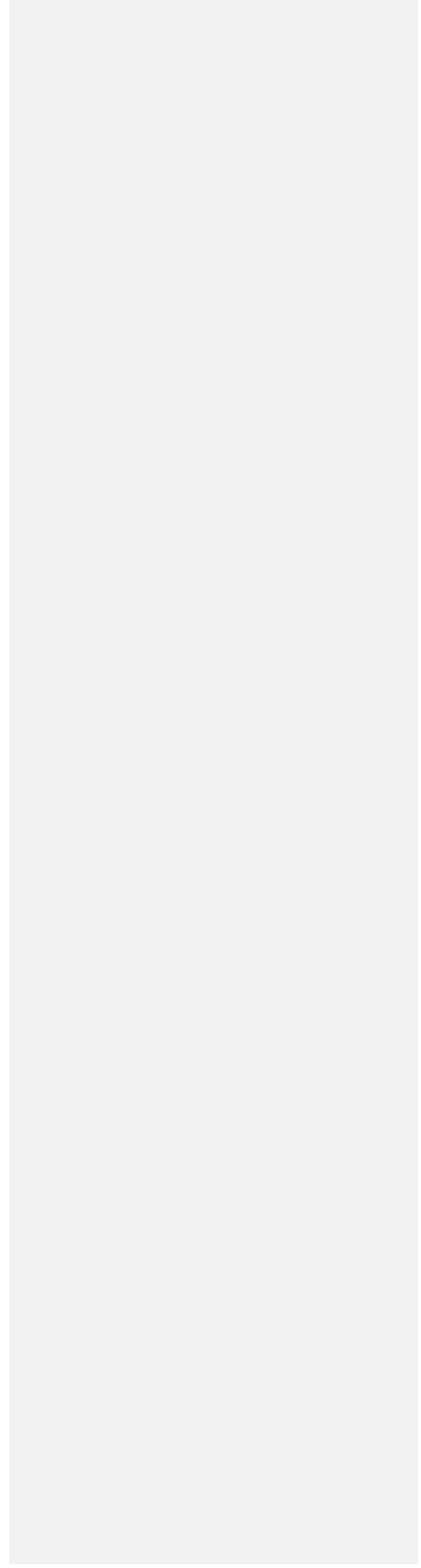


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EVALUATION OF PLANTAIN PEEL ASH AS AN
ADMIXTURE

BY

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POST
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NIGERIA

JULY, 2016

DECLARATION

I declare that the work in this project thesis entitled “EVALUATION OF PLANTAIN PEEL ASH AS AN ADMIXTURE” has been carried out by me in the Department of Civil engineering. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this project thesis was previously presented for another degree or diploma at this or any other institution.

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Date

CERTIFICATION

This project thesis entitled “EVALUATION OF PLANTAIN PEEL ASH AS AN ADMIXTURE by INUSA LAWAN” meets the regulations governing the award of the degree of MSC. (CIVIL ENGINEERING) OF The Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

This study had investigated the admixture properties of plantain peel ash through a series of laboratory experiments. This was targeted at obtaining an effective admixture while relieving the environment from the menace of environmental pollution arising from indiscriminate disposal of agricultural wastes. Plantain peel ash was blended with dry cement at 11 different percentage additions at 0%, 0.2%, 0.4% up to 2.0% for cement pastes and mortar. The cement paste was tested for setting time and soundness to BS EN 196:3-1995 while mortar prisms were tested for flexural and compressive strength to BS EN 196:1 1995, after which, scan electron microscopy (SEM) was carried out on samples of mortar tested at 28 days. Setting time tests results has indicated a retardation in setting of the cement paste with the addition of plantain peel ash whereas the early strength development of the cement was delayed by the ash additions as indicated by the strength tests. From the soundness test results, the ash was found to have no impact on the soundness of the cement as the maximum expansion recorded was 1mm at 0.2% and 1.0% ash contents. The result of the SEM analysis indicated that a mortar prism with higher ash contents tends to have a more porous microstructure. Based on the results, the ash was categorized into a class of set retarding admixture as per the provisions of BS EN 934 part 2(2000) while the optimum ash content recommended for use is 1.0% by weight of cement.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	American Society of Testing and Materials
SEM	Scanning Electron Microscope
XRF	X-Ray Fluorescence
PPA	Plantain Peel Ash

Cement Chemistry Nomenclature

SO ₃	Sulfur Trioxide
C ₃ A	Tricalcium Aluminate, 3CaO. Al ₂ O ₃
C ₄ AF	Tetracalcium AluminoFerrite, 4CaO. Al ₂ O ₃ . Fe ₂ O ₃
C ₂ S	Dicalcium Silicate, 2CaO. SiO ₂
C ₃ S	Tricalcium Silicate, 3CaO. SiO ₂
CH	Calcium Hydroxide, Ca(OH) ₂
CS ₂	H ₂ Gypsum, Ca ₂ SO ₄ .H ₂ O
C-S-H	Calcium Silicate Hydrate
Na ₂ O _e	Equivalent Alkali Content as Na ₂ O

CHAPTER ONE

INTRODUCTION

1.1 General Background

According to ASTM C 494 (1992), Admixture is defined as a material, other than cement, water and aggregates, that is used as an ingredient of concrete and is added to the batch immediately before or during mixing. They are broadly divided into mineral and chemical admixtures. Chemical admixtures are commonly classified by their functions in concrete into seven types, as specified in ASTM C 494 (1992) viz: Type A- Water reducing, Type B-Retarding, Type C- Accelerating, Type D- Water – Reducing and Retarding, Type E -Water-Reducing and Accelerating, Type F-High-range water-reducing or Superplasticizing and Type G-High-range water-reducing and Retarding or Superplasticizing and retarding. These are added to concrete in very small amounts mainly for the entrainment of air, reduction of water or cement content, plasticization of fresh concrete mixtures, or control of setting time.

Mineral admixtures in the other hand are usually added to concrete in larger amounts to enhance the workability of fresh concrete; to improve resistance of concrete to thermal cracking, alkali-aggregate expansion, and sulfate attack; and to enable a reduction in cement content. The source of mineral admixtures could be natural or artificially obtained as a by-product in the form of ashes, from the combustion of coal and some crop residues. .

Neville, 2005

Dumping of these by-products into landfills and streams, amounts to a waste of the material and causes serious environmental pollution. With proper quality control, large amounts of many industrial by-products can be incorporated into concrete, either in the form of blended Portland cement or as mineral admixtures.

Plantain peel are by-products of the plantain processing industry, which are normally dumped in landfills, rivers or unregulated grounds. National and international production of banana and plantain is ever booming, while local and domestic consumption is on the increase; but national and international programs for the resulting waste peel are rare, perhaps because information is lacking on the resources inherent in the waste peel; consequently, a huge amount of waste peel is dumped daily especially in Nigeria. A geometric increase in the generation of solid wastes in Nigeria calls for a sustainable management options in which reuse and recycling top the list (Babayemi and Dauda 2009).

From the available literature, most of the studies conducted on the waste peel of plantain are science based. These researches however provide an idea of the chemical composition of the peel, based on which further studies could be carried out on the material especially its engineering properties.

In this study, the admixture properties of unripe plantain peel ash and its effect on the strength of cement will be investigated. Due to its alkaline nature as established by Onyegbado et al, 2002, its possible adverse effect on the total alkali content of the paste will be assessed.

1.2 Statement of the Problem

.A study of the various researches carried out on mineral admixture derived from agricultural wastes, shows that they mostly focus on their use as pozzolanas. This study will therefore rather aim at producing a mineral admixture derived from plantain peel that will only be required in small dosages to perform its functions as an accelerator, retarder or any other type of admixture as established after characterizing the material.

Nigeria is one of the largest plantain producing countries in the world (FAO, 2006). She ranked first in Africa and fifth in the world producing 2,722,000 metric tones in 2011 (FAO, 2012). Despite this large production, she does not export plantain because its production is largely consumed locally. The rise in cottage industries that make use of plantain for snacks (plantain chips) in the non-farming urban population coupled with the demand for easy and convenient foods made from plantain locally, made its consumption to be on the increase (Akinyemi et al., 2010). The high demand for plantain also generates wastes which are often discarded, and sometimes used for animal feeds.

1.3 Justification for the study

Based on the findings of Olabanji et al.2012, the plantain peel ash contain high percentage of potassium(K), calcium (Ca) and iron (Fe) as reported by Olabanji et al (2012).

Bentz (2006) has reported that the addition of alkalis of lithium, sodium and potassium increases the early rate of cement hydration but reduces later age hydration and strength development. Based on the foregoing, it is important to study the admixture properties this material and its possible effects on some cement properties.

1.4 Aim and Objectives

1.4.1 Aim

The aim of this study is to investigate the admixture properties of plantain peel ash (PPA), characterize same study its effect on the strength and soundness of cement.

1.4.2 Objectives

The objectives of this research are to:

- i. Determine the chemical composition of PPA
- ii. Investigate the effect of PPA on hydration, strength and soundness.
- iii. Study and analyze the effect of the ash on the micro structure of cement-sand mortar
- vi. Characterize the ash into the appropriate category of admixture as per BS EN 934 part 2, 2000, based on its properties observed.

1.5 Scope and limitations

1.5.1 Scope

This research work presents an investigation into the suitability of PPA as an admixture in concrete. The effect of PPA on the strength and soundness of cement will be investigated. Setting time tests will be conducted on normal cement paste to obtain control data. The test shall then be carried out on cement paste with various contents of the ash. The percentages of the ash used in the setting time test shall then be applied to produce mortar prisms, which would be eventually subjected to flexural and compressive

strength tests, soundness and micro structure analysis. Mortar prisms will also be cast with concrete produced at 0% ash content to serve as control specimens.

1.5.2 Limitations

The research will be limited to the characterization of unripe plantain peel ash into the appropriate category of admixture in accordance with the specific requirements of BS EN 934 part 2, (2000)after studying its effect on the strength, setting time and soundness of cement. Other parameters like water reduction and air content will not be checked.

CHAPTER TWO
LITERATURE REVIEW

2.1 Preamble

This chapter reviews the relevant literature on the topic of this study. It presents the works of other researchers in the fields of applied sciences and engineering as they relate to this study, which covers the plantain peel ash (PPA), cement and admixtures.

2.2 Plantain Peel Ash (PPA)

Plantain peel are by-products of the plantain processing industry, which are normally dumped in landfills, rivers or unregulated grounds (Osma *et al.*, 2007). The peel of the fruit is discarded as waste after the inner fleshy portion has been eaten, thereby constituting a menace to the environment, especially where its consumption is common.

Although the use of the plantain peel ash as an admixture in concrete was not found to have been reported, ash of the plantain peel has been studied by many researchers in the field of applied sciences. According to Crosby (1977), the ash is produced by burning the dried peel in a porcelain crucible placed in a Gallenkamp muffle furnace for 6 h by stepwise increase of the temperature up to 500°C The ashed samples (grey in colour) are then homogenized in porcelain mortar and pestle and sieved (Olabanji et al 2012).

Igboegwu (2013) has analyzed the metals contained in the plantain peel ash, and he obtained the ash through an open air burning of the dried peel.

2.2.1 Chemical composition of plantain peel ash (PPA)

Olabanji et al (2012) have carried out an analysis on the elemental composition of plantain peel ash, with a view to using it as a cheap source of alkali for soap making. They collected a sample of unripe plantain from a farmland in Obafemi Awolowo University Ile-Ife, Nigeria. The plantain peel ash was made from the sample as stated above.

The analysis revealed the ash to have a chemical composition as presented in Table 2.1.

Table 2. 1: Concentrations and percentage compositions of ash derived alkali from banana and plantain peel.

<u>Element</u>	<u>Concentration in PP (mg/kg) ± SD</u>	<u>Composition of elements (%)</u>	<u>Conc. of BP (mg/kg) ± SD</u>	<u>Composition of elements (%)</u>
<u>Ca</u>	<u>106.78±0.00</u>	<u>14.98</u>	<u>76.86±0.00</u>	<u>17.5</u>
<u>Mg</u>	<u>66.48±0.00</u>	<u>9.33</u>	<u>32.33±0.01</u>	<u>7.36</u>
<u>K</u>	<u>231.93±0.00</u>	<u>32.54</u>	<u>181.99±0.0</u>	<u>41.45</u>
<u>Na</u>	<u>2.66±0.00</u>	<u>0.37</u>	<u>3.18±0.00</u>	<u>0.72</u>
<u>Mn</u>	<u>29.64±0.00</u>	<u>4.16</u>	<u>23.74±0.00</u>	<u>5.41</u>
<u>Fe</u>	<u>241.63±0.00</u>	<u>33.9</u>	<u>99.18±0.02</u>	<u>22.58</u>
<u>Cu</u>	<u>2.45±0.00</u>	<u>0.34</u>	<u>1.67±0.00</u>	<u>0.38</u>
<u>Zn</u>	<u>30.70±0.00</u>	<u>4.31</u>	<u>19.74±0.00</u>	<u>4.5</u>
<u>Pb</u>	<u>0.02±0.00</u>	<u>0.003</u>	<u>0.02±0.00</u>	<u>0.005</u>
<u>Cr</u>	<u>0.02±0.00</u>	<u>0.003</u>	<u>0.04±0.00</u>	<u>0.009</u>
<u>Cd</u>	<u>0.003±0.00</u>	<u>0</u>	<u>0± 0.00</u>	<u>0</u>
<u>Pd</u>	<u>0.07±0.03</u>	<u>0.01</u>	<u>0.05±0.02</u>	<u>0.01</u>
<u>Ni</u>	<u>0.06±0.02</u>	<u>0.0084</u>	<u>0.05±0.02</u>	<u>0.011</u>
<u>Ag</u>	<u>0.02±0.01</u>	<u>0.0028</u>	<u>0.02±0.00</u>	<u>0.005</u>
<u>B</u>	<u>0.23±0.02</u>	<u>0.03</u>	<u>0.19±0.01</u>	<u>0.04</u>
<u>Al</u>	<u>0.03±0.01</u>	<u>0.004</u>	<u>0.019±0.01</u>	<u>0.044</u>
<u>Total</u>	<u>712.72</u>	<u>-</u>	<u>99.99</u>	<u>439.08</u>
<u>PP-Plantain peel</u>			<u>BP-Banana peel</u>	

Olabanji et al (2012)

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One of the most widely used method for the determination of chemical composition of solid minerals and other substances is the X-ray fluorescence (XRF). This is a process used for routine, relatively non-destructive chemical analyses of rocks, minerals, sediments and fluids. The analysis of major and trace elements in geological materials by x-ray fluorescence is made possible by the behavior of atoms when they interact with radiation. When materials are excited with high-energy, short wavelength radiation (e.g., X-rays), they can become ionized. If the energy of the radiation is sufficient to dislodge a tightly-held inner electron, the atom becomes unstable and an outer electron replaces the missing inner electron. When this happens, energy is released due to the decreased binding energy of the inner electron orbital compared with an outer one. The emitted radiation is of lower energy than the primary incident X-rays and is termed fluorescent radiation. Because the energy of the emitted photon is characteristic of a transition between specific electron orbital's in a particular element, the resulting fluorescent X-rays can be used to detect the abundances of elements that are present in the sample. (Karl et al.,2013)

Igboegwu (2013), has analyzed plantain peel ash with a view of using it as an alternative source for bases in acid-base titrations in chemistry practicals, and the study had shown that plantain peel ash have the following properties:

- Has a bitter test
- Soapy to touch
- Turned moist red litmus paper blue
- Concentrated forms not corrosive

From the above studies, it is understood that PPA is rich in calcium, potassium, iron and magnesium, the oxides of which were found to have one effect or another on the properties of cement/concrete either in fresh or hardened state.

2.2.2 Properties of other agro waste ashes

Ghassan and Hilmi (2010) have investigated the properties of rice husk ash and their study revealed the specific gravity of the ash to be 2.11. The works of Padma et al (2014) and Naveen et al (2015) had shown that partial replacement of cement with rice husk ash had improved the compressive strength of concrete.

Saw-dust which is another agricultural waste, was reported by Marthong (2012) to have a Specific gravity of 2.51.he cocluded that the partial replacement of cement with saw dust ash has increased the setting btime and improved the compressive strength of concrete.
Abdurr-Raheem and Sulaiman (2013) and the chemical analysis carried out in the course of his study revealed the ash to contain the oxides presented in Table 2.2

Table 2.2: Detectable chemical composition of saw dust ash

<u>Chemical Constituent</u>	<u>Percentage Composition</u>
<u>SiO₂</u>	<u>66.74</u>
<u>Al₂O₃</u>	<u>5.67</u>
<u>Fe₂O₃</u>	<u>3.39</u>
<u>CaO</u>	<u>1.85</u>
<u>MgO</u>	<u>3.72</u>
<u>SO₃</u>	<u>2.54</u>
<u>K₂O</u>	<u>12.67</u>
<u>Na₂O</u>	<u>0.92</u>
<u>PK₂</u>	<u>2.5</u>

Abdurr-Raheem and Sulaiman (2013)

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2.3 Chemical composition of ordinary Portland cement (OPC)

The raw materials used in the manufacture of Portland cement consist mainly of lime (CaO), silica (SiO₂), alumina (Al₂O₃) and iron oxide (Fe₂O₃). The four compounds are usually regarded as the major constituents of cement. They are described in abbreviated form by cement chemists as follows: CaO = C; SiO₂ = S; Al₂O₃ = A; and Fe₂O₃ = F. Likewise, H₂O in hydrated cement is denoted by H, and SO₃ by S. In addition to the main compounds listed above, there exist minor compounds, such as MgO, TiO₂, Mn₂O₃, K₂O and Na₂O; they usually amount to not more than a few per cent of the mass of cement. Two of the minor compounds are of particular interest: the oxides of sodium and potassium, Na₂O and K₂O, known as the alkalis.

They have been found to react with some aggregates, the products of the reaction causing disintegration of the concrete, and have also been observed to affect the rate of the gain of strength of cement(Neville,2005).

The relative proportions of these oxide compositions are responsible for influencing the various properties of cement; in addition to rate of cooling and fineness of grinding.

Table 2.3 shows the approximate oxide composition limits of ordinaryPortland cement.

Table 2.3: Approximate Oxide Composition Limits of Ordinary PortlandCement

<u>Oxide</u>	<u>Per cent content</u>
<u>CaO</u>	<u>60-67</u>
<u>SiO₂</u>	<u>17-25</u>
<u>Al₂O₃</u>	<u>3.0-8.0</u>
<u>Fe₂O₃</u>	<u>0.5-6.0</u>
<u>MgO</u>	<u>0.1-4.0</u>
<u>Alkalies (K₂O, Na₂O)</u>	<u>0.4-1.3</u>
<u>SO₃</u>	<u>1.3-3.0</u>
	-

Shetty ,(2005).

The oxides present in the raw materials when subjected to highclinkering temperature Combine with each other to form complex compounds. The identification of the major compounds is largely based on R.H. Bogue’s work and hence it is called “Bogue’s Compo unds”. The four compounds usually regarded as major compounds are tricalcium silicate

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(C₃S), dicalcium silicate (C₂S), tricalcium aluminate (C₃A) and tetracalciumaluminoferrite (C₄AF). Shetty, (2005).The Bogue's formula used in calculating the percentage of the various compounds is given as follows:

$$\underline{C_3S = 4.07 (CaO) - 7.60 (SiO_2) - 6.72 (Al_2O_3) - 1.43 (Fe_2O_3) - 2.85 (SO_3)}$$

$$\underline{C_2S = 2.87 (SiO_2) - 0.754 (3CaO.SiO_2)}$$

$$\underline{C_3A = 2.65 (Al_2O_3) - 1.69 (Fe_2O_3)}$$

$$\underline{C_4AF = 3.04 (Fe_2O_3)}$$

2.3.1 Effect of Alkali on the properties of cement

Bentz (2006) reported that the addition of the alkalis of lithium, sodium and potassium have each accelerated the early age hydration of cement paste. However what is considered as the critical adverse effect of alkalis in cement is the propagation of alkali-silica reaction (ASR) when the alkali level is beyond the specified maximum. However, Ahmed and Asmaa (2012) opined that the addition of alkalis has retarded the initial and final setting times of ordinary Portland cement ASTM Type I, while its later age strength was improved.

According to Newzealand ready mixed concrete association (NZRMCA 2004), most alkali in concrete is supplied as sodium (Na) or potassium (K) ions. The other alkali metals may not contribute significantly to ASR damage. The total alkali content of a concrete or cement paste is therefore taken as the sum of the equivalent alkali of the individual constituents given by

$$\underline{Na_2O_e (\%) = Na_2O (\%) + 0.658 K_2O (\%) \dots \dots \dots (1)}$$

Where: Na_2O_e is the total equivalent alkali in the form of Na_2O from various constituents (cement, aggregates, water and admixture).

Na_2O is the percentage of sodium oxide from various constituent materials K_2O is the percentage of potassium oxide from various constituent materials. ASTM C-150 has restricted the total alkali content in concrete to 0.6% by mass of the cement or 3kg/m^3 of concrete where there is tendency of alkali-silica reactivity (ASR).

In a research conducted by Reddy *et al.* (2011), in which the effect of potassium chloride (KCl) on Ordinary Portland cement (OPC) concrete was investigated, it has been reported that both compressive and tensile strength of the concrete increases with an increase in KCl concentration. Meanwhile, initial and final setting times were both retarded with the addition of KCl in the mixing water when compared with the control specimen. Halaweh (2006) carried out a detailed study on the effect of alkalis and sulphates on Portland cement. He concluded that the addition of alkalis influences the rate of hydration, decreases strength development but increases the porosity of the microstructure of cement sand mortar. He also concluded that sulphates addition counteract the hydration effect of the alkalis. Smaoui *et al.* (2005) also opined that cement pastes with high alkali content in the form of NaOH have a more porous micro-texture at all ages, translating to lower compressive strength as compared to the one with low alkali level. The porosity of the microstructure of mortar or concrete is commonly observed and analyzed through scan electron microscope (SEM).

According to Susan (2012), the scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that are derived from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample. These signals include secondary electrons (that produce SEM images), backscattered electrons (BSE), diffracted backscattered electrons (EBSD that are used to determine crystal structures and orientations of minerals), photons (characteristic X-rays that are used for elemental analysis and continuum X-rays), visible light (cathodoluminescence-CL), and heat.

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2.4 Standard Tests on Cement

2.4.1 Fineness Test on cement

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence fastens the development of strength.

Fineness of cement is tested by sieving or by determination of specific surface (total surface area of all the particles in one gram of cement) by air permeability

expressed as cm²/gm or m²/kg. Generally, Blaine Air permeability apparatus is used. This test is conducted as per BS EN196-6:1995. This should be 3.25cm²/g according to BS EN 197:1 (2000)

2.4.2 Consistency test on cement

Standard consistency of a cement paste is defined as that water content which will permit a vicat plunger having 10 mm dia and 50 mm length to penetrate to a depth of 33-35 mm from top of the mould. For the determination of the initial setting time, final setting time and soundness, neat cement paste of standard consistency has to be used. The consistency is determined by the Vicat apparatus, which measure the length of the plunger under its own weight.

2.4.3 Setting time test on cement

Setting time is the term used to describe the stiffening of the cement paste. Broadly speaking, setting refers to a change from fluid to a rigid state, caused by the selective hydration of C₃A and C₂S and which is accompanied by a temperature rise.

Initial setting time is that time period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould.

Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression.

The setting time test is carried out using the Vicat apparatus as per BS-EN 196 part3 (1995). The results of the test should comply with the requirements of BS-EN 197 part1 (2000), which recommend a minimum of 60 minutes and a maximum of 10 hours as the initial and final setting times of ordinary Portland cement respectively.

According to Marthong, (2012), the addition of saw dust ash in OPC grade 42.5 R had increased the initial and final setting times. This was attributed to the low rate of hydration in the paste containing the saw dust ash.

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2.4.4 Soundness test on cement

In the soundness test a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is sped up and can be detected. Soundness means the ability to resist volume expansion. For ordinary Portland cement, BS-EN 197 part1 (2000) has specified a maximum expansion of 10mm.

The work of Chowdhury et al. (2015) indicated that the soundness of cement was improved with the addition of saw dust ash as partial replacement. In the research, cement was replaced by the ash within the range of 5% to 30% and the soundness was found to increase with an increase in the ash content.

2.4.5 Strength test on cement

Marthong. (2012) reported that the addition of saw dust ash in OPC concrete has delayed the early strength development of the concrete due to its retarding effect as established in the course of his study.

The work of Musbau(2012) revealed that cassava peel ash if blended into concrete contribute more to its later age strength than the early age. In the research, cassava peel ash was used as partial replacement for cement between 5% to 25%, at intervals of 5%.

The strength of cement is tested through compression, direct tension or flexure tests. According to BS-EN 196 part1 (1995), prisms of size 40mmx40mmx160mm are cast of a cement sand mortar produced using 1:3 mix ratio. The test prisms are tested for compressive strength at 2days and 28 days. According to BS 5826, cement mortar is classified into M4, M6, and M12 with compressive strengths of 4N/mm², 6N/mm², and 12N/mm² respectively at 28 days. BS EN 998 part 2 (2003) had also provided similar specifications. These are presented in Tables 2.4 and 2.5.

Table 2.4: BS EN 998 :1:2003 Mortar specifications

<u>CLASS</u>	<u>Compressive strength</u>
<u>M1</u>	<u>1.0 N/mm²</u>
<u>M 2.5</u>	<u>2.5 N/mm²</u>
<u>M 5</u>	<u>5.0 N/mm²</u>
<u>M10</u>	<u>10 N/mm²</u>
<u>M15</u>	<u>15 N/mm²</u>
<u>M 25</u>	<u>25 N/mm²</u>
<u>M d</u>	<u>d N/mm²</u>
<u>d is a compressive strength greater than 25 N/mm² declared by the manufacturer.</u>	

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Table 2.5: BS 5628-1:1991/EN 1996-1-1 Mortar specifications

<u>BS 5628-1: 1991 mortar designation</u>	<u>EN 1996-1-1 classification</u>	<u>Mortar compressive strength</u>
<u>(i)</u>	<u>M12</u>	<u>12.0 N/mm²</u>
<u>(ii)</u>	<u>M6</u>	<u>6.0 N/mm²</u>
<u>(iii)</u>	<u>M4</u>	<u>4.0 N/mm²</u>
<u>(iv)</u>	<u>M2</u>	<u>2.0 N/mm²</u>

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2.5 Standard sand for cement mortar

According to the European committee on standardization (CEN), the sand to be used for the testing of the compressive strength of cement should be natural, siliceous sand consisting preferably of rounded particles and has a silica content of at least 98 %. It should also comply with the grading standard provided by BS-EN 196 part1 (1995) as contained in Table 2.6.

Table 2.6: Specification for sand

<u>Square mesh size (mm)</u>	<u>Cumulative sieve residue (%)</u>
<u>2</u>	<u>0</u>
<u>1.6</u>	<u>7 ± 5</u>
<u>1</u>	<u>33 ± 5</u>
<u>0.5</u>	<u>67 ± 5</u>
<u>0.16</u>	<u>87 ± 5</u>
<u>0.08</u>	<u>99 ± 1</u>

BS-EN 196 part1 (1995)

2.6 Admixtures

Apart from the types of admixture mentioned in chapter I as classified by the ASTM, other special admixtures exist which include water proofing admixtures, coloring admixtures, corrosion inhibitors, air entrainers etc. For any type of admixture, EN 934-2:2001 has prescribed a general requirements which shall be met for a material to be categorized as an admixture. These requirements are presented in Table 2.7.

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Table 2.7 General Requirements of an admixture

<u>NO</u>	<u>PROPERTY</u>	<u>TEST METHOD</u>	<u>REQUIREMENTS</u>
<u>1</u>	<u>Homogeneity</u>	<u>Visual</u>	<u>Homogeneous when used. Segregation shall not exceed the limit stated by the manufacturer</u>
<u>2</u>	<u>Colour</u>	<u>Visual</u>	<u>Uniform and similar to the description provided by the manufacturer</u>
<u>3</u>	<u>Effective component</u>	<u>EN 480-6</u>	<u>IR spectra to show no significant change with respect to the effective component when compared to reference spectrum provided by the manufacturer</u>
<u>4</u>	<u>Relative densitya (for liquids only)</u>	<u>ISO 758</u>	<u>$D \pm 0.03$ if $D > 1.10$, $D \pm 0.02$ if $D \leq 1.10$ where D is manufacturer's stated value</u>
<u>5</u>	<u>Conventional dry material content</u>	<u>EN 480-8</u>	<u>$0.95 T \leq X < 1.05 T$ for $T \geq 20$ % $0.90 T \leq X < 1.10 T$ for $T < 20$ % T is manufacturer's stated value % by mass; X is test result % by mass</u>
<u>6</u>	<u>pH value</u>	<u>ISO 4316</u>	<u>Manufacturer's stated value ± 1 or within manufacturer's stated range</u>
<u>7</u>	<u>Effect on setting at maximum recommended dosage</u>	<u>EN 480-2 using maximum recommended dosage in reference mortar with 4 different cements as EN 480-1</u>	<u>Report results</u>
<u>8</u>	<u>Total chlorinea</u>	<u>ISO 1158</u>	<u>Either ≤ 0.10 % by mass or not above the manufacturer's stated value</u>
<u>9</u>	<u>Water soluble chloride (Cl⁻)</u>	<u>EN 480-10</u>	<u>Either ≤ 0.10 % by mass or not above the manufacturer's stated value</u>
<u>10</u>	<u>Alkali content (Na₂O equivalent)</u>	<u>EN 480-12</u>	<u>Not above the manufacturer's stated maximum</u>

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Table 2.7 continued

<u>11</u>	<u>Corrosion behaviour</u>	<u>f. g</u>	<u>No corrosion promoting effects on steel embedded in concrete</u>
*	-	-	-
<u>A</u>	<u>Manufacturer's stated value shall be provided in writing to the user.</u>		
<u>B</u>	<u>If the method in EN 480-6 is not suitable the manufacturer shall recommend an alternative test method.</u>		
<u>C</u>	<u>If the method in EN 480-8 is not suitable the manufacturer shall recommend an alternative test method.</u>		
<u>D</u>	<u>If there is no significant difference between total chlorine and water soluble chloride content, only</u>		
*	<u>the water soluble chloride content should be determined in subsequent tests on the admixture involved.</u>		
<u>E</u>	<u>The procedure in ISO 1158 shall be modified as follows:</u>		
<u>F</u>	<u>For testing, cement CEM I with C3A content less than 5 % by mass shall be used.</u>		
<u>G</u>	<u>Until there is an accepted European Standard the national regulations in the place of use shall</u>		
<u>H</u>	<u>Where the chloride content is £ 0.10 % by mass, the admixture may be described as "chloride"</u>		

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BS EN 934:2:2000

2.6.1 Water-reducing admixtures

According to ASTM C 494-10, admixtures which are only water-reducing are called Type A, but if the water-reducing properties are associated with retardation, the admixture is classified as Type D. There exist also water-reducing and accelerating

admixtures (Type E) but these are of little interest. However, if the water-reducing admixture exhibits, as a side effect, set retardation, this can be combated by an integral incorporation of an accelerator in the mix. The most common accelerator is triethanolamine.

As their name implies, the function of water reducing admixtures is to reduce the water content of the mix, usually by 5 or 10 per cent, sometimes(in concretes of very high workability) upto 15 per cent. The specific requirements for water reducing admixtures as prescribed by BS EN 934-2:2001 in the Table 2.8.

Table 2.8 – Specific requirements for water reducing/plasticizing admixtures (at equal consistence)

<u>S/N</u>	<u>PROPERTY</u>	<u>REFERENCE CONCRETE</u>	<u>TEST METHOD</u>	<u>REQUIREMENTS</u>
<u>1</u>	<u>Water reduction</u>	<u>EN 480-1 reference concrete I</u>	<u>slump EN 12350-2 or flow EN 12350-5</u>	<u>In test mix ≥ 5 % compared with control mix</u>
<u>2</u>	<u>Compressive strength</u>	<u>EN 480-1 reference concrete I</u>	<u>prEN 12390-3:1999</u>	<u>At 7 and 28 days:Test mix ≥ 110 % of control mix</u>
<u>3</u>	<u>Air content in fresh concrete</u>	<u>EN 480-1 reference concrete I</u>	<u>EN 12350-7</u>	<u>Test mix ≤ 2 % by volume above control mix unless stated otherwise by the manufacturer</u>

BS EN 934:2:2000

2.6.2 Retarding admixtures

A delay in the setting of the cement paste can be achieved by the addition to the mix of a retarding admixture (ASTM Type B), referred to as a retarder. Retarders generally slowdown also the hardening of the paste although some salts may speed up the setting

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but inhibit the development of strength. Retarders do not alter the composition or identity of products of hydration. Retarders are useful in concreting in hot weather, when the normal setting time is shortened by the higher temperature, and in preventing the formation of cold joints. In general, they prolong the time during which concrete can be transported, placed, and compacted. The delaying hardening caused by the retarders can be exploited to obtain an architectural finish of exposed aggregate.

Retarding action is exhibited by sugar, carbohydrate derivatives, soluble zinc salts, soluble borates and some other salts; methanol is also a possible retarder.(Neville 2005). The specific requirements for retarding admixtures as prescribed by BS EN 934-2:2001 in the Table 2.9.

Table 2.9 – Specific requirements for set retarding admixtures (at equal consistence)

S/N	PROPERTY	REFERENCE CONCRETE	TEST METHOD	REQUIREMENTS
1	setting time	EN 480-1 mortar	EN 480-2	Initial: test mix \geq control mix+90 mins Final : test mix \leq control mix +360 mins
2	Compressive strength	EN 480-1 reference concrete I	prEN 12390-3:1999	At 7 days:Test mix \geq 80% of control mix At 28 days: test mix \geq 90% of control mix
3	Air content in fresh concrete	EN 480-1 reference concrete I	EN 12350-7	Test mix \leq 2 % by volume above control mix unless stated otherwise by the manufacturer

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2.6.3 Accelerating admixtures

An accelerating admixture is used to accelerate the rate of hydration (setting) and strength development of concrete at an early age. The most common accelerator used over many decades was calcium chloride. Besides accelerating strength gain, calcium chloride causes an increase in drying shrinkage, potential reinforcement corrosion, discoloration (darkening of concrete), and an increase in the potential for scaling. Steven et al. (1988). The specific requirements for accelerating admixtures as prescribed by BS EN 934-2:2001 in the Table 2.10.

Table 2.10– Specific requirements for set accelerating admixtures (at equal consistence)

<u>S/N</u>	<u>PROPERTY</u>	<u>REFERENCE CONCRETE</u>	<u>TEST METHOD</u>	<u>REQUIREMENTS</u>
<u>1</u>	<u>Initial setting time</u>	<u>EN 480-1 mortar</u>	<u>EN 480-2</u>	<u>At 20° C: test mix ≥ 30 min At 5° C : test mix ≤ 60% of control mix</u>
<u>2</u>	<u>Compressive strength</u>	<u>EN 480-1 reference concrete I</u>	<u>prEN 12390-3:1999</u>	<u>At 28 days: Test mix ≥ 80% of control mix At 90 days: test mix ≥ test mix at 28 days</u>
<u>3</u>	<u>Air content in fresh concrete</u>	<u>EN 480-1 reference concrete I</u>	<u>EN 12350-7</u>	<u>Test mix ≤ 2 % by volume above control mix unless stated otherwise by the manufacturer</u>

BS EN 934:2:2000

2.5.4 Super plasticizers

Super plasticizers are admixtures which are water reducing but significantly and distinctly more so than the water-reducing admixtures. Super plasticizers are also usually

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highly distinctive in their nature, and they make possible the production of concrete which, in its fresh or hardened state, is substantially different from concrete made using water-reducing admixtures of Types A, D, or E because a very low w/c or a high workability can be obtained. The majority of super plasticizers are in the form of sodium salts but calcium salts are also produced; the latter, however, have a lower solubility. A consequence of the use of sodium salts is the introduction of additional alkalis into the concrete which may be relevant to the reactions of hydration of the cement and to a potential alkali-

Silica reaction. For this reason, the soda content of the admixtures should be known; in some countries, e.g. Germany, the content is limited to 0.02 per cent of soda by mass of cement. Super plasticizers do not alter fundamentally the structure of hydrated cement paste, the main effect being a better distribution of cement particles and, consequently, their better hydration. This would explain why, in some cases, these super plasticizers were found to increase the strength of concrete at a constant water/cement ratio. Values of a 10 per cent increase at 24 hours and a 20 per cent increase at 28 days have been quoted, but this behavior has not been universally confirmed. The Table 2.11 presents specific requirements for a super plasticizing admixture.

Table 2.11: Specific requirements for high range water reducing/super plasticizing admixtures (at equal consistence)

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<u>S/N</u>	<u>PROPERTY</u>	<u>REFERENCE CONCRETE</u>	<u>TEST METHOD</u>	<u>REQUIREMENTS</u>
<u>1</u>	<u>Water reduction</u>	<u>EN 480-1 mortar</u>	<u>slump EN 12350-2 or flow EN 12350-5</u>	<u>In test mix \geq 12 % compared with control mix</u>
<u>2</u>	<u>Compressive strength</u>	<u>EN 480-1 reference concrete I</u>	<u>prEN 12390-3:1999</u>	<u>At 1 days: Test mix \geq 140% of control mix At 28 days: test mix \geq 115% of control mix</u>
<u>3</u>	<u>Air content in fresh concrete</u>	<u>EN 480-1 reference concrete I</u>	<u>EN 12350-7</u>	<u>Test mix \leq 2 % by volume above control mix unless stated otherwise by the manufacturer</u>

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CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Introduction

This chapter presents the main materials used in the course of this study which includes Portland cement, sand, water and plantain peel ash (PPA). The methodology adopted in conducting the research, by way of laboratory tests has also been highlighted. These includes tests required to study the basic physical and chemical properties of PPA, the requisite tests conducted on cement and sand as well as the tests carried out on cement-sand mortar, admixed with various ash contents.

3.2 Materials

3.2.1 Plantain peel

(a) Acquisition:

Unripe plantain peel were obtained at the plantain section of Bakindogo vegetables market in Kaduna north local government of Kaduna state.

(b) Drying of plantain peel

The fresh unripe plantain peel were air dried by spreading them on a clean surface in a moisture and dust free environment to expel the moisture contained therein.

(c) Burning of plantain peel

The air dried sample of the peel were carefully burnt to ashes in the open air in a dust free atmosphere.

(d) Sieving and storage

The ash obtained above was sieved through 75micron BS sieve, and the material that passed through was kept in an air tight container for use in the subsequent tests. The sieve was selected such that the test material to be obtained is at least as fine as cement particles.

3.3 Chemical Analysis of PPA

A sample of the sieved ash was subjected to chemical analysis tests in order to determine its chemical/oxide composition. This was carried out at the National Geosciences Laboratories, Barnawa, Kaduna. The analysis was carried out with X-ray fluorescence (XRF) using Minipal4 XRF machine model. During the process, air was used as the carrier medium at 14 kV X-ray current and the measurement time was 100 seconds.

The extract of the results of the analysis are presented in Table 3.1, while a scanned copy of same from the laboratory is attached as an appendix A.

Table 3.1: Oxide compositions of PPA

<u>OXIDE</u>	<u>COMPOSITION(%)</u>
<u>SiO₂</u>	<u>7.84</u>
<u>P₂O₅</u>	<u>3.76</u>
<u>SO₃</u>	<u>2.21</u>
<u>Cl</u>	<u>3.86</u>
<u>K₂O</u>	<u>45.85</u>
<u>TiO₂</u>	<u>0.095</u>
<u>MnO</u>	<u>0.27</u>
<u>Fe₂O₃</u>	<u>0.901</u>
<u>NiO</u>	<u>0.024</u>
<u>CuO</u>	<u>0.081</u>
<u>ZnO</u>	<u>0.29</u>
<u>Na₂O</u>	<u>1.28</u>
<u>MgO</u>	<u>0.38</u>
<u>LOI</u>	<u>33.15</u>

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3.4 Specific gravity test on PPA

The specific gravity of the material was determined in accordance with BS EN 1097-3:1998 using the specific gravity bottle in the concrete laboratory of the Civil engineering department of Ahmadu Bello university Zaria. The results obtained are presented in Table 3.2.

Table 3.2: Results of specific gravity of PPA

<u>Test no.</u>	<u>Specific gravity of ash</u>
<u>1</u>	<u>2.16</u>
<u>2</u>	<u>2.13</u>
<u>3</u>	<u>2.03</u>
<u>Average specific gravity</u>	<u>2.11</u>

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3.5 Fineness test on PPA

The plantain peel ash used in this research has been sieved through a 75micronsieve, which is finer than 90micron sieve specified for fineness test on cement. Hence the material is assumed to have satisfied the fineness requirements that will qualify it to be placed on the same scale with cement.

3.6 Cement

3.6.1 Acquisition:

The cement used in this study was Dangote cement obtained from local outlets.

3.6.2 Fineness Test on Cement

This has been carried out on the cement sample using 90micron sieve as specified in BS-EN 196:6:1995. The test was conducted in the in the concrete laboratory of civil engineering department of Ahmadu Bello university Zaria. The result obtained is presented in Table 3.3.

Table 3.3: Fineness test results

<u>Test no.</u>	<u>Total Weight of cement (g)</u>	<u>weight of residue (g)</u>	<u>percentage residue (%)</u>
<u>1</u>	<u>100</u>	<u>9.5</u>	<u>9.5</u>
<u>2</u>	<u>100</u>	<u>8</u>	<u>8</u>
<u>Average residue (%)</u>			<u>8.75</u>

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3.7 Fine aggregate:

3.7.1 Acquisition

Fine aggregate used for this study was sourced from the river bed.

3.7.2 Grading

The sand used for the strength tests has been subjected to grading analysis in order to ensure its conformity with the standard sand for the purpose as provided in Table 3.3. The grading was carried out as per BS-EN 196-1 1995. The result of the particle size analysis is presented in Table 3.4.

Table 3.4: Results of particle size analysis for sand

<u>Sieve size (mm)</u>	<u>Weight retained (g)</u>	<u>Percentage retained (%)</u>	<u>Cumulative Residue (%)</u>
<u>2</u>	<u>0</u>	<u>0</u>	<u>0</u>
<u>1.6</u>	<u>46</u>	<u>11.5</u>	<u>11.5</u>
<u>1</u>	<u>95</u>	<u>23.75</u>	<u>35.25</u>
<u>0.5</u>	<u>122</u>	<u>30.5</u>	<u>65.75</u>
<u>0.15</u>	<u>88</u>	<u>22</u>	<u>87.75</u>
<u>0.075</u>	<u>46</u>	<u>11.5</u>	<u>99.25</u>
<u>Pan</u>	<u>2</u>	<u>0.5</u>	<u>99.75</u>
<u>Total</u>	<u>399</u>	<u>99.75</u>	<u>-</u>

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3.7.3 Specific gravity of sand.

The specific gravity of the test sand was determined using pycnometer as per ASTM D 854-00. The test was conducted in the in the concrete laboratory of civil engineering department of Ahmadu Bello university Zaria.The results obtained is presented in Table 3.5.

Table 3.5: Results of specific gravity of sand

<u>Test no.</u>	<u>Specific gravity of sand</u>
<u>1</u>	<u>2.50</u>
<u>2</u>	<u>2.78</u>
<u>3</u>	<u>2.38</u>
<u>Average specific gravity</u>	<u>2.55</u>

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3.8 Tests on cement-ash paste

The cement used in this study has been subjected to consistency/setting time, fineness, soundness and strength tests for control purposes while same tests were conducted on the cement containing various percentages of the ash.

3.8.1 Consistency test

The consistency of the fresh cement paste without ash was determined in accordance with BS EN 196: 3-1995 using the vicat apparatus. During this test, a water content equivalent to 31% of the mass of the cement was determined as the consistency of the cement. This value was maintained throughout the setting time and soundness tests conducted at various percentages of ash additions.

3.8.2 Setting Time Tests

The setting time tests were carried out as per the provisions of BS-EN 196:3:1995, carried out to determine the initial and final setting times of the cement pastes produced with various ash content, ranging from 0% to 2% by weight of cement at intervals of 0.2%. the test was carried out in the concrete laboratory of the Civil engineering department of the University. Table 3.6 presents the results of the setting time tests as obtained in the laboratory.

Table 3.6: Setting time test results

<u>Ash content</u> <u>(%)</u>	<u>Setting time (mins)</u>	
	<u>INITIAL</u>	<u>FINAL</u>
<u>0.00</u>	<u>92</u>	<u>272.00</u>
<u>0.2</u>	<u>138</u>	<u>284</u>
<u>0.40</u>	<u>178</u>	<u>296</u>
<u>0.60</u>	<u>216</u>	<u>360</u>
<u>0.80</u>	<u>246</u>	<u>380</u>
<u>1.00</u>	<u>314</u>	<u>394</u>
<u>1.20</u>	<u>220</u>	<u>355</u>
<u>1.40</u>	<u>245</u>	<u>356</u>
<u>1.60</u>	<u>254</u>	<u>355</u>
<u>1.80</u>	<u>253</u>	<u>376</u>
<u>2.00</u>	<u>287</u>	<u>387</u>

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3.8.3 Soundness Test

The soundness test was conducted in order to assess the quality of the cement and also study the effect of the plantain peel ash on the soundness of the cement. The test was carried out as prescribed in BS-EN 196 part 3 (1995).

The results obtained are presented in Table 3.7.

Table 3.7: Results of soundness tests

<u>Ash content (%)</u>	<u>Expansion(mm)</u>
<u>0.00</u>	<u>0.00</u>
<u>0.20</u>	<u>1.00</u>
<u>0.40</u>	<u>0.50</u>
<u>0.60</u>	<u>0.00</u>
<u>0.80</u>	<u>0.00</u>
<u>1.00</u>	<u>1.00</u>
<u>1.20</u>	<u>0.00</u>
<u>1.40</u>	<u>0.00</u>
<u>1.60</u>	<u>0.00</u>
<u>1.80</u>	<u>0.50</u>
<u>2.00</u>	<u>0.00</u>

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3.9 Tests on cement-sand mortar

In the course of the study, the effect of the PPA on the strength of cement was investigated through flexural and compressive strengths of cement-sand mortar admixed with PPA at various percentages.

3.9.1 Preparation of test specimens

The test specimens for the strength tests were 40mmx40mmx160mm cement-mortar prisms. These were prepared at 1:3 mix ratio and 0.5 water-cement ratio. The percentages of the plantain peel ash used was varied into a total number of eleven points, which include 0.0% (control), 0.2%,0.4%,0.6%,0.8%,1.0%,1.2%,1.4%,1.6%,1.8% and 2.0%.

All other procedures in the tests were in accordance with BS EN 196:1:1995.

3.9.2 Flexural strength test

The flexural test was carried out on the prisms by center point using flexural testing machine capable of applying loads up to 10kN. The flexural load was applied at the rate of about 0.15 kN per second. The 160mm long mortar prism was supported at both ends, 30mm from the edge, giving a central gauge length of 100mm. The test was conducted in accordance with BS EN 196:1:1995 as depicted in plate 1.

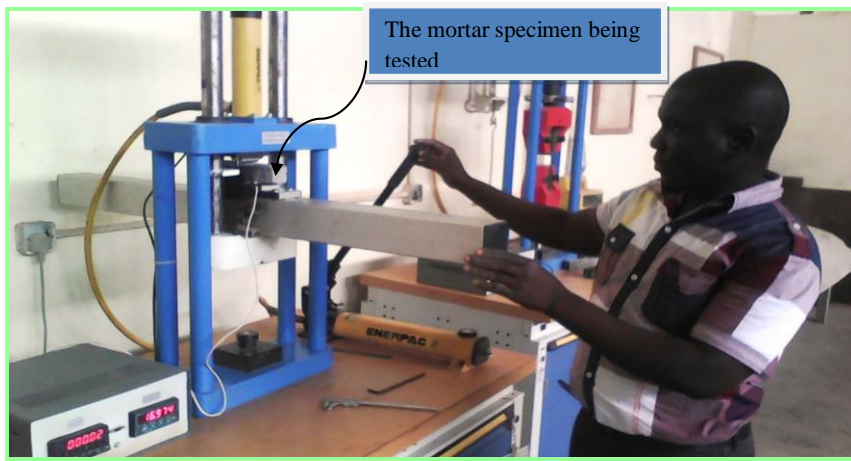


Plate 1: The student conducting flexural test

The flexural strength for each specimen was calculated from the formula provided in BS-

EN 196 part 1 (1995) which is, $R_f = \frac{1.5 \times F_f \times L}{b^3}$ where,

R_f is the flexural strength in N/mm^2

F_f is the load applied to the middle of the prism at fracture in Newtons

b is the side of the square section of the prism in mm and

L is the distance between the supports in mm

The results of the flexural tests at the various ages are presented in Tables 3.8, 3.9, 3.10 and 3.11.

Table 3.8: Flexural strength test results at 2 days

Specimen No. Ash cont. (%)	Strength (N/mm ²)			
	1	2	3	Average
0.00	3.89	4.34	4.83	4.35
0.20	3.63	3.82	3.61	3.69
0.40	3.30	2.84	3.42	3.19
0.60	3.73	3.80	3.47	3.66
0.80	3.91	3.59	3.38	3.63
1.00	4.22	3.49	3.87	3.86
1.20	4.17	4.15	4.29	4.20
1.40	4.24	4.08	3.94	4.09
1.60	3.63	4.22	3.70	3.85
1.80	3.87	3.35	4.24	3.82
2.00	4.15	3.98	4.45	4.20

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Table 3.9: Flexural strength test results at 7 days

Specimen No. Ash cont. (%)	Strength (N/mm ²)			
	1	2	3	Average
0.00	5.86	6.02	4.92	5.60
0.20	6.35	6.56	6.42	6.45
0.40	4.59	5.23	6.05	5.29
0.60	6.05	5.37	5.41	5.61
0.80	5.72	6.42	6.19	6.11
1.00	5.79	5.95	5.74	5.83
1.20	5.30	5.23	5.27	5.27
1.40	6.00	6.38	6.14	6.17
1.60	7.03	6.19	7.59	6.94
1.80	6.87	6.63	6.70	6.73
2.00	5.23	5.60	5.98	5.60

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Table 3.10: Flexural strength test results at 14 days

Specimen No.	Strength (N/mm ²)			
	1	2	3	Average
0.00	6.59	6.98	5.51	6.36
0.20	4.62	4.41	4.80	4.61
0.40	6.00	5.04	1.50	4.18
0.60	4.69	4.80	4.92	4.80
0.80	4.66	5.84	4.88	5.13
1.00	6.07	4.99	5.09	5.38
1.20	4.95	5.72	4.69	5.12
1.40	5.39	4.97	6.28	5.55
1.60	4.57	4.83	4.92	4.77
1.80	4.52	4.90	6.73	5.38
2.00	4.50	5.86	4.78	5.05

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Table 3.11: Flexural strength test results at 28 days

Specimen No.	Strength (N/mm ²)			
	1	2	3	Average
0.00	5.86	5.91	7.29	6.35
0.20	5.91	7.38	6.28	6.52
0.40	7.45	6.82	5.95	6.74
0.60	7.13	5.86	5.39	6.13
0.80	6.96	6.49	7.41	6.95
1.00	6.94	6.49	6.19	6.54
1.20	6.45	6.89	6.12	6.48
1.40	6.07	6.02	6.23	6.11
1.60	6.54	6.14	7.27	6.65
1.80	7.88	7.13	6.89	7.30
2.00	6.75	7.20	4.71	6.22

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3.9.3 Compressive strength test

The compressive strength test was carried out on the two halves of the mortar prisms obtained after the flexural test was carried out. The compressive load was applied on the specimens automatically at the rate of 0.4 kN per second. The test was conducted in accordance with BS EN 196:1 (1995) with compressive strength testing machine in the concrete laboratory of civil engineering department of the university. The results obtained are presented in the tables 3.12 to 3.15.

Table 3.12: Compressive strength test results at 2 days

Specimen no.	Strength (N/mm ²)						Average
	1	2	3	4	5	6	
Ash Cont(%)							
0.00	5.31	5.00	4.69	5.63	5.63	5.31	5.26
0.20	5.00	4.88	4.67	4.82	4.25	4.19	4.64
0.40	4.06	3.75	4.69	4.53	4.38	4.39	4.30
0.60	4.35	4.21	4.21	4.43	4.11	4.35	4.28
0.80	4.55	4.41	4.38	4.60	4.34	4.45	4.46
1.00	4.68	4.38	4.06	4.38	3.97	4.00	4.25
1.20	4.22	4.51	4.38	4.41	4.48	4.01	4.34
1.40	4.04	4.15	4.36	4.36	4.11	4.08	4.18
1.60	4.25	4.27	4.22	4.35	4.44	4.08	4.27
1.80	4.19	4.39	4.25	4.30	4.15	4.22	4.25
2.00	4.38	4.31	4.56	4.50	4.33	4.19	4.38

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Table 3.13: Compressive strength test results at 7 days

Specimen no.	Strength (N/mm ²)						
	1	2	3	4	5	6	Average
Ash Cont(%)							
0.00	7.19	7.00	6.95	6.87	6.96	7.01	7.00
0.20	6.25	6.45	6.38	6.23	6.52	6.44	6.38
0.40	6.56	6.67	6.39	6.55	6.43	6.67	6.55
0.60	8.13	8.18	8.31	8.12	8.24	8.45	8.24
0.80	7.81	7.91	8.05	7.99	8.11	8.20	8.01
1.00	7.50	7.67	7.45	7.39	7.91	7.24	7.53
1.20	9.38	9.40	9.41	9.37	9.61	9.28	9.41
1.40	8.44	8.62	8.45	8.39	8.56	8.38	8.47
1.60	8.13	8.41	8.27	8.55	8.19	8.25	8.30
1.80	8.75	8.59	8.67	8.37	8.59	8.44	8.57
2.00	7.50	7.86	7.77	7.54	7.48	7.38	7.59

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Table 3.14: Compressive strength test results at 14 days

Specimen no.	Strength (N/mm ²)						
	1	2	3	4	5	6	Average
Ash Cont(%)							
0.00	7.50	7.33	7.50	6.88	6.88	7.50	7.27
0.20	5.52	5.38	5.44	5.47	5.60	5.50	5.49
0.40	5.63	5.00	4.38	5.00	5.63	5.55	5.20
0.60	5.60	5.10	5.00	5.11	5.15	5.22	5.20
0.80	5.32	5.00	5.10	5.09	4.99	5.12	5.10
1.00	5.63	4.38	4.38	5.63	5.72	5.44	5.20
1.20	5.39	5.44	5.70	5.68	5.41	5.25	5.48
1.40	5.50	5.36	5.37	5.45	5.31	5.65	5.44
1.60	5.49	5.65	5.81	6.00	5.77	5.48	5.70
1.80	5.89	5.47	6.05	6.11	5.74	5.44	5.78
2.00	6.88	6.25	5.63	6.25	6.25	5.63	6.15

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Table 3.15: Compressive strength test results at 28 days

Specimen no.	Strength (N/mm ²)						Average
	1	2	3	4	5	6	
0.00	7.50	7.81	7.68	7.66	7.97	8.01	7.77
0.20	8.13	7.80	7.96	8.18	8.06	8.00	8.02
0.40	8.11	7.82	8.15	8.22	8.11	8.13	8.09
0.60	8.43	8.41	8.19	8.75	8.53	8.45	8.46
0.80	6.25	7.50	7.85	8.05	7.23	7.55	7.41
1.00	7.50	7.65	7.34	6.88	6.88	7.22	7.25
1.20	6.88	6.88	7.55	8.25	8.11	7.07	7.46
1.40	8.23	8.75	8.75	8.25	9.38	9.15	8.75
1.60	6.87	6.88	7.50	7.50	8.15	7.50	7.40
1.80	6.90	6.87	8.15	8.23	7.50	8.00	7.61
2.00	6.88	8.13	8.13	7.15	7.00	6.88	7.36

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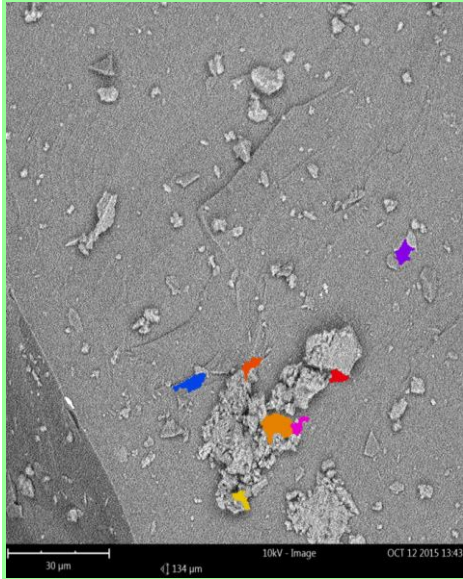
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3.10 Specimen Analysis Using Scan Electron Microscopy

Specimens produced at 0%, 0.2%, 0.6%, 1.0%, 1.4%, 1.8% and 2.0% ash content were subjected to scan electron microscopy (SEM) after crushing at 28 days in order to study the effect of the ash on the morphology and texture of the cement. The results of the SEM analysis are presented in Plates 2-8 and table 3.18



**Plate 2: micro structure for 0.0% PPA content
(Average Pore Area Ratio = 3.76%)**

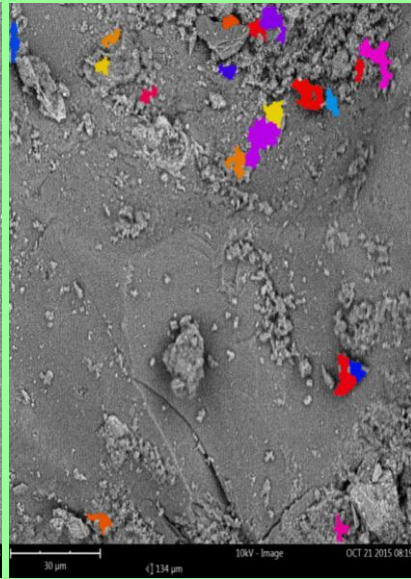
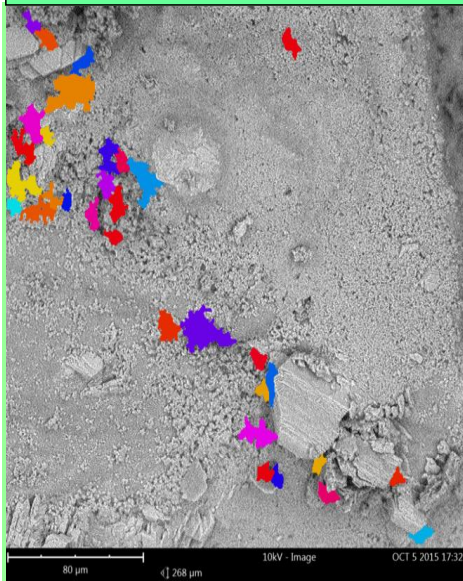
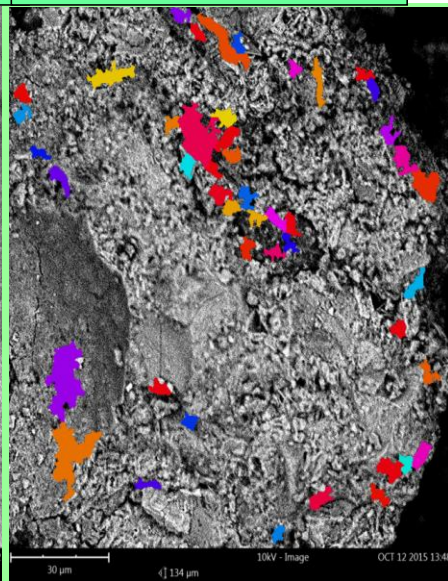


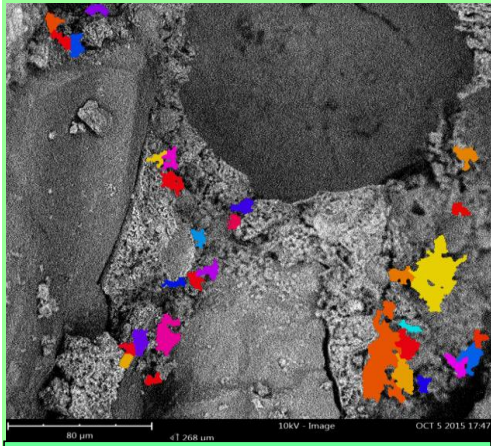
Plate 3: micro structure for 0.2% PPA content



**Plate 4: micro structure for 0.6% PPA content
(Average Pore Area Ratio = 8.56%)**



**Plate 5: micro structure for 1.0% PPA content
(Average Pore Area Ratio = 20.47%)**



**Plate 6: micro structure for 1.4% PPA content
(Average Pore Area Ratio = 49.24%)**

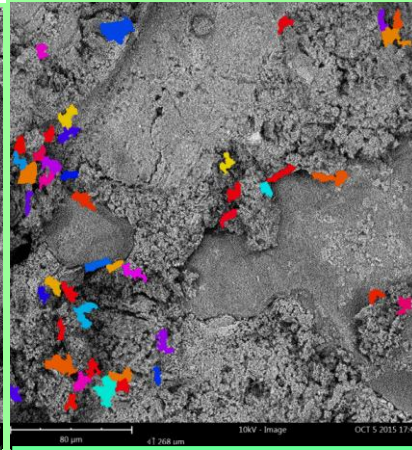
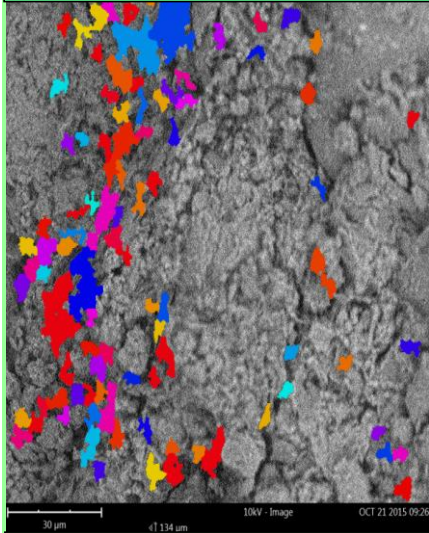


Plate 7: micro structure for 1.8% PPA content



**Plate 8: micro structure for 2.0% PPA content
(Average Pore Area Ratio = 13.95%)**

Table 3.17: Average pore size of mortar relative to ash content.

<u>Ash content (%)</u>	<u>Average pore size (%)</u>
<u>0.0</u>	<u>3.76</u>
<u>0.2</u>	<u>7.08</u>
<u>0.6</u>	<u>8.56</u>
<u>1</u>	<u>20.47</u>
<u>1.4</u>	<u>49.24</u>
<u>1.8</u>	<u>5.96</u>
<u>2.0</u>	<u>13.95</u>

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CHAPTER FOUR

4.0 DISCUSSION OF RESULTS

4.1 Preamble

This chapter discusses and analyses the results obtained in the various tests conducted in chapter three. It compares the results obtained with that of other researchers in similar topics as presented in chapter two. The implication of the results has been also highlighted by drawing appropriate conclusions regarding the effect of the PPA on the particular parameter in issue.

4.2 Analysis of chemical composition of PPA

The results of chemical composition of PPA as presented in Table 3.1 indicated that the ash is lacking in calcium oxide (CaO) and alumina (Al₂O₃) which are very essential for a cementitious property (Neville, 2005). This differ with ordinary Portland cement which contains the two compounds within the ranges of (60-67)% and (3-8)% for CaO and Al₂O₃ respectively. The lack of cementitious property of the ash on itself could be attributed to the absence of CaO in its compositionThe ash is also having only 7.8% silica (SiO₂) as compared to cement with 17-25%. This could be considered as the fundamental reasons why the test material (PPA) lacks pozzolanic properties.

However, the contents of MgO,SO₃ and Fe₂O₃ in the ash are all within similar ranges contained in an ordinary Portland cement as presented in table 2.1. Other oxides found in the ash that are of significance are K₂O and chlorine, which may combine to form KCl. According to Reddy *et al.* (2011), the addition of KCl in concrete had retarded both initial and final setting times while compressive and tensile strengths were

increased. Table 4.1 shows the oxide compositions of Ordinary Portland Cement (OPC) and Plantain Peel Ash (PPA)

Table 4.1: Comparison of OPC, PPA and saw dust ash (SDA) chemical compositions

<u>Oxide</u>	<u>Per cent content</u>	
	<u>OPC (%)</u>	<u>PPA (%)</u>
<u>CaO</u>	<u>60-67</u>	<u>0.00</u>
<u>SiO₂</u>	<u>17-25</u>	<u>7.84</u>
<u>Al₂O₃</u>	<u>3.0-8.0</u>	<u>0.00</u>
<u>Fe₂O₃</u>	<u>0.5-6.0</u>	<u>0.90</u>
<u>MgO</u>	<u>0.1-4.0</u>	<u>0.38</u>
<u>Alkalies (K₂O, Na₂O)</u>	<u>0.4-1.3</u>	<u>47.13</u>
<u>SO₃</u>	<u>1.3-3.0</u>	<u>2.21</u>

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Based on the chemical analysis results in Table 3.1, the percentage contribution of alkali in the form of Na₂O_e from the ash in the mix was calculated for various ash content by using the equation below:

$$\text{Na}_2\text{O}_e = \text{Na}_2\text{O}\% + 0.685 \text{K}_2\text{O}\%$$

Where Na₂O% is the percentage composition of Na₂O in the sample and

K₂O% is the percentage composition of K₂O% in the sample

From the results of chemical composition as contained in Table 3.1,

$$\text{Na}_2\text{O} = 1.28\%$$

$$\text{K}_2\text{O} = 45.85\%$$

Substituting in the above equation, the equivalent alkali was obtained as follows

General alkali contribution due to the ash is thus given by $(1.28+0.685 \times 45.85)/100 = 0.327$.

For the various ash contents, the percentage contribution of alkali into the mix is obtained as a product of the ash percentage (with respect to the cement) and the above factor. This has been used to calculate the alkali contribution into the mix as presented in Table 4.2.

Table 4.2: Plantain peel ash alkali contribution

Ash content in the mix	Alkali contribution from ash (Na ₂ Oe) (%)
0.0	0.00
0.2	0.06
0.4	0.13
0.6	0.19
0.8	0.25
1.0	0.31
1.2	0.38
1.4	0.44
1.6	0.50
1.8	0.57
2.0	0.63

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4.3 Effect of PPA on Setting Time

From the results of setting time tests presented in Table 3.5, it is evident that the setting time of the cement is retarded with an increase in the percentage of the ash added to the mix from 0.2% up to 1%. Beyond 1% the retardation was observed to decline. This has further been demonstrated by the curve in Fig. 4.1. The retarding effect of the ash was also found to be more significant on the initial setting time of the cement. Based on the

results, a further analysis was made to determine the level of retardation of the setting times with respect to the control values. This analysis is presented in Table 4.3.

Table 4.3: Effect of ash content on cement hydration

Ash content (%)	Setting time (mins)		Retardation		Percentage retardation	
	Initial	Final	Initial (min)	Final (mins)	Initial (%)	Final (%)
0.00	92.00	272.00	0.00	0.00	0.00	0.00
0.20	138.00	284.00	46.00	12.00	33.33	4.23
0.40	178.00	296.00	86.00	24.00	48.31	8.11
0.60	216.00	360.00	124.00	88.00	57.41	24.44
0.80	246.00	380.00	154.00	108.00	62.60	28.42
1.00	314.00	394.00	222.00	122.00	70.70	30.96
1.20	220.00	355.00	128.00	83.00	58.18	23.38
1.40	245.00	356.00	153.00	84.00	62.45	23.60
1.60	254.00	355.00	162.00	83.00	63.78	23.38
1.80	253.00	376.00	161.00	104.00	63.64	27.66
2.00	287.00	387.00	195.00	115.00	67.94	29.72

From Table 4.3, it has been observed that the longest retardation of final setting time occurs at 1.0% ash content, at which the final setting time was 394 minutes which translates to 6.6 hours, which is less than 10 hours specified as maximum by BS EN 197:1 (2000). It is also evident that the setting time of the cement was retarded by up to 70% of the normal setting time at 1.0% ash content.

The retardation of setting time could be attributed to the formation of potassium chloride in the paste after water was added to the mix, due to the presence of potassium and chlorine in the ash in the chemical composition, which when adsorbed onto the cement

surface will slow down the rate of initial hydration of the cement. This is in agreement with the work of Reddy et al. (2011) who found out that the addition of KCl in OPC concrete had led to a significant retardation in the setting time. The finding has also agreed with the work of Ahmed and Asmaa (2012), who discovered that the addition of alkalis had led to retardation of initial and final setting time.

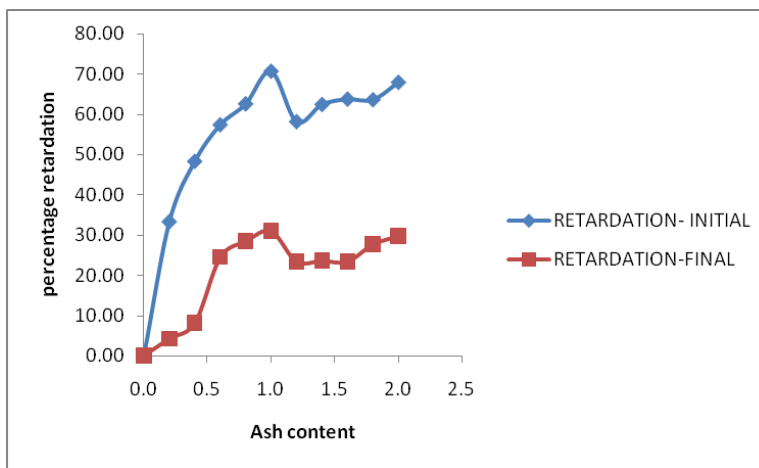


Fig. 4.1: Effect of PPA on retardation of setting time

4.4 Effect Of PPA On Early Strength Development Of Mortar Admixed With Plantain Peel Ash.

From Tables 3.12 and 3.17 of chapter three, it has been noticed that the ash significantly delay early strength development of the cement mortar. This is particularly evident at 2 days at which 5.26N/mm² compressive strength was obtained in control specimen while 4.64N/mm² was obtained at 0.2% ash content, and it has continued to slightly decrease with increase in the ash up to 1.4% beyond which the trend changed. A similar behavior has also been observed with the flexural strength. The reduction in strength at the initial

stages of hydration may be attributed to the retarding effect of the PPA. The initial processes of hydration get retarded, which invariably may affect the initial process of strength development. This concur with the findings of Marthong, 2012 who discovered that the addition of saw dust ash in concrete had reduced its early strength development. This behavior has been depicted on figure 4.2 below.

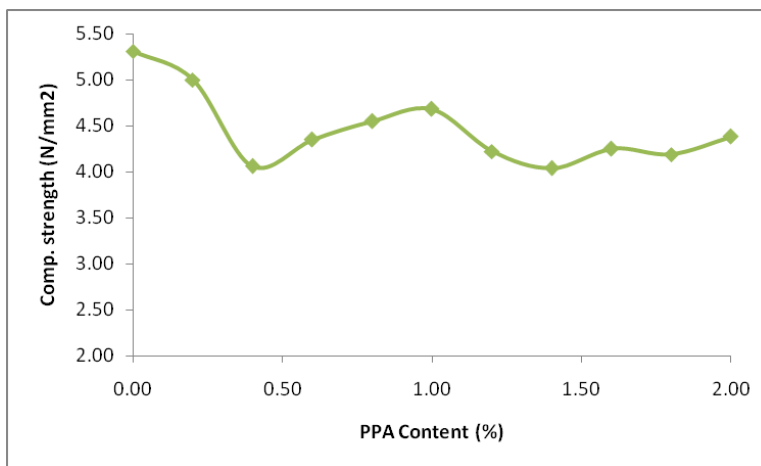


Fig. 4.2: Effect of ash content on early strength development (2 days)

4.5 Effect of curing age on flexural strength of mortar admixed with PPA

From table 3.12, it will be observed that the flexural strength increases gradually from 0 to 14 days for the control specimens. Beyond 14 days, no increase in flexural strength was recorded up to 28 days. The flexural strength was however found to increase with age for most of the points at 2, 7 and 28 days while a slight fall was noticed at 14 days. This behavior is illustrated in figure 4.3.

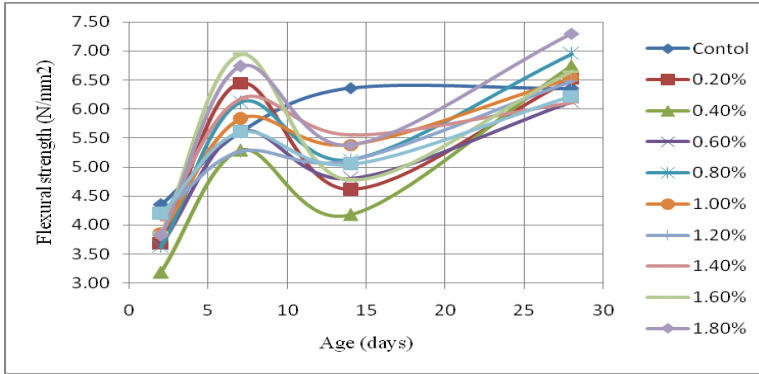


Figure 4.3: Variation of flexural strength with age

4.6 Effect of curing age on compressive strength of mortar admixed with PPA

From Table 3.17 above, it will be observed that the strength obtained for the control specimen at 28 days is 7.77N/mm². This had fallen under M5 mortar class according to BS EN 998 part 2(2003) or M6 mortar as per BS 5826 part 1 mortar classifications as presented in Tables 2.2 and 2.3 respectively.

For the specimens containing ash, it is seen that the strength gain has been retarded by the ash within the age of 2 days. From 2 to 7 days, the compressive strength was improved by the ash content as it will be observed that the control value of 7.00N/mm² obtained at 7 days is less than that obtained at 0.6% to 2.0%. The trend at 14 days however resembled that obtained for flexural strength; i.e. the strength has fallen lower than the 7 days values. From 14 to 28 days, the strength has appreciated at all points. For instance, the strength has increased from 5.44 to 8.75N/mm² at 1.4% ash content. This trend of strength development at later age had followed the findings of Ahmed and Asmaa (2012) which concluded that the addition of alkalis has increased the compressive strength of

ordinary Portland cement ASTM type I. The behavior of the strength development with age is depicted in figure 4.4.

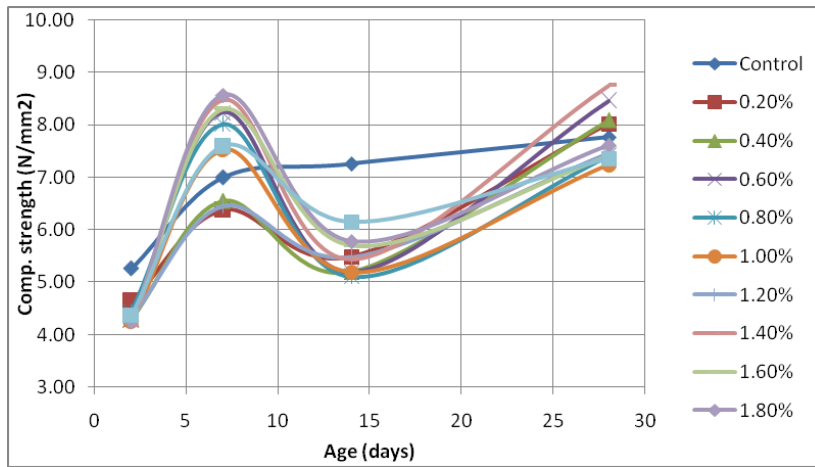


Figure 4.4: Variation of compressive strength with age

4.7 The effect of PPA on soundness

Due to the alkaline nature of the plantain peel ash, it has become necessary to provide a means of ascertaining the total alkali content of a concrete or mortar admixed with the ash and also check its possible adverse effect. The means adopted in this study is to control the alkali coming into the cement paste from the ash and measure the expansion caused at that particular point. Based on the results of chemical analysis of the ash presented in Table 3.1, Table 4.2 was developed, which shows the amount of alkali as a percentage by weight of cement that is going into the overall mix. From this analysis, it was found out that the maximum ash alkali is 0.63% at 2.0% ash content. At this point, no expansion was recorded as indicated by the soundness test results in Table 3.7.A

comparison has also been made between the results of expansion obtained and the maximum limit of 10mm specified by the code. This has been depicted in the bar chart of figure 4.5.

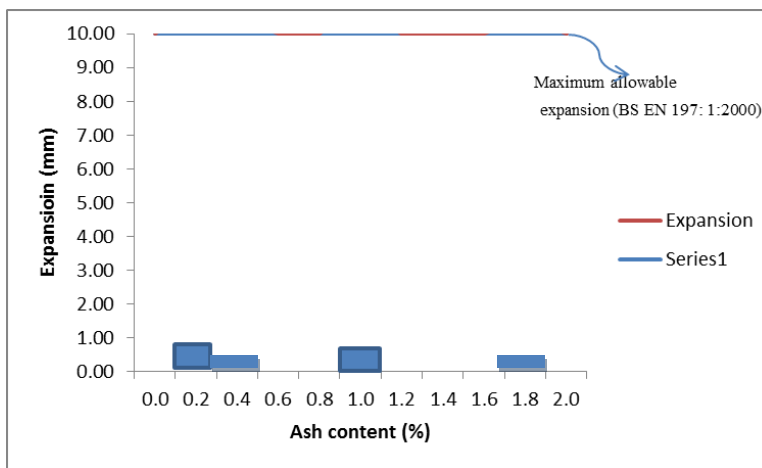


Figure 4.5: Expansion of cement mortar with ash

In general the addition of the ash up to 2% was not found to be harmful to the soundness of the cement. this is because the maximum expansion recorded among the various points is 1mm, which is only 1/10th of the maximum value specified by BS EN 197 part 1 (2000). This agrees with the work of Halaweh (2006) who concluded that the addition of alkalis up to 2.0% did not impact on the expansion of the cement mortar. Based on the findings of Chowdhury et al. (2015) and Marthong (2012), the PPA has similar behaviors with saw dust ash, owing to the fact that it had no negative effect on the soundness and the early hydration of the cement was retarded.

4.8 The effect of PPA on microstructure

From the results of the scan electron microscopy presented in plates 2 to 8, it was observed that the average pore area ratio increases with an increase in the ash content from 3.76% on the control sample up to 49.24% at 1.4%, beyond which the parameter declined. The SEM images also illustrates that mortars with higher ash content had more reticular and porous structure than those with lower ash content. This could be attributed to the higher alkali content in mixes with higher ash content, which is in agreement with the work of Smaoui et al (2005), who found out cement pastes with high alkali content to be more porous. However, this did not affect the compressive strength of the mortar at later ages. This could be due to the effect of SO₃ contained in the ash, which counteract the effect of alkalis on loss of compressive strength as established by Halaweh (2006). The sulfate although has the effect of causing delayed ettringite formation which causes expansion, he had concluded that sulfate levels on the order of 3-3.6%, did not pose any major durability drawbacks under normal curing temperatures and low alkali contents (<1%).

4.9 Characterization of the ash as per BS EN 934 part 2 (2000)

BS EN 934 part 2 (2000) had set a general and specific requirements for materials to satisfy before being classified into a particular admixture type as presented in Tables 2.5 to 2.9. Based on the results obtained in the course of this study, it is evident that the setting time of the cement was retarded by the plantain peel ash while early strength

development has also been delayed. Based on this, the specific requirements of the above code for a set retarder admixture will be used to assess the material by comparing the results obtained with the recommended ones in the code. The analysis was carried out on data obtained on initial and final setting times, 7days and 28 days compressive strength, the summary of which is presented in Tables 4.6 through 4.9.

Table 4.4: Initial setting time criteria for charachterization

<u>Ash content (%)</u>	<u>Initial Setting time (mins)</u>	<u>BS EN 934 requirement (Test mix \geq control mix + 90 mins)</u>	<u>Remarks</u>
Control mix	92	-	-
<u>0.2</u>	<u>138.00</u>	<u>≥ 182</u>	<u>not Satisfied</u>
<u>0.4</u>	<u>178.00</u>	<u>≥ 182</u>	<u>not Satisfied</u>
<u>0.6</u>	<u>216.00</u>	<u>≥ 182</u>	<u>Satisfied</u>
<u>0.8</u>	<u>246.00</u>	<u>≥ 182</u>	<u>Satisfied</u>
<u>1.0</u>	<u>314.00</u>	<u>≥ 182</u>	<u>Satisfied</u>
<u>1.2</u>	<u>220.00</u>	<u>≥ 182</u>	<u>Satisfied</u>
<u>1.4</u>	<u>245.00</u>	<u>≥ 182</u>	<u>Satisfied</u>
<u>1.6</u>	<u>254.00</u>	<u>≥ 182</u>	<u>Satisfied</u>
<u>1.8</u>	<u>253.00</u>	<u>≥ 182</u>	<u>Satisfied</u>
<u>2.0</u>	<u>287.00</u>	<u>≥ 182</u>	<u>Satisfied</u>

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Table 4.5: Final setting time criteria for charachterization

<u>Ash content (%)</u>	<u>Final Setting time (mins)</u>	<u>BS EN 934 requirement (Test mix \leq control mix + 360 mins)</u>	<u>Remarks</u>
Control mix	272.00	-	-
<u>0.2</u>	<u>284.00</u>	<u>≤ 632</u>	<u>Satisfied</u>
<u>0.4</u>	<u>296.00</u>	<u>≤ 632</u>	<u>Satisfied</u>
<u>0.6</u>	<u>360.00</u>	<u>≤ 632</u>	<u>Satisfied</u>
<u>0.8</u>	<u>380.00</u>	<u>≤ 632</u>	<u>Satisfied</u>
<u>1.0</u>	<u>394.00</u>	<u>≤ 632</u>	<u>Satisfied</u>
<u>1.2</u>	<u>355.00</u>	<u>≤ 632</u>	<u>Satisfied</u>
<u>1.4</u>	<u>356.00</u>	<u>≤ 632</u>	<u>Satisfied</u>
<u>1.6</u>	<u>355.00</u>	<u>≤ 632</u>	<u>Satisfied</u>

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<u>1.8</u>	<u>376.00</u>	<u>< 632</u>	<u>Satisfied</u>
<u>2.0</u>	<u>387.00</u>	<u>< 632</u>	<u>Satisfied</u>

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Table 4.6: 7 days compressive strength criteria for characterization

<u>Ash content (%)</u>	<u>7 Days comp. strength (N/mm2)</u>	<u>BS EN 934 requirement (Test mix ≥ 80% of control mix) (N/mm2)</u>	<u>Remarks</u>
<u>Control mix</u>	<u>7.00</u>	<u>-</u>	<u>-</u>
<u>0.2</u>	<u>6.38</u>	<u>≥ 5.6</u>	<u>Satisfied</u>
<u>0.4</u>	<u>6.55</u>	<u>≥ 5.6</u>	<u>Satisfied</u>
<u>0.6</u>	<u>8.24</u>	<u>≥ 5.6</u>	<u>Satisfied</u>
<u>0.8</u>	<u>8.01</u>	<u>≥ 5.6</u>	<u>Satisfied</u>
<u>1.0</u>	<u>7.53</u>	<u>≥ 5.60</u>	<u>Satisfied</u>
<u>1.2</u>	<u>9.41</u>	<u>≥ 5.60</u>	<u>Satisfied</u>
<u>1.4</u>	<u>8.47</u>	<u>≥ 5.60</u>	<u>Satisfied</u>
<u>1.6</u>	<u>8.30</u>	<u>≥ 5.60</u>	<u>Satisfied</u>
<u>1.8</u>	<u>8.57</u>	<u>≥ 5.60</u>	<u>Satisfied</u>
<u>2.0</u>	<u>7.59</u>	<u>≥ 5.60</u>	<u>Satisfied</u>

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Table 4.7: 28 days compressive strength criteria for characterization

<u>Ash content (%)</u>	<u>28 Days comp. strength (N/mm2)</u>	<u>BS EN 934 requirement (Test mix ≥ 90% of control mix) (N/mm2)</u>	<u>Remarks</u>
<u>Control mix</u>	<u>7.77</u>	<u>-</u>	<u>-</u>
<u>0.2</u>	<u>8.02</u>	<u>> 6.99</u>	<u>Satisfied</u>
<u>0.4</u>	<u>8.09</u>	<u>> 6.99</u>	<u>Satisfied</u>
<u>0.6</u>	<u>8.46</u>	<u>> 6.99</u>	<u>Satisfied</u>
<u>0.8</u>	<u>7.41</u>	<u>> 6.99</u>	<u>Satisfied</u>
<u>1.0</u>	<u>7.25</u>	<u>> 6.99</u>	<u>Satisfied</u>
<u>1.2</u>	<u>7.46</u>	<u>> 6.99</u>	<u>Satisfied</u>
<u>1.4</u>	<u>8.75</u>	<u>> 6.99</u>	<u>Satisfied</u>
<u>1.6</u>	<u>7.4</u>	<u>> 6.99</u>	<u>Satisfied</u>
<u>1.8</u>	<u>7.61</u>	<u>> 6.99</u>	<u>Satisfied</u>
<u>2.0</u>	<u>7.36</u>	<u>> 6.99</u>	<u>Satisfied</u>

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The above analysis has shown that plantain peel ash has satisfied all the specific requirements of BS EN 934 part2 (2000) for set retarding admixture except for initial setting time at 0.2% and 0.4%.

4.10 Optimum content of PPA

From the setting time test results, it was observed that maximum retardation of initial and final setting time was achieved at 1.0% ash content. Beyond this point, the level of retardation declined. In terms of strength criteria, the early strength development was found to decrease with an increase in the ash content up to 1.4%. However, at later ages especially 28 days, the ash content did not impact on the strength of the mortar. Based on the fore going, the recommended optimum content is 1.0% because of its economic benefit of being a small quantity. Secondly, at 1.0% ash content the equivalent alkali (Na_2O_e) from table 3.1 is 0.31% by weight of the cement. This value will give room to accommodate cement born alkali, to raise the total alkali content of the whole mix to a maximum of 1.3% (Jawed and Skalny,1978)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Based on the tests conducted in the course of this study, the results obtained and analysis made, the following conclusions could be drawn:

1. An increase in the plantain peel ash content resulted in an increase in retardation of the cement setting time of the cement.
2. Both flexural and compressive strengths of the mortar were delayed at early ages of 2 and 7 days.
3. A loss in strength was experienced over a period of 10 to 16 days at all ash contents
4. The optimum quantity of the ash to be applied to obtain safe and economic effect is 1.0%
5. The addition of plantain peel ash had increase the porosity of the microsture of cement-sand mortar.
6. Based on the characteristics of the ash established, the ash could be classified as a set retardar because it had satisfied all the specific requirements of BS EN 934 part 2 (2000) for a set retarding admixture. However this is subject to further research on the material

5.2 Recommendations

Premised on the findings of this study, it is recommended as follows:

1. Plantain peel ash could be used as a set retarder in concrete placed in moisture free locations.
2. The recommended optimum dosage to be applied is 1.0%.
3. Further research should be conducted on the long term effect of the PPA on the properties of hardened concrete.

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APPENDICES

APPENDIX A: Chemical analysis results for PPA

LABORATORY REPORT NO 2953
RESULT OF ANALYSIS

OXIDE %	PLANTAIN PEELS ASH
SiO ₂	7.84
P ₂ O ₅	3.76
SO ₃	2.21
Cl	3.86
K ₂ O	45.85
TiO ₂	0.095
MnO	0.27
Fe ₂ O ₃	0.901
NiO	0.024
CuO	0.081
ZnO	0.29
Na ₂ O	1.28
MgO	0.38
LOI	33.15

Analyst:


P. B. Otiono
Deputy Director (Lab)

Appendix B: Results of sand grading analysis

Total weight of sand = 400g						Formatted: Font color: Auto			
Sieve size (mm)	Weight retained (g)	Percentage retained (%)	Cumulative Residue (%)	Cumulative percentage passing (%)	CODE PROVISIONS				Formatted: Font color: Auto
					Cum Percentage residue (%)		Cum.percentage passing (%)		
					Lower	Upper	Lower	Upper	
2	0	0	0	100	0	0	100	100	Formatted: Font color: Auto
1.6	46	11.5	11.5	88.5	2	12	98	88	Formatted: Font color: Auto
1	95	23.75	35.25	64.75	28	38	72	62	Formatted: Font color: Auto
0.6	122	30.5	65.75	34.25	62	72	38	28	Formatted: Font color: Auto
0.15	88	22	87.75	12.25	82	92	18	8	Formatted: Font color: Auto
0.075	46	11.5	99.25	0.75	98	100	2	0	Formatted: Font color: Auto
Pan	2	0.5	99.75	-	-	-	-	-	Formatted: Font color: Auto
Total	399	99.75	-	-	-	-	-	-	Formatted: Font color: Auto

Appendix C: 2 Days Flexural Strength Test Results

ASH CONTENT (%) / SPECIMEN NO.	Load (kN)				Average	Formatted: Font color: Auto
	1	2	3			Formatted: Font color: Auto
0.00	1.66	1.85	2.06		1.86	Formatted: Font color: Auto
0.20	1.55	1.63	1.54		1.57	Formatted: Font color: Auto
0.40	1.41	1.21	1.46		1.36	Formatted: Font color: Auto
0.60	1.59	1.62	1.48		1.56	Formatted: Font color: Auto
0.80	1.67	1.53	1.44		1.55	Formatted: Font color: Auto
1.00	1.80	1.49	1.65		1.65	Formatted: Font color: Auto
1.20	1.78	1.77	1.83		1.79	Formatted: Font color: Auto
1.40	1.81	1.74	1.68		1.74	Formatted: Font color: Auto
1.60	1.55	1.80	1.58		1.64	Formatted: Font color: Auto
1.80	1.65	1.43	1.81		1.63	Formatted: Font color: Auto
2.00	1.77	1.70	1.90		1.79	Formatted: Font color: Auto

Appendix D: 7 Days Flexural Strength Test Results

STRENGTH (N/mm ²)	LOAD AT FRACTURE (kN)			
ASH CONTENT (%) / SPECIMEN NO.	1	2	3	Average
0.0	2.50	2.57	2.10	2.39
0.2	2.71	2.80	2.74	2.75
0.4	1.96	2.23	2.58	2.26
0.6	2.58	2.29	2.31	2.39
0.8	2.44	2.74	2.64	2.61
1.0	2.47	2.54	2.45	2.49
1.2	2.26	2.23	2.25	2.25
1.4	2.56	2.72	2.62	2.63
1.6	3.00	2.64	3.24	2.96
1.8	2.93	2.83	2.86	2.87
2.0	2.23	2.39	2.55	2.39

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Appendix E: 14 Days Flexural Strength Test Results

STRENGTH (N/mm ²)	LOAD AT FRACTURE (kN)			
ASH CONTENT (%) / SPECIMEN NO.	1	2	3	Average
0.00	2.81	2.98	2.53	2.77
0.20	1.97	1.88	2.05	1.97
0.40	2.56	2.15	0.64	1.78
0.60	2.00	2.05	2.10	2.05
0.80	1.99	2.49	2.08	2.19
1.00	2.59	2.13	2.17	2.30
1.20	2.11	2.44	2.00	2.18
1.40	2.30	2.12	2.68	2.37
1.60	1.95	2.06	2.10	2.04
1.80	1.93	2.09	2.87	2.30
2.00	1.92	2.50	2.04	2.15

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Appendix F: 28 Days Flexural Strength Test Results

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ASH CONTENT (%) / SPECIMEN NO.	LOAD AT FRACTURE (kN)			
	1	2	3	Average
0.00	2.50	2.52	3.11	2.71
0.20	2.52	3.15	2.68	2.78
0.40	3.18	2.91	2.54	2.88
0.60	3.04	2.50	2.30	2.61
0.80	2.97	2.77	3.16	2.97
1.00	2.96	2.77	2.64	2.79
1.20	2.75	2.94	2.61	2.77
1.40	2.59	2.57	2.66	2.61
1.60	2.79	2.62	3.10	2.84
1.80	3.36	3.04	2.94	3.11
2.00	2.88	3.07	2.01	2.65

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Appendix G: 2 Days compressive strength test results

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ASH CONTENT (%) / SPECIMEN NO.	LOAD AT FRACTURE (kN)						
	1	2	3	4	5	6	Average
0.00	8.50	8.00	7.50	9.01	9.01	8.50	8.42
0.20	8.00	7.81	7.47	7.71	6.80	6.70	7.42
0.40	6.50	6.00	7.50	7.25	7.01	7.02	6.88
0.60	6.96	6.74	6.74	7.09	6.58	6.96	6.84
0.80	7.28	7.06	7.01	7.36	6.94	7.12	7.13
1.00	7.49	7.01	6.50	7.01	6.35	6.40	6.79
1.20	6.75	7.22	7.01	7.06	7.17	6.42	6.94
1.40	6.46	6.64	6.98	6.98	6.58	6.53	6.69
1.60	6.80	6.83	6.75	6.96	7.10	6.53	6.83
1.80	6.70	7.02	6.80	6.88	6.64	6.75	6.80
2.00	7.01	6.90	7.30	7.20	6.93	6.70	7.01

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Appendix H: 7 Days compressive strength test results

<u>ASH CONTENT</u> <u>(%)/SPECIMEN NO.</u>	<u>LOAD AT FRACTURE (kN)</u>						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>Average</u>
<u>0.00</u>	<u>11.50</u>	<u>11.20</u>	<u>11.12</u>	<u>10.99</u>	<u>11.14</u>	<u>11.22</u>	<u>11.19</u>
<u>0.20</u>	<u>10.00</u>	<u>10.32</u>	<u>10.21</u>	<u>9.97</u>	<u>10.43</u>	<u>10.30</u>	<u>10.21</u>
<u>0.40</u>	<u>10.50</u>	<u>10.67</u>	<u>10.22</u>	<u>10.48</u>	<u>10.29</u>	<u>10.67</u>	<u>10.47</u>
<u>0.60</u>	<u>13.01</u>	<u>13.09</u>	<u>13.30</u>	<u>12.99</u>	<u>13.18</u>	<u>13.52</u>	<u>13.18</u>
<u>0.80</u>	<u>12.50</u>	<u>12.66</u>	<u>12.88</u>	<u>12.78</u>	<u>12.98</u>	<u>13.12</u>	<u>12.82</u>
<u>1.00</u>	<u>12.00</u>	<u>12.27</u>	<u>11.92</u>	<u>11.82</u>	<u>12.66</u>	<u>11.58</u>	<u>12.04</u>
<u>1.20</u>	<u>15.01</u>	<u>15.04</u>	<u>15.06</u>	<u>14.99</u>	<u>15.38</u>	<u>14.85</u>	<u>15.05</u>
<u>1.40</u>	<u>13.50</u>	<u>13.79</u>	<u>13.52</u>	<u>13.42</u>	<u>13.70</u>	<u>13.41</u>	<u>13.56</u>
<u>1.60</u>	<u>13.01</u>	<u>13.46</u>	<u>13.23</u>	<u>13.68</u>	<u>13.10</u>	<u>13.20</u>	<u>13.28</u>
<u>1.80</u>	<u>14.00</u>	<u>13.74</u>	<u>13.87</u>	<u>13.39</u>	<u>13.74</u>	<u>13.50</u>	<u>13.71</u>
<u>2.00</u>	<u>12.00</u>	<u>12.58</u>	<u>12.43</u>	<u>12.06</u>	<u>11.97</u>	<u>11.81</u>	<u>12.14</u>

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Appendix I: 14 Days compressive strength test results

<u>ASH CONTENT</u> <u>(%)/SPECIMEN NO.</u>	<u>LOAD AT FRACTURE (kN)</u>						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>Average</u>
<u>0.00</u>	<u>12.00</u>	<u>11.73</u>	<u>12.00</u>	<u>11.01</u>	<u>11.01</u>	<u>12.00</u>	<u>11.62</u>
<u>0.20</u>	<u>8.83</u>	<u>8.61</u>	<u>8.70</u>	<u>8.75</u>	<u>8.96</u>	<u>8.80</u>	<u>8.78</u>
<u>0.40</u>	<u>9.01</u>	<u>8.00</u>	<u>7.01</u>	<u>8.00</u>	<u>9.01</u>	<u>8.88</u>	<u>8.32</u>
<u>0.60</u>	<u>8.96</u>	<u>8.16</u>	<u>8.00</u>	<u>8.18</u>	<u>8.24</u>	<u>8.35</u>	<u>8.31</u>
<u>0.80</u>	<u>8.51</u>	<u>8.00</u>	<u>8.16</u>	<u>8.14</u>	<u>7.98</u>	<u>8.19</u>	<u>8.17</u>
<u>1.00</u>	<u>9.01</u>	<u>7.01</u>	<u>7.01</u>	<u>9.01</u>	<u>9.15</u>	<u>8.70</u>	<u>8.31</u>
<u>1.20</u>	<u>8.62</u>	<u>8.70</u>	<u>9.12</u>	<u>9.09</u>	<u>8.66</u>	<u>8.40</u>	<u>8.77</u>
<u>1.40</u>	<u>8.80</u>	<u>8.58</u>	<u>8.59</u>	<u>8.72</u>	<u>8.50</u>	<u>9.04</u>	<u>8.70</u>
<u>1.60</u>	<u>8.78</u>	<u>9.04</u>	<u>9.30</u>	<u>9.60</u>	<u>9.23</u>	<u>8.77</u>	<u>9.12</u>
<u>1.80</u>	<u>9.42</u>	<u>8.75</u>	<u>9.68</u>	<u>9.78</u>	<u>9.18</u>	<u>8.70</u>	<u>9.25</u>
<u>2.00</u>	<u>11.01</u>	<u>10.00</u>	<u>9.01</u>	<u>10.00</u>	<u>10.00</u>	<u>9.01</u>	<u>9.84</u>

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Appendix J: 28 Days compressive strength test results

<u>ASH CONTENT</u> <u>(%)/SPECIMEN NO.</u>	<u>LOAD AT FRACTURE (kN)</u>						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>Average</u>
<u>0.00</u>	<u>12.00</u>	<u>12.50</u>	<u>12.29</u>	<u>12.26</u>	<u>12.75</u>	<u>12.82</u>	<u>12.43</u>
<u>0.20</u>	<u>13.01</u>	<u>12.48</u>	<u>12.74</u>	<u>13.09</u>	<u>12.90</u>	<u>12.80</u>	<u>12.83</u>
<u>0.40</u>	<u>12.98</u>	<u>12.51</u>	<u>13.04</u>	<u>13.15</u>	<u>12.98</u>	<u>13.01</u>	<u>12.94</u>
<u>0.60</u>	<u>13.49</u>	<u>13.46</u>	<u>13.10</u>	<u>14.00</u>	<u>13.65</u>	<u>13.52</u>	<u>13.54</u>
<u>0.80</u>	<u>10.00</u>	<u>12.00</u>	<u>12.56</u>	<u>12.88</u>	<u>11.57</u>	<u>12.08</u>	<u>11.85</u>
<u>1.00</u>	<u>12.00</u>	<u>12.24</u>	<u>11.74</u>	<u>11.01</u>	<u>11.01</u>	<u>11.55</u>	<u>11.59</u>
<u>1.20</u>	<u>11.01</u>	<u>11.01</u>	<u>12.08</u>	<u>13.20</u>	<u>12.98</u>	<u>11.31</u>	<u>11.93</u>
<u>1.40</u>	<u>13.17</u>	<u>14.00</u>	<u>14.00</u>	<u>13.20</u>	<u>15.01</u>	<u>14.64</u>	<u>14.00</u>
<u>1.60</u>	<u>10.99</u>	<u>11.01</u>	<u>12.00</u>	<u>12.00</u>	<u>13.04</u>	<u>12.00</u>	<u>11.84</u>
<u>1.80</u>	<u>11.04</u>	<u>10.99</u>	<u>13.04</u>	<u>13.17</u>	<u>12.00</u>	<u>12.80</u>	<u>12.17</u>

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Appendix K: Initial setting time test results

<u>Ash content</u> <u>(%)</u>	<u>Date of test</u>	<u>Start time</u>	<u>End time</u>	<u>Setting time</u> <u>(mins)</u>
<u>0.0</u>	<u>3/08/1015</u>	<u>9:33 AM</u>	<u>11:05 AM</u>	<u>92</u>
<u>0.4</u>	<u>3/08/1015</u>	<u>9:40 AM</u>	<u>12:38 PM</u>	<u>178</u>
<u>0.6</u>	<u>3/08/1015</u>	<u>9:50 AM</u>	<u>1:36 PM</u>	<u>216</u>
<u>0.8</u>	<u>3/08/1015</u>	<u>10:00 AM</u>	<u>2:06 PM</u>	<u>246</u>
<u>1.0</u>	<u>4/08/2015</u>	<u>9:00 AM</u>	<u>2:14 PM</u>	<u>314</u>
<u>1.2</u>	<u>4/08/2015</u>	<u>9:05 AM</u>	<u>12:45 PM</u>	<u>220</u>
<u>1.4</u>	<u>4/08/2015</u>	<u>9:12 AM</u>	<u>1:17 PM</u>	<u>245</u>
<u>1.6</u>	<u>4/08/2015</u>	<u>9:20 AM</u>	<u>1:44 PM</u>	<u>254</u>
<u>1.8</u>	<u>5/08/2015</u>	<u>10:05 AM</u>	<u>2:18 PM</u>	<u>253</u>
<u>2.0</u>	<u>5/08/2015</u>	<u>10:15 AM</u>	<u>3:02 PM</u>	<u>287</u>

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Appendix L: Final setting time test results

<u>Ash content (%)</u>		<u>Start time</u>	<u>End time</u>	<u>Setting time (mins)</u>
<u>0.0</u>	<u>3/08/1015</u>	<u>9:33 AM</u>	<u>2:05 PM</u>	<u>272</u>
<u>0.4</u>	<u>3/08/1015</u>	<u>9:40 AM</u>	<u>2:36 PM</u>	<u>296</u>
<u>0.6</u>	<u>3/08/1015</u>	<u>9:50 AM</u>	<u>3:50 PM</u>	<u>360</u>
<u>0.8</u>	<u>3/08/1015</u>	<u>10:00 AM</u>	<u>4:20 PM</u>	<u>380</u>
<u>1.0</u>	<u>4/08/2015</u>	<u>9:00 AM</u>	<u>3:14 PM</u>	<u>394</u>
<u>1.2</u>	<u>4/08/2015</u>	<u>9:05 AM</u>	<u>3:00 PM</u>	<u>355</u>
<u>1.4</u>	<u>4/08/2015</u>	<u>9:12 AM</u>	<u>3:08 PM</u>	<u>356</u>
<u>1.6</u>	<u>4/08/2015</u>	<u>9:20 AM</u>	<u>3:15 PM</u>	<u>355</u>
<u>1.8</u>	<u>5/08/2015</u>	<u>10:05 AM</u>	<u>4:21 PM</u>	<u>376</u>
<u>2.0</u>	<u>5/08/2015</u>	<u>10:15 AM</u>	<u>4:42 PM</u>	<u>387</u>

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Appendix M: Results of specific gravity of PPA

<u>Test no.</u>	<u>Weight of bottle +stopper w1 (g)</u>	<u>Weight of ash + bottle w2(g)</u>	<u>Weight of ash +bottle +water w3(g)</u>	<u>Weight of bottle +water w4(g)</u>	<u>Specific gravity of</u>
					$\frac{(w2-w1)}{(w2-w1)-(w3-w4) \times 5}$
<u>1</u>	<u>37.70</u>	<u>62.70</u>	<u>100.70</u>	<u>87.30</u>	<u>2.16</u>
<u>2</u>	<u>40.90</u>	<u>65.40</u>	<u>95.00</u>	<u>82.00</u>	<u>2.13</u>
<u>3</u>	<u>41.00</u>	<u>65.50</u>	<u>98.00</u>	<u>85.54</u>	<u>2.03</u>
<u>Average specific gravity</u>	-	-	-	-	<u>2.11</u>

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Appendix N: Results of specific gravity of sand

<u>Test no.</u>	<u>Total weight of sand b (g)</u>	<u>Weight of water + bottle p(g)</u>	<u>Weight of sand +bottle +water (w3)</u>	<u>Specific gravity of sand</u> $\frac{B}{P+B-P_s}$
<u>1</u>	<u>500.00</u>	<u>1300.00</u>	<u>1600.00</u>	<u>2.50</u>
<u>2</u>	<u>500.00</u>	<u>1300.00</u>	<u>1620.00</u>	<u>2.78</u>
<u>3</u>	<u>500.00</u>	<u>1300.00</u>	<u>1590.00</u>	<u>2.38</u>
<u>Average specific gravity</u>	-	-	-	<u>2.55</u>

Appendix O: Results of soundness tests

<u>Ash content (%)</u>	<u>W1 (mm)</u>	<u>W2 (mm)</u>	<u>Expansion(mm)</u>
<u>0.00</u>	<u>10.00</u>	<u>10.00</u>	<u>0.00</u>
<u>0.20</u>	<u>7.00</u>	<u>8.00</u>	<u>1.00</u>
<u>0.40</u>	<u>5.00</u>	<u>5.50</u>	<u>0.50</u>
<u>0.60</u>	<u>7.00</u>	<u>7.00</u>	<u>0.00</u>
<u>0.80</u>	<u>7.00</u>	<u>7.00</u>	<u>0.00</u>
<u>1.00</u>	<u>10.00</u>	<u>11.00</u>	<u>1.00</u>
<u>1.20</u>	<u>5.00</u>	<u>5.00</u>	<u>0.00</u>
<u>1.40</u>	<u>7.00</u>	<u>7.00</u>	<u>0.00</u>
<u>1.60</u>	<u>10.00</u>	<u>10.00</u>	<u>0.00</u>
<u>1.80</u>	<u>5.00</u>	<u>5.50</u>	<u>0.50</u>
<u>2.00</u>	<u>7.00</u>	<u>7.00</u>	<u>0.00</u>

W1 = Distance between indicators before heating

W2 = Distance between indicators after heating

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