as to determine the causes of concrete failure that could be attributed to ASR. SEM-SE examination is also utilized to identify unknown materials/deposits, evaluate corrosion products, and examine surface contamination and staining. The test method is shown in Figure 3.1.

**Figure 3. 1: Procedure for Scanning Electron Microscopy (SEM) analysis of concrete samples**

**Table 3. 6**: **Mix Proportion of Constituent Materials for Each Sample (Compressive Cube Test)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Constituent Materials** | | | | | |
| **Mix ID** | **Water**  **(Kg)** | **Cement**  **(Kg)** | **CPA**  **(Kg)** | **Sand**  **(kg)** | **Coarse Aggregate (Kg)** |
| B0 | 10.80 | 18 | 0 | 18 | 36 |
| B5 | 10.80 | 17.10 | 0.9 | 18 | 36 |
| B10 | 10.80 | 16.20 | 1.8 | 18 | 36 |
| B15 | 10.80 | 15.30 | 2.7 | 18 | 36 |
| B20 | 13.30 | 14.40 | 3.6 | 18 | 36 |
| B30 | 13.30 | 12.60 | 5.4 | 18 | 36 |
| **Total** | **69.80** | **93.60** | **14.40** | **108.00** | **216.00** |

Cube mould size = 15cm × 15cm × 15cm

Volume of mould = 0.15m × 0.15m × 0.15m = 3.375 X 10-3 m3

Total number of cubes per sample = 90 samples

**Table 3. 7:** **Mix Proportion of Constituent Materials for Each Sample (Accelerated Mortar Bar Test)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Constituent Materials** | | | | | |
| **Mix ID** | **Water**  **(Kg)** | **Cement**  **(Kg)** | **CPA**  **(Kg)** | **Sand**  **(kg)** | **Coarse Aggregate (Kg)** |
| B0 | 0.09 | 0.15 | 0 | 0.15 | 0.3 |
| B5 | 0.09 | 0.143 | 0.007 | 0.15 | 0.3 |
| B10 | 0.09 | 0.135 | 0.015 | 0.15 | 0.3 |
| B15 | 0.09 | 0.128 | 0.023 | 0.15 | 0.3 |
| B20 | 0.11 | 0.120 | 0.030 | 0.15 | 0.3 |
| B30 | 0.11 | 0.105 | 0.045 | 0.15 | 0.3 |
| **Total** | **0.580** | **0.780** | **0.120** | **0.900** | **1.800** |

The mix proportion for the constituent materials for each mixed sample for the electrical resistivity test is presented in Table 3.8.

**Table 3. 8:** **Mix Proportion of Constituent Materials for Each Sample (Electrical Resistivity Test)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Constituent Materials** | | | | | |
| **Mix ID** | **Water**  **(Kg)** | **Cement**  **(Kg)** | **CPA**  **(Kg)** | **Sand**  **(kg)** | **Coarse Aggregate (Kg)** |
| M1 | 4.80 | 8.00 | 0 | 8 | 16 |
| M2 | 4.80 | 7.60 | 0.4 | 8 | 16 |
| M3 | 4.80 | 7.20 | 0.8 | 8 | 16 |
| M4 | 4.80 | 6.80 | 1.2 | 8 | 16 |
| M5 | 5.60 | 6.40 | 1.6 | 8 | 16 |
| M6 | 5.60 | 5.60 | 2.4 | 8 | 16 |
| **Total** | **30.40** | **41.60** | **6.40** | **48** | **96** |

## 3.12 Statistical Analysis

The experiment for this study was made using Design-Expert software, version 10.0.8. The response surface methodology's Central Composite Designs (CCD) were employed for this investigation since their designs accommodated and suited the experimental technique required to accomplish a 2-level experiment with a sufficient array.

# CHAPTER FOUR

# 4.0 RESULTS AND DISCUSSION

## 4.1 Result of various tests on Cement

The following are the findings of several tests performed on the cement used.

### 4.1.1 Result of Elemental Oxide Composition

Table 4.1 shows the elemental oxide content of the typical Portland cement utilized in the investigation.

Table 4. 1: Elemental Oxide Composition of Selected Cement Sample

|  |  |
| --- | --- |
| Elemental Oxide | Weight Detected (%) |
| SiO₂ | 20.76 |
| Fe₂O₃ | 4.35 |
| Al₂O₃ | 5.83 |
| CaO | 62.89 |
| MgO | 1.42 |
| SO₃ | 2.00 |
| K₂O | 1.61 |
| Na₂O | 1.03 |
| Al₂O₃ + Fe₂O₃ | 10.18 |
| SiO₂ + Fe₂O₃ + Al₂O₃ | 30.94 |
| SiO₂ + Fe₂O₃ + Al₂O₃ + CaO | 93.83 |

### 4.1.2 Setting Time of Cement

Table 4.2 below summarizes the findings of the initial and final cement setting times.

Table 4. 2: Setting time result for cement

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **S/N** | **Determination No:** | **1st trial** | **2nd trial** | |  |
| 1 | Time when water is introduced to the cement | 5 min | 5 min |  |  |
| 2 | Time at the initial setting | 50 min | 40min |  |  |
| 3 | Total time is taken for the initial setting | 55 min | 45 min |  |  |
| 4 | **Initial Setting Time** | **50 min** | |  |  |
| 5 | Time at final setting time | 450min | 480min |  |  |
| 6 | Total time is taken for the final setting | 455min | 485 min |  |  |
| 7 | **Final setting time** | **470 min (7hrs, 50 min)** | | |  |
| 8 | Expected results | Min. 5hrs and Max. 10hrs | | |  |
| 9 | Comment | It is okay since it is less than 10hrs | | | |

Because the cement's initial and final setting times were less than 10 hours, the setting time was satisfactory**.**

### 4.1.3 Fineness Test

Table 4.3 below displays the results of the fineness test.

Table 4. 3: Result of fineness test on cement

|  |  |  |
| --- | --- | --- |
| **Observation** | **First Trial** | **Second Trial** |
| Weight of sample before the experiment (g) | 100 | 100 |
| Weight of sample before the experiment (g) | 4.5 | 4.2 |
| fineness (%) | 4.5 | 4.2 |
| **Average fineness (%)** | **4.35** |  |
| Expected values | It must be less than 10% | |
| Comment | Passed |  |

The result was less than 10%, indicating that the cement fineness test was successful.

## 4.2 Test on Cassava Peel Ash (CPA)

The elemental oxide makeup of the cassava peel ash used in the experiment is displayed in Table 4.4. Silica, Aluminum Oxide (Al2O3), and Iron Oxide (Fe2O3) have a combined percent composition of more than 70. This demonstrates that it is an excellent pozzolan that can aid in the synthesis of cementitious compounds from cement hydration reaction products.

Table 4. 4: Geochemical Analysis Result (Elemental Oxide Composition) of CPA Sample

|  |  |
| --- | --- |
| **Elemental Oxide** | **Weight Detected (%)** |
| SiO₂ | 54.86 |
| Fe₂O₃ | 11.14 |
| Al₂O₃ | 11.42 |
| CaO | 9.30 |
| MgO | 4.74 |
| SO₃ | 1.00 |
| K₂O | 3.56 |
| Na₂O | 2.18 |
| SiO₂ + Fe₂O₃ + Al₂O₃ | 77.42 |

## 4.3 Result of various tests on Fine aggregate Used

### 4.3.1 Silt Content Test for the Fine Aggregate

Table 4.5 displays the findings of the fine aggregate silt content test. The outcome reveals that the fine aggregate contains 3.5 percent silt, which is below the 6 percent maximum limit advised by BS 812-103.2 (1985) and hence suitable for the study. As a result, silt cannot be a source of concrete faults. The formula in equation 4.1 is used to calculate the silt content.

Table 4. 5: Silt Content Test for the Fine Aggregate

|  |  |  |
| --- | --- | --- |
|  | **First Trial** | **Second Trial** |
| Height of sand in the 250ml cylinder (mm) | 100 | 100 |
| Height of silt (mm) | 3.00 | 4 |
| Silt/clay content (%) | 3.0 | 4 |
| **Silt/clay content (%)** | **3.5** | |

Silt Content = \* 100 equation 4.1

First trial = \* 100 = 3%

Second trial = \* 100 = 4%

= = 3.5%

### 4.3.2 Moisture Content Test for the Fine Aggregate

Table 4.6 displays the findings of the fine aggregate moisture content test. The outcome demonstrates that 18% moisture is present in the fine aggregate. The formula in equation 4.2 is used to compute the moisture content.

**Table 4. 6:** **Moisture Content Test for the Fine Aggregate**

|  |  |  |
| --- | --- | --- |
| Sample | A (g) | B (g) |
| M1 | 34 | 34 |
| M2 | 184 | 184 |
| M3 | 160 | 162 |
| Ms | 126 | 128 |
| Mw | 24 | 22 |
| Water content (%) | 19% | 17% |

### 4.3.3 Sieve Analysis Result for Fine Aggregate

Table 4.7 displays the result for fine aggregate. The 950 grams of dry soil used in the experiment was sampled. According to AASHTO, the sand is categorized as A-1-b, meaning that, when properly drained, it can be used as a subgrade or subbase material. Particle size uniformity is essential to prevent voids and keep concrete workable. Equations 4.3 and 4.4's formulas are used to calculate the Cu and the CC respectively.

Cu = equation 4.3

Cc = equation 4.4

Table 4. 7: Sieve Analysis Result for Fine Aggregate

|  |  |  |  |
| --- | --- | --- | --- |
| Sieve Diameter (mm) | Soil Weight Retained (g) | Soil Retained (%) | Soil Passing (%) |
| 4.75 | 90.0 | 9.5 | 90.5 |
| 2.00 | 162.0 | 17.1 | 73.5 |
| 0.85 | 250.7 | 26.4 | 47.1 |
| 0.43 | 285.0 | 30.0 | 17.1 |
| 0.25 | 89.0 | 9.4 | 7.7 |
| 0.75 | 60.0 | 6.3 | 1.4 |
| Pan | 13.3 | 1.4 | 0.0 |
| Total | 950 | 100 |  |

Figure 9 depicts the particle size distribution curve for the study's fine aggregates.

Figure 4. 1: Particle Size Distribution Curve.

## 4.4 Test on Coarse aggregate

Table 4. 8: Specific Gravity Test for Cement

|  |  |  |
| --- | --- | --- |
| Description | 1st Trial (g) | 2nd Trial (g) |
| Mass of bottle + stopper (M1) | 295 | 295 |
| Mass of bottle + dry cement (M2) | 305 | 305 |
| Mass of bottle + cement + water (M3) | 536.71 | 536.78 |
| Mass of bottle filled with water (M4) | 530 | 530 |

Result: Calculation for the specific gravity

G =

For 1st test: G1 = = 3.04

For 2nd test: G2 = = 3.11

Actual Specific Gravity =

Actual Specific Gravity = 3.08

**The specific gravity for the Cement = 3.08**

The summary graph for the specific gravity of the concrete constituents is shown in Figure 4.2.

Figure 4. 2: Summary Graph for Specific Gravity of Concrete Constituents

The results for the different constituent materials' specific gravities showed that when water is added to concrete, the moisture content of the resulting concrete won't affect its workability and mechanical strength because the constituents of concrete are all heavier than the specific gravity of water, with cement being 3.08 times heavier, as shown in figure 4.2.

## 4.5 Test on Concrete

Compressive strength testing, electrical resistivity testing, accelerated mortar bar testing, and scanning electron microscope (SEM) analysis are among the concrete tests performed.

### 4.5.1 Slump test result

Table 4.12 and figure 4. 3 show the results of the w/c ratio at various CPA content levels. Cassava peel ash has a larger water absorption potential, which could explain this behavior. As a result, additional water may be required, depending on the amount of CPA used, to produce concrete containing CPA.

Table 4. 9: Results of slump test

|  |  |  |
| --- | --- | --- |
| **CPA Replacement (%)** | **Slump (mm)** | **Comment** |
| 0 | 200 | Collapse slump |
| 5 | 130 | Shear slump |
| 10 | 30 | True slump |
| 15 | 10 | True slump |
| 20 | 1 | True slump |
| 30 | 0 | True slump |

**Figure 4. 3: graph of slump test against percentage replacement of CPA**

The discovered workability feature of the concrete matrix shows that as the amount of cassava peel ash in the concrete mixture rises, the slump test value falls, requiring more water to make the mixture more workable. The high-water need is due to the presence of silica and the ash sample's higher surface area. This is because the silica-lime reaction requires more water than the water used in the cement hydration reaction process (Salau *et al.,* 2012).

### 4.5.2 Water absorption result

As can be seen in Figure 4.4 and Table 4.13, the amount of cement that CPA replaces increases the concrete sample's ability to absorb water.

Table 4. 10: Water Absorption Result

|  |  |  |
| --- | --- | --- |
| **CPA Replacement (%)** | **Water Absorption Result (%)** | |
| **7 days** | **28 days** |
| 0 | 0.51 | 2.60 |
| 5 | 0.54 | 2.89 |
| 10 | 0.60 | 3.35 |
| 15 | 0.73 | 3.62 |
| 20 | 0.75 | 4.01 |
| 30 | 1.10 | 4.95 |

**Figure 4. 4: graph of water absorption result**

The findings of the water absorption test shown in figure 4.4 above indicated that adding CPA to the finished concrete increased the water absorption rate because of the pozzolanic nature of cassava peel ash. It was also discovered that as the percentage rises, so does the amount of water absorbed. For both 7 and 28 days, according to the measured amounts of absorbed water, 5 percent CPA cement replacement had the least quantity and 30 percent CPA cement replacement had the most. This corresponds to the findings of (Olatokunbo *et al.,* 2018). With each passing year of cure, the amount of water absorbed increases.

### 4.5.3 Bulk Density

The findings for densities of concrete made with 0 to 30% CPA replacement at intervals of 5% are depicted in table 4.14 and figure 4.5. The densities vary between 2400.10 and 2574.55 kg/m3, indicating normal concretes. Concrete is defined as normal concrete if its density value is not less than 2400 Kg/m3.

**Table 4. 11: Bulk Density Test Results at Varying CPA Percentages and Days**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Bulk Density (Kg/m3)** | | | | | | |
|  | **0%** | **5%** | **10%** | **15%** | **20%** | **30%** |
| 7th Day | 2483 | 2400.1 | 2414.19 | 2403.39 | 2480.35 | 2402.2 |
| 14th Day | 2510.05 | 2618.9 | 2419.15 | 2426.12 | 2430.01 | 2409.77 |
| 21st Day | 2522 | 2421.11 | 2500.2 | 2441.65 | 2421.11 | 2405.05 |
| 28th Day | 2574.55 | 2444.03 | 2542.59 | 2409.72 | 2477.78 | 2409.23 |
|  |
|  |

**Figure 4. 5: Variation of Bulk Density of Concrete Cubes (Kg/m3)**

Table 4.14 and Plate 4.5 indicate bulk densities that are all higher than the minimum criteria for ordinary concrete. This further indicates that the aggregate size, the quantity of air captured or purposely absorbed, the density of the aggregate, and not only the amount of binder, control the concrete density.

### 4.5.4 Split Tensile Result

Table 4.15 and Figure 4.6 below show the tensile splitting strength data. Additionally, it was revealed that between 7 and 28 days of curing, 0 percent CPA substitution had the highest tensile splitting strength range, 2.02N/mm2 to 3.31N/mm2, and 30 percent CPA replacement had the lowest, 1.01N/mm2 to 1.48N/mm2. The results of Olatokunbo *et al.,* (2018) likewise revealed this declining tendency in the split tensile strength of CPA-admixed concrete.

Table 4. 12: Split Tensile Result

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Split Tensile (N/mm2)** | | | | | | |
|  | **0%** | **5%** | **10%** | **15%** | **20%** | **30%** |
| 7th Day | 2.02 | 1.72 | 1.79 | 1.66 | 1.37 | 1.01 |
| 14th Day | 2.16 | 2.03 | 2.29 | 1.61 | 1.52 | 1.31 |
| 21st Day | 2.64 | 2.49 | 2.31 | 2.02 | 1.59 | 1.34 |
| 28th Day | 3.31 | 3.25 | 2.80 | 2.46 | 2.09 | 1.48 |

Figure 4. 6: graph showing result of split tensile test

Based on this performance, a 5–10% cement replacement for CPA can be regarded as the ideal cement replacement for CPA that will increase the serviceability of cement concrete containing cassava peel ash. Concrete's tensile strength is typically regarded as negligible because it is not frequently built to carry loads under tension. Tensile strength is crucial in concrete buildings, however, particularly when it comes to preventing fractures, as Jagadeesh (2017) notes. In many cases, compressive strength is less important for serviceability Limit states than tensile strength.

### 4.5.5 Compressive Strength

The compressive strength of cement-CPA concrete increases over time, regardless of the amount of CPA in the mix. On the other hand, as the CPA concentration increases, the compressive strength decreases. Table 4.16 and Figure 4.6 display the compressive strength findings.

Table 4. 13: Compressive Strength Test Results

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Compressive Strength (N/mm2)** | | | | | | |
|  | **0%** | **5%** | **10%** | **15%** | **20%** | **30%** |
| 7th Day | 21.27 | 19.23 | 18.86 | 16.61 | 13.54 | 12.01 |
| 14th Day | 23.56 | 21.30 | 20.89 | 18.40 | 15.00 | 13.31 |
| 21st Day | 27.16 | 24.55 | 24.08 | 21.21 | 17.29 | 15.34 |
| 28th Day | 32.72 | 31.50 | 29.01 | 25.55 | 20.83 | 15.48 |

Figure 4. 7: Graph showing compressive strength results

The study's findings, as shown in Figure 4.7, show that all of the concrete cube samples for 0%, 5%, 10%, and 15% CPA replacement passed the necessary compressive strength for grade 25 concrete (M25). The results show that useful strength can be achieved with only a little amount of OPC replaced with CPA. This is further demonstrated by the fact that all compressive strengths obtained with varying degrees of replacement were lower than those produced with 100% OPC. This study also suggests that when less than 15% by weight of cement is employed, CPA can contribute to late strength development. This behavior indicates that CPA has pozzolanic properties.

Furthermore, these data show that up to 15% is adequate, exceeding the ASTM C311-98 standard of 75%. Because the strength values are within acceptable bounds, the study's findings also imply that substituting cement with CPA up to 15% is permissible, which is consistent with those of Salau *et al.,* (2012).

The strength durability performance outcomes degrade as the CPA replacement ratio rises, claim Ogbonna *et al.,* (2020). The findings show that a 5 percent CPA replacement blend gave concrete with a 90-day curing time the best durability. The findings of this study also showed that a CPA replacement rate of 5% is a safe bet.

### 4.5.6 Acid Solubility Test Result

Table 4.17 and Figure 4.8 display the outcomes of water and acid solubility tests on samples of hardened concrete.

Table 4. 14: Percentage solubility of samples in acid

|  |  |  |  |
| --- | --- | --- | --- |
| **Sample** | **Solubility**  **in HNO3 (%)** | **Solubility**  **in HCL (%)** | **Solubility in**  **H2O (%)** |
| 0% | 8.01 | 4.90 | 3.45 |
| 5% | 8.70 | 6.95 | 6.57 |
| 10% | 9.79 | 14.72 | 9.38 |
| 15%  20%  30% | 14.61  15.27  18.93 | 17.30  14.39  12.58 | 9.39  11.84  13.10 |

**Figure 4. 8: Graph showing the result of the water and acid solubility test**

As shown in Figure 4.8, the solubility rate of hardened samples in water and HNO3 differed from that of HCL. Solubility in water and HNO3 increases as CPA quantity increases from 8.01% to 18.93% and 3.45% to 13.10% at 24hours respectively. Solubility in HCL also increased from 0-15% CPA replacement but started declining in value as the replacement level was put above 15% CPA replacement. The rate of solubility is lowest in 0% CPA replacement and experiences high values as CPA replacement was above 10% replacement. The findings reveal that CPA replacement of less than 15% fell within the permissible range and therefore will perform better when expose to acidic conditions or in the event of acidic rain.

## 4.6 Thermal conductivity, Thermal diffusivity, Bulk Density and Specific heat capacity Test Results.

Tables 4.18 and 4.19, and Figure 4.9 show the results of the thermal conductivity test when the samples were exposed to temperatures of 1000C and 3000C.

Table 4. 15: Thermal conductivity, thermal diffusivity, specific heat capacity result at 28 days.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Thermal conductivity at 1000c** | | | | | | |
|  | 0% | 5% | 10% | 15% | 20% | 30% |
| I (A) | 0.613 | 0.612 | 0.650 | 0.648 | 0.561 | 0.421 |
| V (v) | 272 | 268 | 240 | 233 | 234 | 227 |
| P (w) | 166.74 | 164.02 | 156 | 150.98 | 131.27 | 95.55 |
| T1 (oC)  T2 (oC)  K (w/m°C) | 100  33  48.21 | 100  31.5  45.75 | 100  32.5  44.16 | 100  30.5  41.51 | 100  27.5  34.60 | 100  36.5  28.75 |
| Cp (kJ/kgK)  (kg/m3)  A (kJ/kg) | 2768  2832  6.25 | 2618  2794.57  6.25 | 2552  2767.40  6.25 | 2406  2758.91  6.25 | 2056  2691  6.25 | 1583  2903.23  6.25 |

Table 4. 16: Thermal conductivity, thermal diffusivity, specific heat capacity result at 28 days.

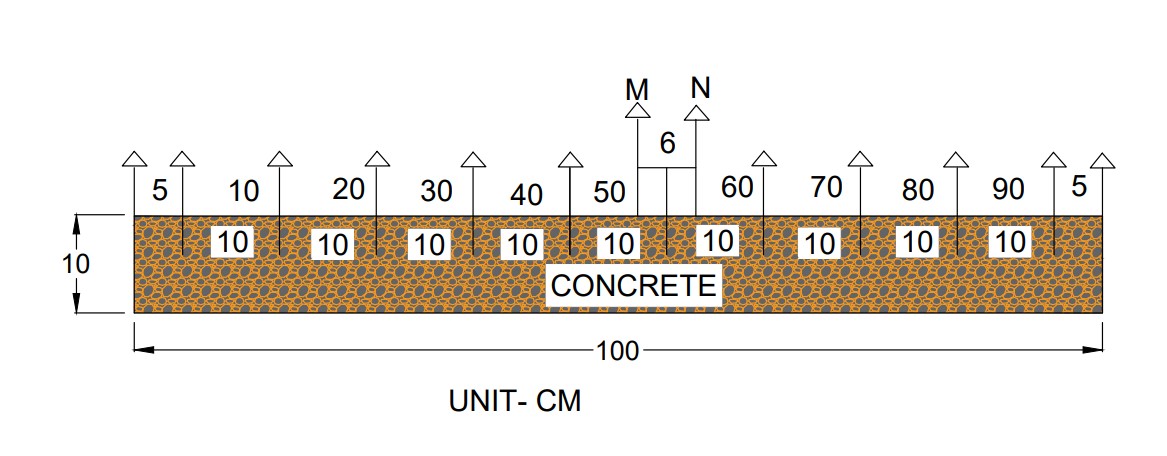
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Thermal conductivity at 3000c** | | | | | | |
|  | **0%** | **5%** | **10%** | **15%** | **20%** | **30%** |
| I (A) | 0.608 | 0.624 | 0.589 | 0.550 | 0.489 | 0.556 |
| V (v) | 237 | 231 | 218 | 240 | 238 | 232 |
| P (w) | 150.18 | 144.14 | 128.4 | 132 | 116.38 | 113.99 |
| T1 (oC)  T2 (oC)  K (w/m°C) | 300  38  15.61 | 300  36  10.43 | 300  46  9.66 | 300  41.5  9.76 | 300  47.5  8.81 | 300  41  8.41 |
| Cp (kJ/kgK)  (kg/m3)  A (kJ/kg) | 621  2832  6.25 | 597  2794.57  6.25 | 558  2767.40  6.25 | 566  2758.91  6.25 | 523  2691  6.25 | 463.28  2903.23  6.25 |

Figure 4. 9: Graph showing the thermal properties of the concrete at different temperatures

When compared to the control sample with thermal conductivity of 45.75 w/moC with cassava peel ash incorporation at a temperature rate of 100°C, the average thermal conductivity values conducted for concrete samples with CPA varied from 0% to 30%, as shown in Tables 4.18 and 4.19, and Figure 4.9, improved thermal conductivity performance by gradually lowering the thermal conductivity value from 44.16w/moC (5%) to 28.75w/moC (30 percent). When the sample is heated to 300°C and the thermal conductivity value is gradually reduced from 10.43w/moC to 8.41w/moC, a similar pattern emerges. Higher CPA inclusions, on the other hand, led to lower heat conductivity values. Lower thermal conductivity materials are typically regarded as superior thermal insulators and provide greater building insulation.

## 4.7 Electrical Resistivity Test Using Schlumberger Array Probe Method

As the core voids that allow for gel development and cracking are eliminated, the higher the resistivity of a concrete sample, the higher its strength. The electrical resistivity nodes are depicted in Plate 4.1.



**Plate 4.1: Setup Showing Positioning of Electrodes in the Concrete**

Table 4. 17: Average Resistance Values obtained from the Concrete Cubes

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Average Resistance (Ohm)** | | | | | | |
|  | 0% | 5% | 10% | 15% | 20% | 30% |
| 1st Day | 15.45 | 36.69 | 81.21 | 48.51 | 26 | 18 |
| 7th Day | 131.48 | 299.14 | 508.8 | 248.74 | 17.02 | 11.99 |
| 14th Day | 91.96 | 143.98 | 246.5 | 84.99 | 15 | 12.02 |
| 21st Day | 69.92 | 131.41 | 235.91 | 65.86 | 13 | 11 |
| 28th Day | 209.35 | 253.45 | 265.50 | 70.43 | 10 | 8 |

**Figure 4. 10: Graph showing electrical resistivity values obtained from the Concrete Cubes**

**Table 4. 18**: **Average Resistivity Values obtained from the Concrete Cubes**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Resistivity (ρ) (Ώm)** | | | | | | |
|  | **0% CPA** | **5% CPA** | **10% CPA** | **15% CPA** | **20% CPA** | **30% CPA** |
| 1st Day | 148 | 157 | 310 | 157 | 44 | 39 |
| 7th Day | 174 | 243 | 322 | 169 | 54 | 45 |
| 14th Day | 176 | 280 | 486 | 181 | 63 | 55 |
| 21st Day | 265 | 289 | 518 | 187 | 74 | 56 |
| 28th Day | 321 | 372 | 617 | 281 | 99 | 72 |

Figure 4. 11: graph showing the average resistivity of the concrete cube

After 28 days, concrete cube samples' average resistivity for 0% CPA replacement is 321Ώm, however at 5% CPA replacement, the resistivity rose to 372Ώm, and at 10% CPA replacement, it reached an optimum value of 617Ώm, indicating that CPA addiction at 10% replacement increased the concrete's resistivity, thereby improving mechanical strength and durability. When the percentage rise in CPA exceeds 10% replacement, there is a decrease in resistivity values. Resistivity values for 15%, 20%, and 30% CPA replacements were 281Ώm, 99Ώm, and 72Ώm, respectively. It has been established that as the percentage of CPA replacement goes beyond 10%, the resistivity values decrease, with the lowest value reported at 30% replacement (see table 4.20).

### 4.7.1 Resistivity and Concrete Corrosion

Adniikin et al (2019) states that corrosion is rare when resistivity is more or equivalent to 120Ώm, plausible when it is between 80Ώm and 120Ώm, and practically unavoidable when it is less than 80Ώm. The investigation demonstrates that the concrete samples with various CPA additions will be corrosion-free on the first day excluding 20 and 30 percent CPA replacement. This same pattern was observed for days 7, 14, and 21 since they all had higher resistivity values that exceeded 120Ώm. At 28 days, % CPA substitution had a resistivity value of 99Ώm, which falls between 80Ώm and 120Ώm, indicating that corrosion is conceivable or feasible, whereas 30 percent CPA replacement had a resistivity value of 72Ώm, indicating that corrosion is unavoidable. Other CPA replacements have values larger than 120Ώm, reducing the likelihood of corrosion when applied.

## 4.8 Scanning Electron Microscopy (SEM) Test

The early strength of the concrete is significantly influenced by the calcium concentration. The high carbon content in concrete samples, according to Chen, Fu, and Chun (2006), both lessens drying shrinkage and boosts flexural toughness. The compressive strength and crack resistance of concrete are enhanced by its high carbon content, claim Liu *et al.,* (2018). Oxygen is another crucial component found in concrete samples. According to Kotaro, Sachiko, Hideki, and Eiji (2018), oxygen serves as a critical binder in concrete buildings and is necessary for the structures to be stiff. The properties of the concrete have undergone several effects as a result.

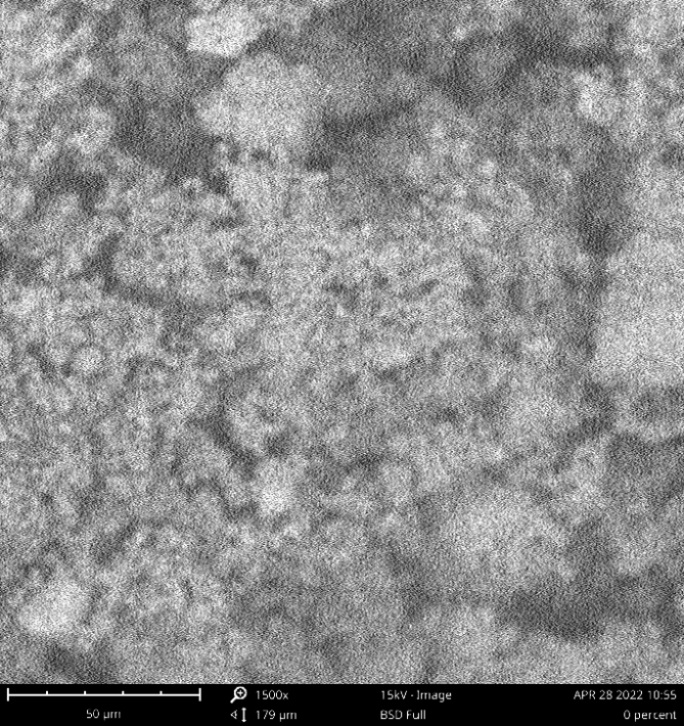
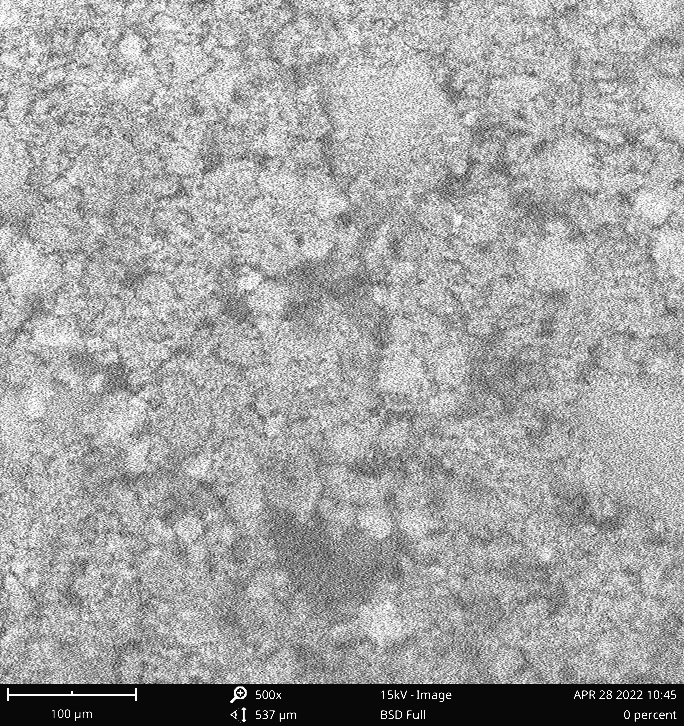
 

Figure 4. 12: Image of 0% CPA Sample

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 4. 19 : Backscatter electron detector (BSD) of 0% CPA Sample   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Element Number** | **Element Symbol** | **Element Name** | **Atomic Conc.** | **Weight Conc.** | | 20 | Ca | Calcium | 59.76 | 61.93 | | 14 | Si | Silicon | 22.00 | 15.98 | | 26 | Fe | Iron | 5.62 | 8.12 | | 28 | Ni | Nickel | 4.83 | 7.33 | | 24 | Cr | Chromium | 1.79 | 2.41 | | 12 | Mg | Magnesium | 3.63 | 2.28 | | 16 | S | Sulfur | 2.36 | 1.95 | |

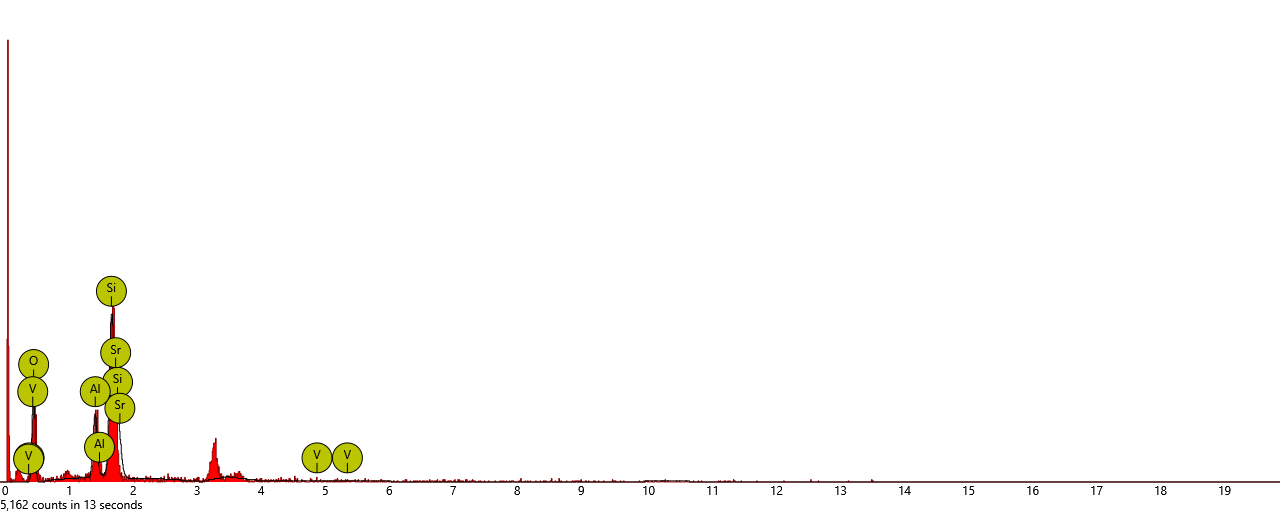
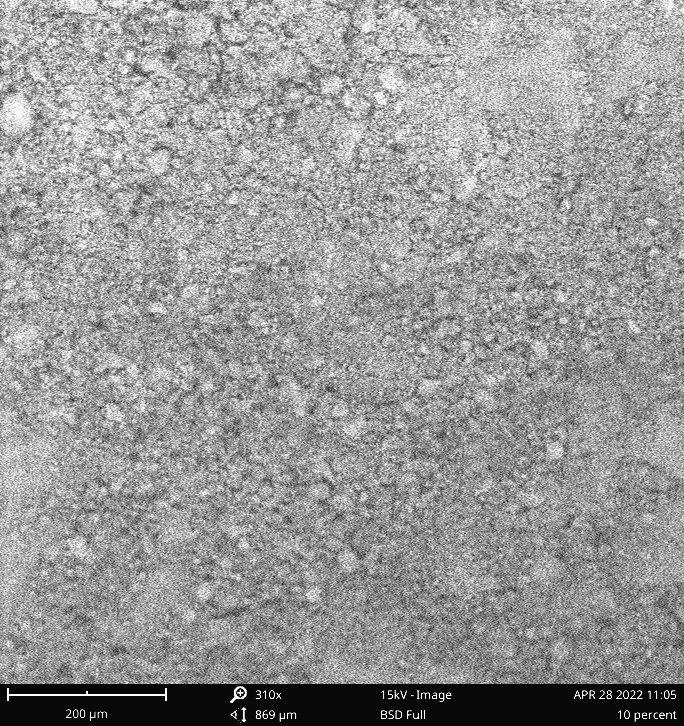
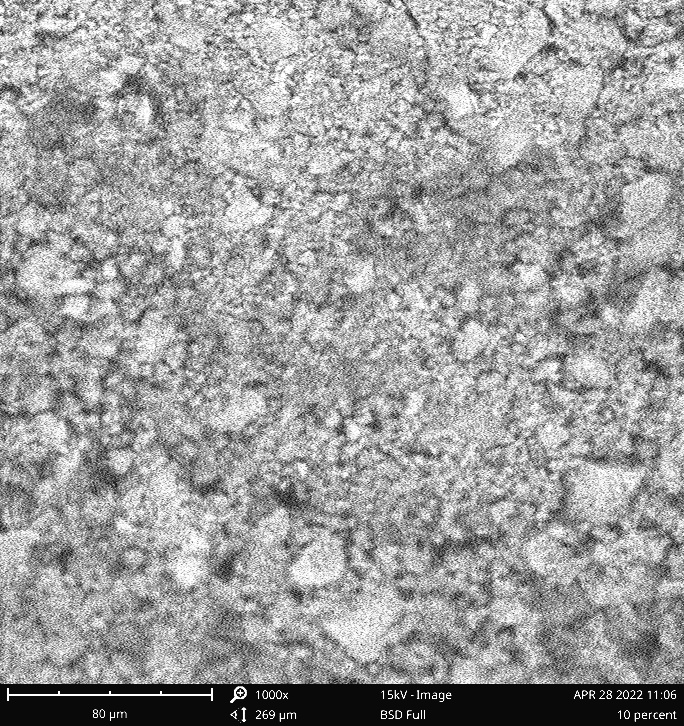


Figure 4. 13: Energy Dispersive Spectroscopy (EDS) of 0% CPA Sample

**Figure 4. 14: SEM Image of 10% CPA Sample**

**Table 4. 20**: **Backscatter electron detector (BSD) of 10% CPA Sample**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Element Number** | **Element Symbol** | **Element Name** | **Atomic Conc.** | **Weight Conc.** |
| 52 | Te | Tellurium | 27.59 | 53.28 |
| 20 | Ca | Calcium | 40.34 | 24.47 |
| 14 | Si | Silicon | 19.10 | 8.12 |
| 35 | Br | Bromine | 5.94 | 7.19 |
| 26 | Fe | Iron | 4.98 | 4.21 |
| 38 | Sr | Strontium | 2.06 | 2.74 |

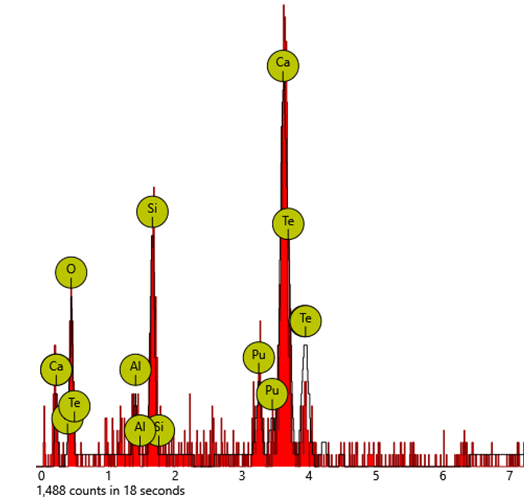


Figure 4. 15 : Energy Dispersive Spectroscopy (EDS) of 10% CPA Sample

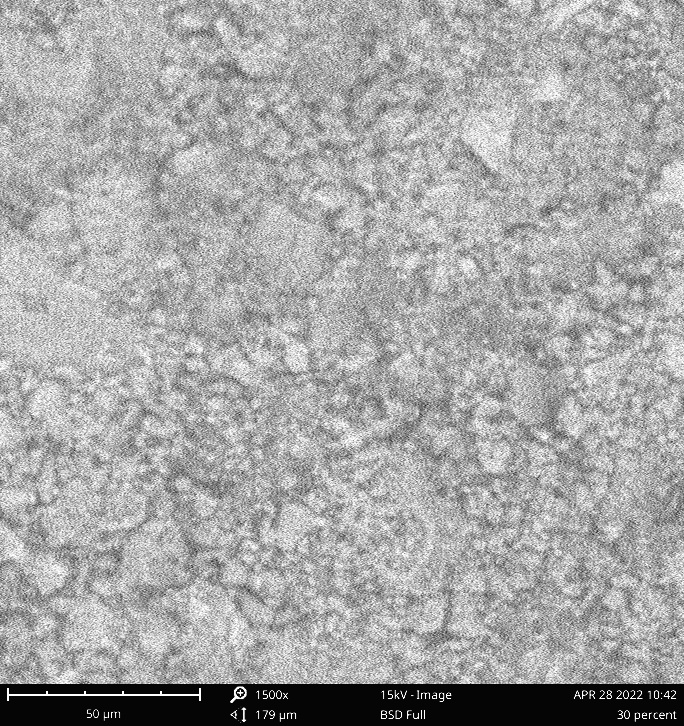
 

Figure 4. 16: SEM Image of 30% CPA Sample

**Table 4. 21**: **Backscatter electron detector (BSD) of 30% CPA Sample**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Element Number** | **Element Symbol** | **Element Name** | **Atomic Conc.** | **Weight Conc.** |
| 52 | Te | Tellurium | 16.56 | 35.39 |
| 94 | Pu | Plutonium | 7.40 | 30.24 |
| 20 | Ca | Calcium | 25.50 | 17.12 |
| 8 | O | Oxygen | 31.82 | 8.53 |
| 14 | Si | Silicon | 14.39 | 6.77 |
| 13 | Al | Aluminum | 4.33 | 1.96 |

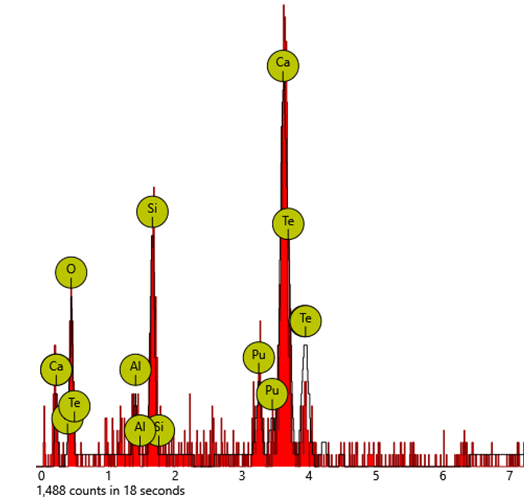


Figure 4. 17: Energy Dispersive Spectroscopy (EDS) of 30% CPA Sample

**4.8 Accelerated Mortar Bar Test**

The immersion solution for concrete is made using sodium hydroxide (NaOH). Sodium chloride is used to enhance the ASR reaction in concrete during the accelerated aging process since it is an alkali activator. ASR-free concrete bars have expansion values that are fewer than the expansion values. By measuring the length increase of typical concrete bars with and without CPA after storage under high-temperature test circumstances, the outcome is achieved. Table 4.25 displays the mass of the cubes.

Table 4. 22: Accelerated Mortar Bar Test Result Readings

|  |  |  |
| --- | --- | --- |
| **CPA Substitution (%)** | **Sample Weight Before Immersion (g)** | **Sample Weight after Immersion (g)** |
| 0 | 400 | 444 |
| 5 | 500 | 520 |
| 10 | 404 | 414 |
| 15 | 448 | 478 |
| 20 | 408 | 480 |
| 30 | 372 | 402 |

Tables 4.26 and 4.27 display the acquired and specified requirements as well as the classification for ASR growth in concrete. Figure 4.16 shows the concrete cube samples' expansion before and after being submerged in 100g of NaOH at 80oC for 7, 14, and 28 days.

Table 4. 23: Concrete Cubes Expansion Result

|  |  |  |  |
| --- | --- | --- | --- |
| **CPA Substitution (%)** | **Expansion of Concrete Cubes** | | |
| **7th Day** | **14th Day** | **28th Day** |
| 0 | 0.009 | 0.020 | 0.039 |
| 5 | 0.003 | 0.005 | 0.025 |
| 10 | 0.001 | 0.002 | 0.013 |
| 15 | 0.006 | 0.007 | 0.027 |
| 20 | 0.014 | 0.027 | 0.040 |
| 30 | 0.028 | 0.034 | 0.056 |

Figure 4. 18: Variation of concrete cube expansion with CPA replacement (%)

Table 4. 24: Standard Concrete Reactivity Classification

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Mortar Bar Expansion (%) in 1M NaOH (80%) | | | | | | Classification |
| VicRoads Standard Specification Section 610 | | ASTM C1260 | | | ASTM C1293 |
| 10 Days | 21 Days | | 14 Days | 28 Days | |
| < 0.010\* | < 0.010\* | | < 0.020 | < 0.040 | | Non-reactive |
| = 0.010\* | = 0.010\* | | = 0.020 | = 0.040 | | Slowly reactive |
| > 0.010\* | > 0.010\* | | > 0.020 | > 0.040 | | Reactive |
| \*0.015% for naturally occurring fine aggregate | | | | | | |

According to the VicRoads standard, 0% CPA replacement is minimally reactive, however, 20% and 30% CPA replacement are too prone to alkaline assaults and should be avoided. Alkaline attacks are not a problem for concrete with a CPA content of 5%, 10%, or 15%. The optimum replacement is 10%.

According to the study, concrete bars with CPA replacement levels of 5%, 10%, 15%, and 20% are non-reactive/non-delirious on day 7, but concrete bars with CPA replacement levels of 30% exhibit substantial levels of ASR. The 28th-day data reveal that the 0% CPA replacement is slow to react to alkaline attacks, whereas the 20% and 30% CPA replacements are extremely vulnerable to alkaline attacks. According to the studies, 5 percent, 10%, and 15% of CPA replacements are non-reactive to ASR attacks. The optimum value is 10% replacement

## 4.9 Empirical Modelling of Concrete Admixed With CPA

Empirical models developed from input-output data for the concrete pavement admixed with CPA using Central Composite Design. Equations 11 to 13 illustrate the predictive model equations for the compressive strength (CS), split tensile strength (ST), and concrete cube expansion (CCE) of the concrete where cement is partially substituted with variable percentages of CPA.

**Table 4. 25: ANOVA for Response Surface Reduced Quartic Model for Compressive Strength**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Source** | **Sum of Squares** | **Df** | **Mean Square** | **F-value** | **p-value** |  |
| **Model** | 493.85 | 7 | 70.55 | 263.21 | < 0.0001 | Significant |
| A-DAYS | 61.62 | 1 | 61.62 | 229.91 | < 0.0001 |  |
| B-Cassava Peel Ash (%) | 90.14 | 1 | 90.14 | 336.31 | < 0.0001 |  |
| AB | 17.29 | 1 | 17.29 | 64.49 | 0.0005 |  |
| A² | 2.42 | 1 | 2.42 | 9.01 | 0.0300 |  |
| B² | 0.6037 | 1 | 0.6037 | 2.25 | 0.1937 |  |
| A²B | 2.70 | 1 | 2.70 | 10.07 | 0.0247 |  |
| AB² | 1.33 | 1 | 1.33 | 4.95 | 0.0766 |  |
| **Residual** | 1.34 | 5 | 0.2680 |  |  |  |
| **Cor Total** | 495.19 | 12 |  |  |  |  |

Model significance is suggested by the model's Model F-value of 263.21. An F-value this large could only happen owing to noise in 0.01 percent of cases.

Table 4. 26: Fit Statistics

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Std. Dev.** | | 0.5177 | **R²** | 0.9973 |
| **Mean** | | 20.89 | **Adjusted R²** | 0.9935 |
| **C.V. %** | | 2.48 | **Predicted R²** | 0.9601 |
|  |  | | **Adeq Precision** | 51.5505 |

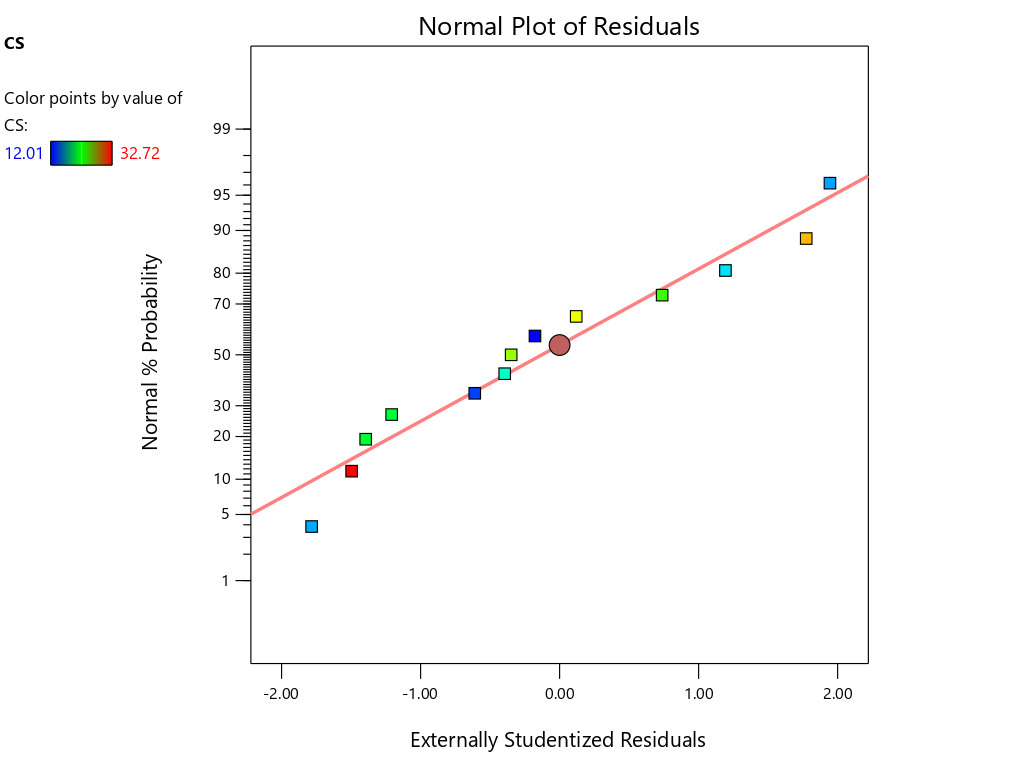


Figure 4. 19: Variation of the Observed (Actual) Response Values Versus the Predicted Response Values for Compressive Strength

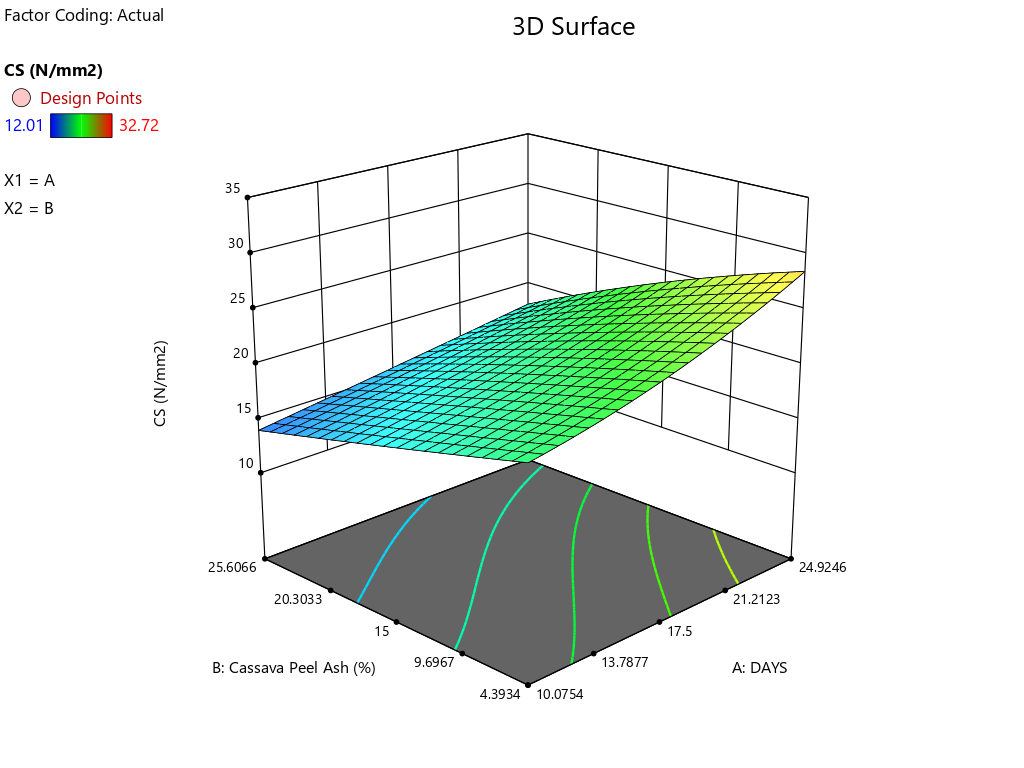


Figure 4. 20: 3D Model of Compressive Strength Test

Table 4. 27: ANOVA for Response Surface Reduced Quartic Model for Split Tensile

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Source** | **Sum of Squares** | **Df** | **Mean Square** | **F-value** | **p-value** |  |
| **Model** | 4.71 | 7 | 0.6725 | 100.05 | < 0.0001 | significant |
| A-DAYS | 0.4834 | 1 | 0.4834 | 71.91 | 0.0004 |  |
| B-Cassava Peel Ash (%) | 0.8306 | 1 | 0.8306 | 123.58 | 0.0001 |  |
| AB | 0.2175 | 1 | 0.2175 | 32.35 | 0.0023 |  |
| A² | 0.0622 | 1 | 0.0622 | 9.26 | 0.0287 |  |
| B² | 0.0018 | 1 | 0.0018 | 0.2688 | 0.6263 |  |
| A²B | 0.0610 | 1 | 0.0610 | 9.08 | 0.0297 |  |
| AB² | 0.0006 | 1 | 0.0006 | 0.0934 | 0.7722 |  |
| **Residual** | 0.0336 | 5 | 0.0067 |  |  |  |
| **Cor Total** | 4.74 | 12 |  |  |  |  |

Model significance is suggested by the model's Model F-value of 100.05. An F-value this large might be caused by noise only 0.01 percent of the time.

Table 4. 28: Fit Statistics

|  |  |  |  |
| --- | --- | --- | --- |
| **Std. Dev.** | 0.0820 | **R²** | 0.9929 |
| **Mean** | 1.93 | **Adjusted R²** | 0.9830 |
| **C.V. %** | 4.24 | **Predicted R²** | 0.8839 |
|  |  | **Adeq Precision** | 35.6150 |

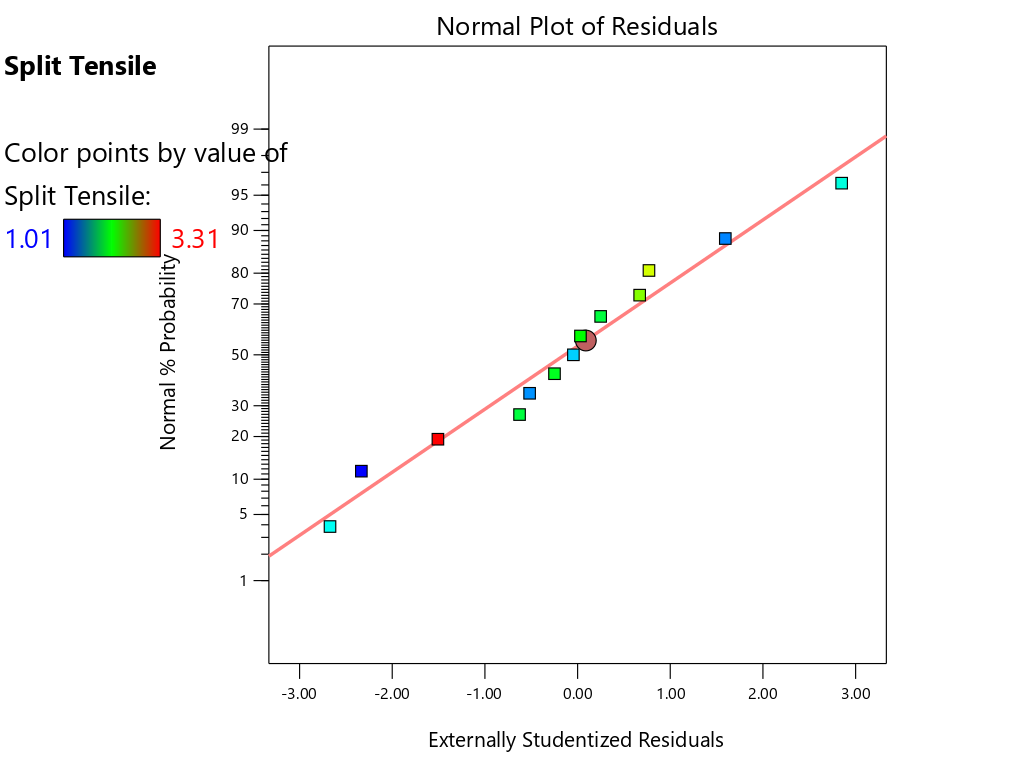
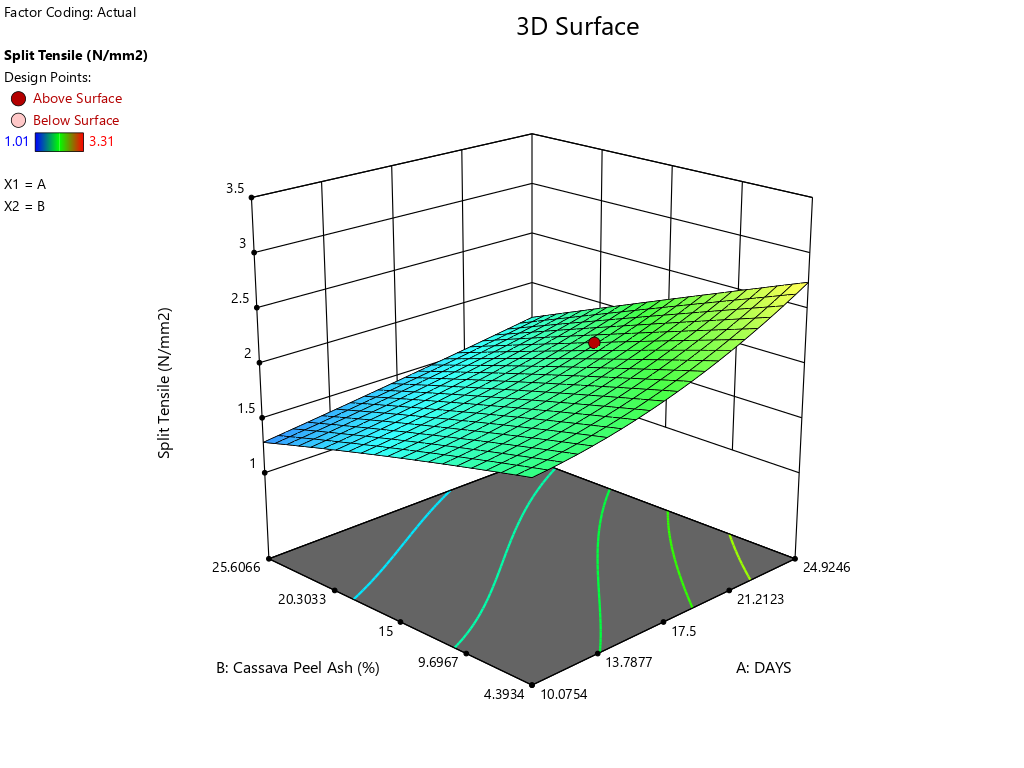


Figure 4. 21: Variation of the Observed (Actual) Response Values Versus the Predicted Response Values for Split Tensile



**Figure 4.20:** **3D Model of Split Tensile Test**

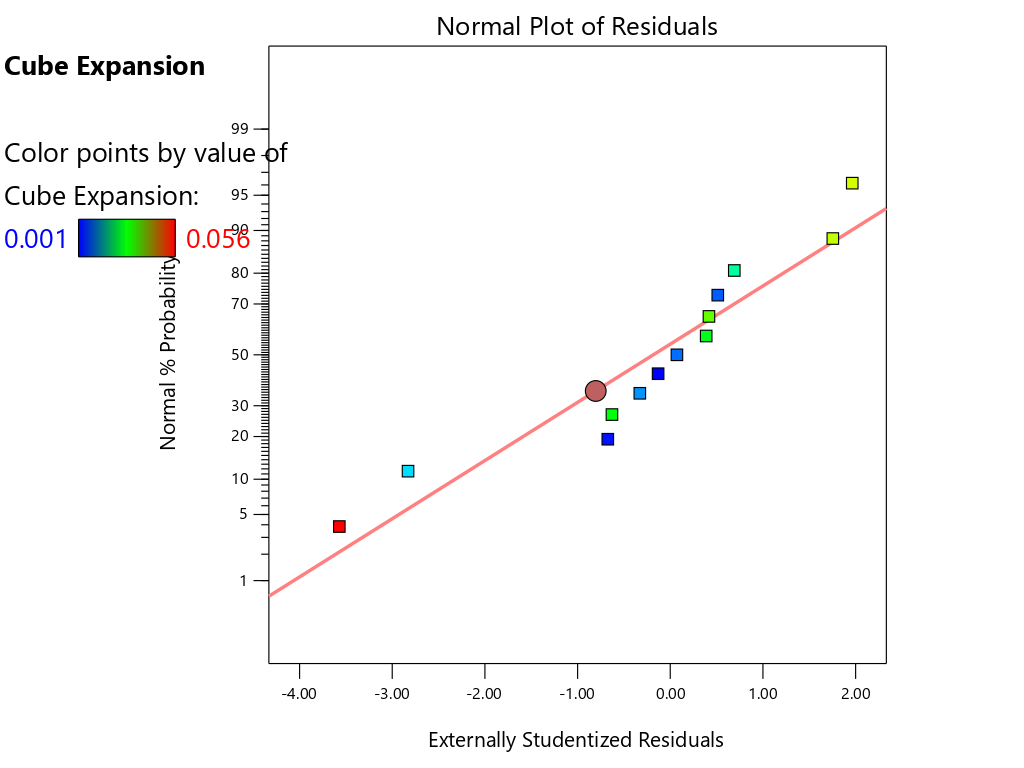
**Table 4.29:** **ANOVA for Response Surface Reduced Quartic Model for Compressive Strength**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Source** | **Sum of Squares** | **Df** | **Mean Square** | **F-value** | **p-value** |  |
| **Model** | 0.0033 | 7 | 0.0005 | 9.57 | 0.0122 | significant |
| A-DAYS | 0.0005 | 1 | 0.0005 | 10.08 | 0.0247 |  |
| B-Cassava Peel Ash (%) | 0.0001 | 1 | 0.0001 | 1.86 | 0.2311 |  |
| AB | 4.581E-06 | 1 | 4.581E-06 | 0.0929 | 0.7728 |  |
| A² | 0.0000 | 1 | 0.0000 | 0.7500 | 0.4261 |  |
| B² | 0.0011 | 1 | 0.0011 | 22.32 | 0.0052 |  |
| A²B | 9.402E-06 | 1 | 9.402E-06 | 0.1907 | 0.6806 |  |
| AB² | 0.0000 | 1 | 0.0000 | 0.4985 | 0.5117 |  |
| **Residual** | 0.0002 | 5 | 0.0000 |  |  |  |
| **Cor Total** | 0.0035 | 12 |  |  |  |  |

The Model F-value of 9.57 suggests that the model is significant. An F-value of this size can occur randomly only 1.22 percent of the time.

Table 4. 30: Fit Statistics

|  |  |  |  |
| --- | --- | --- | --- |
| **Std. Dev.** | 0.0070 | **R²** | 0.9305 |
| **Mean** | 0.0217 | **Adjusted R²** | 0.8333 |
| **C.V. %** | 32.37 | **Predicted R²** | -0.4985 |
|  |  | **Adeq Precision** | 10.5023 |



**Figure 4.21:** **Variation of the Observed (Actual) Response Values Versus the Predicted Response Values for Cube Expansion**

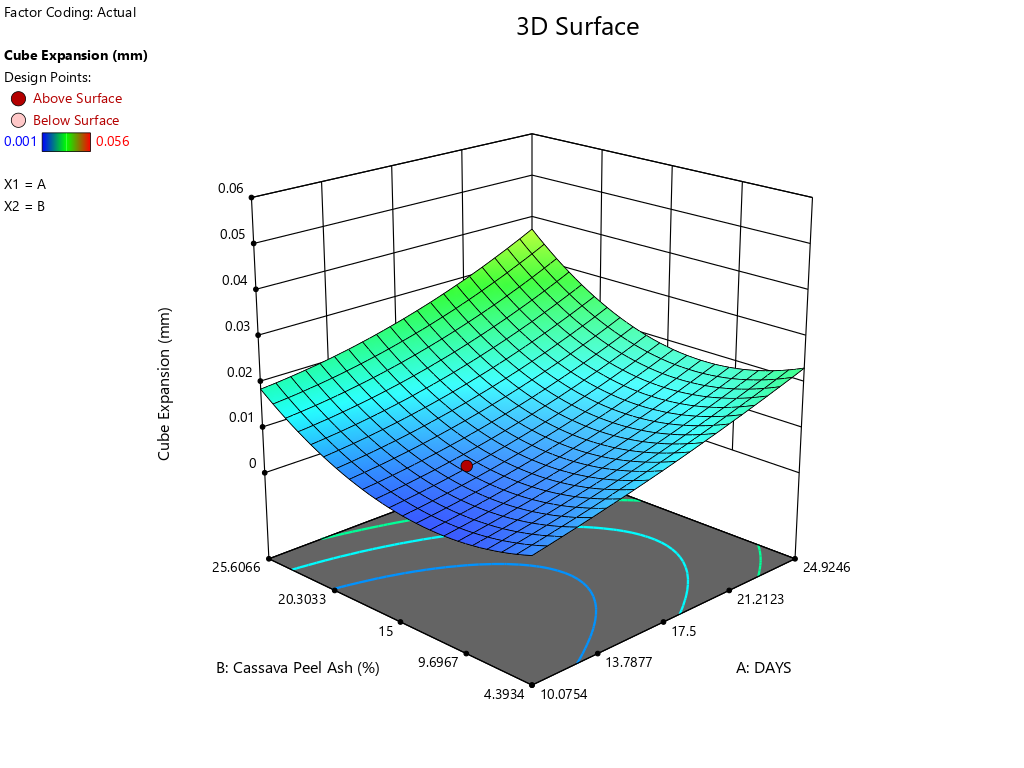


Figure 4. 22: 3D Model of Cube Expansion Test

# CHAPTER FIVE

# 5.0 CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

The fundamental aim of the thesis is to determine how efficiently cassava peel ash inhibits alkaline silica reactions in concrete. This chapter provides a summary of the findings that address that purpose. The test results gathered during the study can be used to draw the following conclusions:

* CPA has a chemical composition of 77.42% silica, Aluminum Oxide (Al2O3), and Iron Oxide (Fe2O3), it is therefore considered an excellent pozzolan for stimulating the synthesis of cementitious compounds during the cement hydration reaction.
* The investigation discovered that all concrete cube samples for CPA replacement of 5%, 10%, and 15% met the necessary compressive strength for grade 25 concrete (M25). The results reveal that with only a little amount of OPC replaced with CPA, acceptable strength can be obtained.
* The statistics indicate that CPA replacement of less than 15% fell within the acceptable range, indicating that the concrete will function better when exposed to acidic circumstances or if acidic rain occurs.
* The concrete's thermal properties were improved by the inclusion of cassava peel ash (CPA).
* The 28th-day analysis revealed that the 0% CPA replacement is slow to react to alkaline attacks, whereas the 20% and 30% CPA replacements are extremely vulnerable to alkaline attacks. According to the studies, 5%, 10%, and 15% of CPA replacements are non-reactive to ASR attacks, respectively. The findings reveal that cassava peel ash at appropriate doses (5%, 10%, and 15%) significantly reduces ASR development even in types of cement with adequate alkali content. Utilizing portlandite, releasing silicon and aluminum into solution, and lowering the alkali content of the pore solution are all SCM capabilities that are associated with reduced ASR growth. It was also discovered that the 10% substitution was more effective at reducing alkaline silica reactivity.

## 5.2 Recommendation

1. As a result, it is suggested that the effect of superplasticizer be explored on concrete enhanced with CPA at a percentage substitution of cement of no more than 15% by weight.
2. More research should be done on partial cement substitution with CPA utilizing various mix ratios.

## 5.3 Contribution to the knowledge

1. This study closes a knowledge gap on the efficiency of cassava peel ash (CPA) as a pozzolanic material to prevent the ASR in concrete. This study's Accelerated Mortar Bar Test (AMBT) technique more closely resembled the mix of ASR and environmental-caused deterioration observed in the field.

2. Never before has an electrical resistivity test been used to evaluate the mechanical properties of concrete that partially substitutes CPA for cement. The advancement of non-destructive testing (NDT) in the testing of building materials is a fruit of this research.

3. The study contributes to sustainable and cost-effective building by promoting the use of CPA, which reduces CO2 emissions caused by the production of cement.

4. The research establishes a valuable method of transforming waste (cassava peel) into money, thereby reducing ASR in concrete, addressing environmental issues, and offering economic benefits to society.

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# APPENDICES

**Appendix I:** **USCS definition of particle sizes**



**Appendix II: AASHTO classification of soils and soil aggregate mixtures**

