THE STRENGTH CHARACTERISTICS OF CONCRETE CONTAINING EMPTY PALM OIL FRUIT BUNCH ASH (EPO-FBA) AS PARTIAL REPLACEMENT OF ORDINARY PORTLAND CEMENT IN CONCRETE (OPC)

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ABSTRACT

In an attempt to reduce non-renewable material usage, reduce green-house substances and at the same time be relevant to our environment, this research presents the progress of investigation going on to evaluate some properties of EPO-FBA as partial replacement of cement in the production of structural concrete. This research work is carried out to determine the properties of Empty Palm Oil Fruit Bunch Ash (EPO-FBA) when used as partial replacement for Ordinary Portland Cement (OPC) in concrete. The test to be carry out include the test for the chemical properties, fineness and specific gravity of the EPO-FBA and also tests for consistency, density, and compressive strength will be carry out on concrete whose composition of cement is being proportioned and replaced with 5% interval of EPO-FBA by weight up to 15%. The mix design used for the concrete mix was 1:2:4 and the Water/cement ratio used was 0.5. The concrete cubes were cured in water for 7, 14, 28, 60 and 90 days so as to attain its maximum attainable strength due to the process of hydration. At the end of the study, the result showed that the workability of concrete specimen with EPO-FBA as partial replacement of OPC reduces with increasing quantity of EPO-FBA because of its increased water-demanding property. The compressive strength of the concrete was observed to decrease as the addition of EPO-FBA in proportions was increased but there was no significant difference between the compressive strength of the concrete with 5% replacement and the control. The concrete can as well be classified as a heavy weight concrete based on the density range of the whole cube with different proportion of EPO-FBA ranges in densities between 2414.8kg/ m^3 and 2509.6kg/m^3. However, from the above test results it can be recommended that EPO-FBA may be used as replacement material of cement in concrete up to 5%.

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DEDICATION

This report is dedicated to God Almighty, who gives wisdom and inspiration.

CERTIFICATION

I hereby certify that this project proposal was put together and written by OLUWASEGUNOTA OLAWALE BLESSING with matriculation number CVE/14/1648 of the Department of Civil Engineering, Federal University Oye-Ekiti, Ekiti State, in partial fulfilment of the requirement for the award of Bachelor of Engineering (B.Eng) in Civil Engineering.

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LIST OF ABBREVIATIONS

OPC	Ordinary Portland Cement
EPO-FBA	Empty Palm Oil Fruit Brunch Ash
POFA	Palm Oil Fruit Ash
BS	British Standard
ASTM	American Society for Testing Materials
RHA	Rice Husk Ash
GRH	Grinded Rice Husk
POFA	Palm Oil Fuel Ash
PFA	Pulverize Fuel Ash
RAC	Recycled Aggregate Concrete
EPOB	Empty Palm Oil Bunch
POEBA	Palm Oil Empty Bunch Ash
CKD	Cement Kiln Dust
SAI	Strength Activity Index

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CHAPTER ONE

INTRODUCTION

1.1 General Background

Concrete is the world's most consumed man-made material (Naik, 2008). Its great versatility and relative economy in filling wide range of needs has made it a competitive building material (Sashidar and Rao, 2010). Concrete production is not only a valuable source of societal development, but it is also a significant source of employment (Naik, 2008).

Production of concrete relies to a large extent on the availability of cement, sand and coarse aggregates such as granite, the costs of which have risen astronomically over the past few years. Despite the rising cost of production, the demand for concrete is increasing. The negative consequences of the increasing demand for concrete include depletion of aggregate deposits; environmental degradation and ecological imbalance (Johnson A. U. et al., 1978). The major factor responsible for wide usage of cement-concrete are mouldability, early hardening, high early compressive strength, development of desired properties with admixture to be used in adverse situations, suitability, pumpability and durability. Concrete is no doubt an important building material, playing a part in all building structure. It is environmental friendly construction material which offers the stability and flexibility in designing all building structures. Concrete are attractive for use as construction materials. Since, there are many advantages of concrete such as built-in-fire resistance, high compressive strength and low maintenance. However, concrete also have a disadvantage which is that concrete are inherently brittle material (Ahmad et al., 2008).

On the other hand, concrete is also well known of its major problem associated with low tensile strength compared to compressive strength. Because of that, many new technologies of concrete and some modern concrete specifications approach were introduced. There have been many experimental works conducted by introducing a new material or recycled material as a replacement to aggregate or cement in concrete (Ahmad et al., 2008).

Development of high strength concrete is often considered a relatively new material, but its development and usage has been gradual over many years. The growth has been possible as a result of recent developments in material technology and a demand for higher-strength concrete.

The utilization of waste by-products in concrete has garnered positive outcomes over the past few decades in terms of the cost savings and conservation of natural resources. Some of the resources currently being employed for concrete production are prone to having negative effects on the environment besides being non-renewable. This has resulted in an increase in research to develop alternative feed to reduce and maintain a non-excessive usage of natural sources.

Nowadays, the use of recycled materials as concrete ingredients is gaining popularity and development because of increasingly stringent environmental legislation. Furthermore, there is significant research on many different materials for cement usage substitutes and replacement such as Rice Husk Ash (RHA), Grinded rice husk (GRH), palm oil fuel ash (POFA), pulverize fuel ash (PFA) and many others fiber and pozzolanic material. Since Nigeria is one of the largest producers in palm oil industry, the wastage of the palm oil can be used to replace in small amount of cement (Awal and Hussin, 1996).

Palm oil industry is one of the most important agro industries in Nigeria. Besides the production of crude palm oil, a large amount of solid waste is also an output from the palm oil industry. Annually, more than two million tons of solid waste of palm oil residue, such as palm fiber, shells, and empty fruit bunches are produced (Office of the Agricultural Economics, 2002).

Utilization of Empty Palm Oil Bunch (EPOB) powder is minimal and unmanageable, while its quantity increases annually and most of the EPOB are disposed off as waste in landfills causing environmental and other problems. On the other, many researchers have been studied on the use of agro waste ashes as constituents in concrete, namely rice-husk ash (Mehta, 1977) sawdust ash (Udoeyo & Dashibil, 2002) and bagasse ash (Singh et al., 2000). The results revealed that these agro waste ashes contained a high amount of silica in amorphous form and could be used as a pozzolanic material. According to ASTM C 618 (2001) defines pozzolanic material as a material that contains siliceous or siliceous and aluminous material by composition.

In general, a pozzolanic material has little or no cementing properties. However, when it has a fine particle size, in the presence of moisture it can react with calcium hydroxide at ordinary temperatures to provide the cementing property. Empty Palm Oil Bunch is one of the agro waste materials whose chemical composition contains a large amount of silica and has high potential to be used as a cement replacement (Tangchirapat et al., 2003).

1.1.1 Concrete

According to Barry's Introduction to Construction of Building, concrete is the name given to a mixture of particles of sand and gravels bound together by cement. Concrete is a mixture of cement, water and aggregates which take the shape of its mould when cured at a suitable temperature and humidity to form a solid mass (BS 2787, 1956).

Concrete is a widely used construction material in civil engineering projects throughout the world for the following reasons: It has excellent resistance to water, structural concrete elements can be formed into a variety of shapes and sizes and it is usually the cheapest and most readily available material for the job (Mehta O. A. and Monteiro I. E., 2006).

Most of the concrete produced today are a multi component product containing one or more admixtures in addition to the 'four basic component which is cement, water, fine and coarse aggregate. For every component, one usually has several choices that could influence the cost of the end product and its behavior in service. Among the constituent components, however, cement or cementitious materials as a whole play a vital role in producing strong and durable concrete. For many purposes a pozzolan has been regarded as a substitute for a proportion of cement in a concrete.

According to Ahmad et al., (2008) one of the potential recycles material from palm oil industry is palm oil fruit bunch which contains siliceous compositions and reacted as pozzolan to produce a stronger and denser concrete. There are many experimental works conducted by introducing recycled material likes palm oil fuel ash (POFA) as a replacement of the cement with different percentages to improve the properties of concrete.

Through public concerns and research efforts, the waste materials have potential to be utilized as construction material to replace conventional Ordinary Portland cement (OPC) (Ahmad et al., 2008).

Concrete a composite man-made material is the most widely used building material in the construction industry. It consists of a rationally chosen mixture of building material such as lime or cement, well graded fine and coarse aggregates, water and admixtures (to produce concrete with special properties). In a concrete mix, cement and water form a paste or matrix which in addition to filling the voids of the fine aggregate, coats the surface of fine and coarse aggregates and binds them together. Freshly mixed concrete before set is known as **wet or green concrete** whereas after setting and hardening it is known as **set or hardened concrete.** The moulded concrete mix after sufficient curing becomes hard like stone due to chemical action between the water and binding material (Awal and Hussin, 1996).

1.1.2 Pozzolan

A pozzolan is a siliceous and aluminous material which, when combined with calcium hydroxide, in the presence of water to form compounds exhibit the cementitious properties at room temperature and that have the ability to set under water. The American Society for Testing Materials (ASTM) defines pozzolan as a "siliceous or siliceous aluminous material which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties". Pozzolans are commonly used as an addition (the technical term is "cement extender" or "cement replacement materials") to Portland cement concrete mixtures to increase the long-term strength and other material properties of Portland cement concrete and in some cases reduce the material cost of concrete.

Today, modern pozzolanic cements are a mix of natural or industrial pozzolans and Portland cement. Apparently, the usage of pozzolans can decrease in the use of Portland cement when producing concrete; this is more environmental friendly than limiting cementitious materials to Portland cement. The characteristic of high alkalinity in pozzolana materials makes it especially resistant to common forms of corrosion from sulfates for the underwater usage. The extent of the strength development depends upon the chemical composition of the pozzolan: the greater the composition of alumina and silica along with the vitreous phase in the material, the better the pozzolanic reaction and strength display.

The pozzolanic reaction may be slower than the rest of the reactions that occur during cement hydration, and thus the short-term strength of concrete made with pozzolans may not be as high as concrete made with purely cementitious materials; conversely, highly reactive pozzolans, such as silica fume and high reactivity metakaolin can produce "high early strength" concrete that increase the rate at which concrete gains strength (Bentur et al., 1986).

According to Lea (1988), the word pozzolan has been divided into two portions. First portion indicates the pyroclastic rock also termed as zeolites which was available in Rome. Second portion includes inorganic material which may be artificial or natural. This material when react with calcium hydroxide, attains hardness. ASTM 618-01 states that when pozzolan is used inside the concrete or mortar, it reacts with silica present inside the pozzolan and reacts with the lime which is available due to the hydration reactions of tri-calcium silicate and di-calcium silicate which are the main compounds of Portland cement.

Pozzolanic materials are therefore defined with respect to their use as cementitious material instead of chemical and physical phenomena by the virtue of which it hardens. There are lots of pozzolanic materials which are available in the world today. These materials differ entirely in their composition, mineralogical constitution, origin etc. (Lea, 1988) divided the pozzolan into two main group natural and artificial materials.

Natural materials do not require any treatment for their use as pozzolan other than grinding to increase the surface area. However, the artificial materials are produced by improving the properties of weak pozzolan. Natural pozzolan include the materials of volcanic origin, compact materials (Tuffs) and materials of sedimentary origin. Pyroclastic rocks originate from explosive eruptions of volcanoes which results in dispersion of minute particles of melted magma into the atmosphere, the gases evolve into the air and resulting into pozzolan having micro porous structure (Penta, 1954).

1.2 Problem Statement

Generally, the wastage of palm oil from the palm oil industry was increasing eventually. It has then become a major problem to the environmental sustainability because this wastage from palm oil is as non-renewable material causes the emission of green-house gases. Hence to utilize these waste materials as an active pozzolanic admixture, these pozzolanic admixtures are used for reducing the Portland cement content in mortar and concrete production. These hence prompt the investigation to optimize the need to be relevant to our environment through research that could promote small scale industry.

1.3 Justification of Study

Concrete plays an important role in the beneficial use of these materials in construction. Many modification and developments have been made to place industrial waste such as concrete itself and waste material like rice husk ash (RHA), banana peel ash, palm oil fly ash (POFA), pulverize fuel ash (PFA) and many others fiber and pozzolanic material as a cement replacement. This research is to investigate and propose another way as an alternative to revealed that the replacement of Empty Palm Oil Bunch Ash (EPO-FBA) in Portland cement increased the strength and other properties of concrete.

One of the main goals of sustainable waste management is to maximize recycling and reuse. Recycling is a logical option for materials not suitable for composting. With increasing environmental pressure to reduce waste and pollution and to recycle as much as possible, the concrete industry has begun adopting a number of methods to achieve these goals.

1.4 Aim and objectives of study

The major aim of this work is to determine some structural properties of concrete containing palm oil empty bunch ash (EPO-FBA) as partial replacement of cement.

In order to achieve this aim, the following objectives are set:

1. To determine the chemical composition of empty palm oil fruit bunch ash (EPO-FBA)
2. To determine the water demand for consistency
3. To determine the setting time of the concrete containing a proportion of empty palm oil fruit bunch ash (EPO-FBA)
4. To determine the density of concrete containing empty palm oil fruit bunch ash (EPO-FBA)
5. To determine the density of concrete
6. To analyze the results with the aim of making a better recommendation.

1.5 Scope of study

So many properties of concrete such as creep, strength, durability, modulus of elasticity, shrinkage, water tightness etc., are been investigated by researcher and are hence been improved on, but this research work is on the compressive characteristic of concrete containing different proportion of Empty Palm Oil Fruit Bunch Ash (EPO-FBA) as a partial replacement of cement by weight. Investigations into other properties are outside the scope of this work.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

Various research work has been done on partial replacement of cement with different waste material found around us, in other to utilize these materials and as well as a means to reduce green-house gases being emitted from these waste. These research works have help in improving the sustainability of the environment as well the increase in the strength property of concrete. Hence the various work reviewed are highlighted below:

In the investigation conducted by (Fapohunda and Shittu, 2017) on Some Later Ages Structural Characteristics of Concrete Containing Empty Palm Oil Fruit Brunch Ash (EPO-FBA) as Partial Replacement of Ordinary Portland Cement, the latter day strengths of concrete in which the cement constituent of the mix has been partially replaced by empty palm oil fruit brunch (EPO-FBA) was assessed. The structural parameters investigated were: workability, density and compressive strength. Some physical properties and chemical analysis were conducted. Slump test was used to assess the workability, while 150 x 150 x 150mm concrete cube specimens were used to assess the density and compressive strength characteristics. Replacement of Portland cement with EPO-FBA was carried out up to 20% by weight at interval of 5%. The preliminary investigations performed on the ash were: fineness, specific gravity and chemical analysis. Dry sieving was used for the fineness test; specific gravity bottle was used to determine the specific gravity of ash. The chemical analysis was done at the Department of Chemistry University of Lagos. Also some investigations for the purpose of characterization were carried out on the sand and the coarse aggregates. These includes: bulk density, moisture content, water absorption capacity and the particle size distribution by using the sieve analysis text (determined in accordance with BS EN ISO 17892-1 (2014). Concrete specimens were prepared, using a mix ratio of 1:2:4 and water-cement ratio of 0.50. The Portland cement constituent of the mix was subsequently replaced by EPOFBA from 0 – 20 % at 5% interval by weight. The samples without EPO-FBA served as the control. The workability was assessed through the slump test in accordance to the provisions of BS EN 12350: Part 2 (2000). The density and compressive strength tests conducted on concrete cubes 150 x 150m x 150 mm in accordance with BS 12350: Part 6 (2000) and BS EN 12390-3 (2009) respectively. The concrete specimens were moist-cured and tested after 60, 75 and 90 days. The strength characteristics of each cube were determined on WAW-2000B computerized electrohydraulic servo universal testing machine, with accuracy of ± 1% of test force.

Subhashini and Krishnamoorthi (2016) in their experimental investigation on Partial Replacement of Cement by Palm Oil Fuel Ash in Concrete, the strength properties of POFA concrete of M30 grade in different replacement level was compared with control concrete. The concrete mix is designed as per IS: 10262 –2009 and IS 456-2000 for the normal concrete. The grade of concrete adopted is M30 with a water cement ratio of 0.45. Five mixture proportions were made. First was control mix (without palm Oil Fuel Ash) and the other four mixes contained palm oil fuel ash. Cement was replaced with palm oil fuel ash by weight. The proportions of cement replaced ranged from 10% to 40% at 10% interval.

According to Ranjbal N. et al. (2015) on Durability and mechanical properties of self-compacting concrete incorporating palm oil fuel ash, self-compacting concretes were produced by incorporation of palm oil fuel ash at 10, 15 and 20% by weight of Portland cement and their mechanical and durability potential were evaluated under normal, acid and sulfate attack conditions. Ground POFA was used as partial replacement of Type I Portland cement at proportions of 10%, 15%, and 20% of binder weight content. The mix designs of the self-consolidating concretes included 480 kg/m3 of binder and water to binder ratio of 0.35 for all specimens. Sika Viscocrete-1600 superplasticizer (Sika Kimia Sdn Bhd, Malaysia) was used in the self-compacting concrete mixtures in order to obtain the fresh properties. Sika Viscocrete-1600 is an extreme water reduction which meets the requirements for superplasticizers according to ASTM C494 Type G. To obtain similar workability for the specimens, higher superplasticizer was used in mix design of higher POFA content matrices because of the agglomerated shape of POFA particles leading to the demand for more energy to roll over one another.

In their own work, Wan Bakar *et al*., (2014) investigate on the effect of ash from oil palm empty fruit bunch to cement properties, said Cement losses into formation could lead to zonal isolation problem. This may happen in weak formation when equivalent circulating density (ECD) of the cement exceeded formation pressure. One of the methods to avoid cement losses thus providing complete zonal isolation is by using low density cement. In the study, they investigated the effect of ashes from Oil Palm Empty Fruit Bunch (OEFB), being a material with high silicon dioxide (SiO2) content in reducing the cement density. Other important cement properties such as compressive strength should not be compromised for the density. Carboxymethylcellulose (CMC), a standard additive to improve the compressive strength was added to the cement formulation. Result showed that 20% density reduction for standard Class G cement could be achieved with 60% OEFB ashes substitution and addition 0.2% CMC.

The work of Arundeb-Gupta (2012) showed the study of mechanical as well as micro structural properties of recycled aggregate concrete (RAC) exposed to elevated temperature. Fly ash (as replacement of cement) was added while making concrete. Recycled aggregates are mixed with natural aggregates also to prepare concrete. Cubes and cylinder test specimens were prepared and cured under water for 28 days. Test specimens were exposed to different levels of temperature (200°C, 400°C, 600°C, 1000°C) for a period of 6 hours in the furnace. The reduction in compressive strength observed were in the ranges from 21% to as high as 61% when exposed to elevated temperature. Modulus of elasticity reduces appreciably also with the increase of exposure temperature. MIP (Mercury intrusion porosimetry) test was conducted to estimate the percentage of voids and also to appreciate the change of micro voids due to change of exposure temperature. Microscopic study was made to note the change of surface texture. They developed empirical formulae involving major parameters such as fly ash content, exposure temperature etc. to predict modulus of elasticity of recycled aggregate concrete. He concluded that maximum compressive strength at lower temperature was due to stronger interfacial bonding between matrix and aggregates. Strength loss at elevated temperature due to the texture of the sample becomes coarse and several micro cracks appeared, which gradually worsen the strength character of the sample. Due to pore volume increases after heating leads to higher strain in concrete results lower compressive strength.

Chindaprasirt et al (2008) presented a study of the resistance to chloride penetration of blended Portland cement mortar containing ground palm oil fuel ash (POFA), ground rice husk ash (RHA) and fine fly ash (FA). Ordinary Portland cement (OPC) was partially replaced with pozzolan at the dosages of 20% and 40% by weight of cementitious materials. The water to cement ratio is kept constant at 0.5 and the flow of mortar is maintained at 110 ± 5% with the aid of super-plasticizer (SP). Compressive strength, rapid chloride penetration test (RCPT), rapid migration test (RMT) and chloride penetration depth after 30 days of immersion in 3% NaCl solution of mortars were determined. Test results revealed that the resistance to chloride penetration of mortar improves substantially with partial replacement of OPC with POA, RHA and FA. The resistance was higher with an increase in the replacement level. RHA was found to be the most effective pozzolan followed by POA and FA. The use of FA reduced the amount of SP required to maintain the mortar flow, while the incorporations of POA and RHA require more SP. The use of a blend of equal weight portion of POA and FA, or RHA and FA produced mixes with good strength and resistance to chloride penetration. They also required less amount of SP in comparison to that of normal OPC mortar. The incorporations of POA, RHA and FA significantly improved the resistance to chloride penetration of mortar by increasing nucleation sites for precipitation of hydration products, reducing $Ca(OH)_2$ and improving the permeability of mortar. RHA was the most effective, followed by POA and FA. Test results also indicated that the use of blended pozzolan of equal portion of POA and FA, and RHA and FA also effectively improved the mortar in terms of strength and resistance to chloride penetration. The improvement was due to dispersing effect of fly ash and synergic effect of the blend of fine pozzolan.

Chandana Sukesh et al. (2012) have studied about the partial replacement of cement in concrete by use of waste materials like cement kiln dust (CKD), ceramic waste, palm oil fuel ash (POFA) and plastic. All of these materials are industrial waste materials and termed as hazardous waste to environment. They have found that the addition of up to 15% CKD as a cement replacement has a negligible effect on the strength of the block. Several concrete mixes possessing a target mean compressive strength of 30 MPa were prepared with 20% cement replacement by ceramic powder (W/B = 0.6). A concrete mix with ceramic sand and granite aggregates had also prepared as well as a concrete mix with natural sand and coarse ceramic aggregates (W/B = 0.5). Results show that concrete with partial cement replacement by ceramic powder although it has minor strength loss possess increase durability performance. Experiments have been conducted by replacing 10%, 20%, 30%, 40% and 50% of POFA by weight of Ordinary Portland cement. The properties of concrete, such as setting time, compressive strength, and expansion due to magnesium sulfate attack were investigated. The results revealed that the use of POFA in concretes caused delay in both initial and final setting times, depended on the fineness and degree of replacement of POFA. They have observed that they have added 5% plastic by weight, the strength and found to be two times greater than the plain cement concrete. With these results it is very clear that we can effectively use these eco-friendly materials in partial replacement of cement.

Hyung-Min Lee et al. (2010) experimentally investigated the effects of pozzolan made from various by-Product materials on mechanical properties of mortar. Ground fly ash (FA), ground Blast furnace slag (BFS), and palm oil fuel ash (POFA) were partially used to replace Portland cement. The results suggest that mortars containing FA, BFS, and POFA can be used as pozzolanic materials in making concrete with 28days compressive strength. After curing, the mortar containing 10-30% FA or POFA, and 30% BFS exhibited compressive strengths that of the original Portland cement (OPC). The use of FA, POFA, and BFS to partially replace Portland cement has evaluation method of Korea standards (KS) on the activity index.

CHAPTER THREE

METHODOLOGY

3.1 Theoretical Background

The reaction of the silicate components of cement to produce cementing ability and for strength development is approximately represented by Neville (2003) in equations 1 and 2.

$$2C_3S + 6H \Rightarrow C_3S_2H_3 + 3CH \qquad 1$$

$$2C_2S + 4H \Rightarrow C_3S_2H_3 + CH \qquad 2$$

The hydration of silicates produced two products which are: Calcium Silicate Hydrates C-S-H or C-S-H gel which is responsible for strength-formation and the Calcium Hydroxide CH. The CH has been found to be destruction to concrete

On the other hand, there are some siliceous and aluminous materials which are not cementitious in themselves, but when occur in finely divided form and in the presence of water reacts with CH to produce a compound with cementitious value. These materials are called pozzolans. The equation by which pozzolans become a binding agent and produced the strength-forming C-S-H is approximately given by Yilmaz (2010) in equation 3.

$$\text{Pozzolans} + CH \Rightarrow C\text{-}S\text{-}H \qquad 3$$

Thus when a pozzolan is part of the concrete mix, it is expected to react with the destructive CH that will be produce by the cement hydration process to become cementitious through the formation of the C-H-S, the compound that is responsible for strength development in concrete.

To what extent can palm oil empty bunch develops pozzolanic characteristics is one of the major thrust of this research work.

3.2 Materials Design and Preparation

The materials used for this investigation are:

i. Ordinary Portland cement,

ii. Fine aggregate (Sand),

iii. Coarse aggregate (Granite),

iv. Empty Palm Oil Fruit Brunch Ash (EPO-FBA) and

v. Portable water.

3.2.1 Ordinary Portland cement

The cement was Ordinary Portland cement produced to satisfy the requirements NIS 444 (2014), classified as grade 42.5. As cement is the major component of concrete and usually has relatively low unit cost, the selection of its proper type and use has vital importance in obtaining the balance of its desired properties in most economical way for any particular concrete mix.

Type I/II Portland cements, which can provide sufficient levels of strength and durability, are the most common cements used by concrete users. The selection involves the exact knowledge of the connection between cement and performance required and, in particular, between kind of cement and either strength or durability or both the properties of concrete, Lea (1970).

3.2.2 Fine aggregate (Sand)

Natural sand is the fine aggregate chiefly used in concrete mix. Sand may be obtained from sea, river, lake, etc, but when used in a concrete mix, it should be properly washed and tested to ascertain that it is free from clay, silt, and such organic matters.

Commonly used fine aggregate in R.C.C. work is sand. It is either round or angular in grains and is often found mixed in various gradation of fineness. The sand used for mortars should consist of sharp (angular) grains of various sizes. It is generally considered that rounded particles (grain), do not interlock sufficiently to produces strong mortars. This is defined according to ASTM Standard C 33-03. The fine aggregate (river sand) was obtained from Oko-Ootunja, a sand deposit location, closed to Ikole-Ekiti, in Nigeria was used. The sand was dried and sieved through sieve 2.36 mm and treated in accordance with BS EN 12620:2002+A1 (2008).

3.2.3 Coarse aggregate (Granite)

According to ASTM Standard C 33-03, Crushed hard stone and gravel are the common materials used as coarse aggregate for structural concrete. Coarse aggregate is usually obtained by crushing granites, gneiss, crystalline limestone and good variety of sand stone etc.

The material whose particles are of such size as are retained on a 3/16" in B.S. test sieve, is termed as coarse aggregate. The size of the coarse aggregate used depends upon the nature of work. The coarse aggregates, granite chipping was obtained from quarry with sizes ranges from 4.75mm to 20mm was used. The quarry was located in Ikole-Ekiti, Ekiti State.

3.2.4 Empty Palm Oil Fruit Brunch Ash (EPO-FBA)

Palm oil plantation yield huge amount of waste in the form of empty fruit bunch, palm kernel shell, fibrous material of purely biological origin. But considering majorly the material of interest which was the palm oil empty fruit bunch which contain chemical and mineral additives, and depending on proper handling operations at the mill, it is free from foreign elements such as gravel, nails, wood residues, waste etc. However, it is saturated with water due to the biological growth. Since the moisture content in Palm oil empty fruit bunch is around 67%, pre-processing is necessary in order to achieve suitable ash of palm oil empty bunch ash.

The empty fruit bunch is processed into ash through the following process;

1. The unprocessed empty bunch is sun dried to reduce the moisture content,
2. The sundried bunch is separate into pieces for proper pulverization,

3. The separated empty bunch is pounded with mortar and pestle in order to reduce it into fibers,
4. The palm oil empty bunch fiber was burnt for several hours using furnace until it turns to ash.

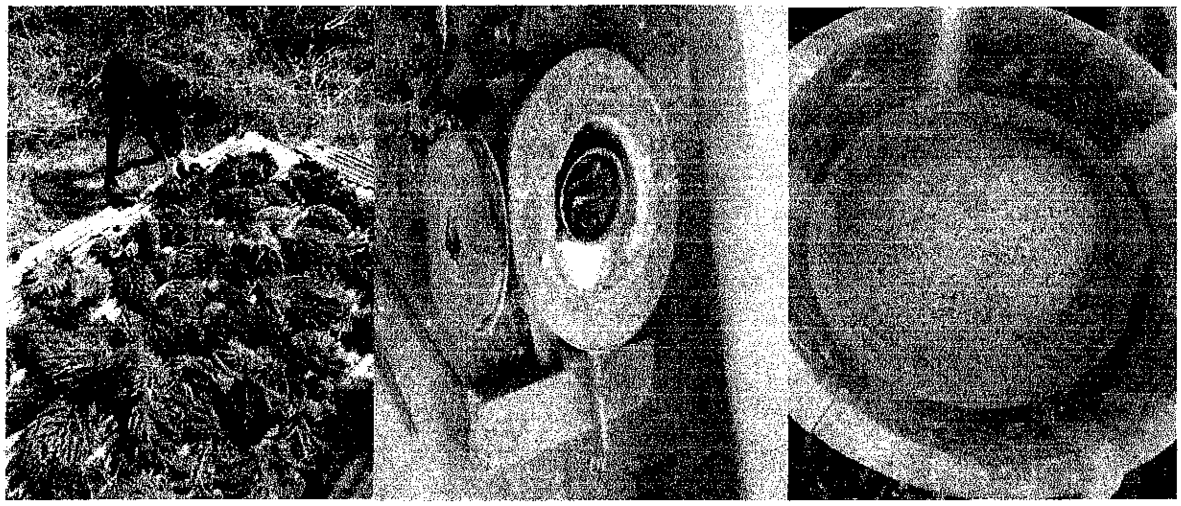

Plate 3.1: Empty Palm Oil Fruit Brunch Ash (EPO-FBA) processing

The empty palm oil fruit brunch ash (EPO-FBA) was obtained from empty palm oil fruit brunch (Plate 3.1). They were wastes products generated through activities of palm oil industries. These industries were numerous around the Ikole and Oye Campuses of the Federal University, Oye-Ekiti, Nigeria, and thus served as the source of the empty palm oil fruit brunched used for this investigation.

3.2.5 Portable water

The water used for the experiment was potable tap water, free from any dissolved metal or ions that might inhibit the setting and hydration process of the foamed concrete.

3.3 Material estimation, mixing calculation and Proportioning of Concrete

3.3.1 Preliminary Information

Mix ratio ⇨ 1:2:4

Water cement ratio (W/C) ⇨ 0.5

No of cubes per sample = 3

No of curing Days = 5 (i.e. 7, 14, 28, 60, 90 days)

No of proportioning = 4 (i.e. 0% to 15%) at 5% interval

No of cubes to be casted per day = $3 \times 4 = 12$ (for different proportions)

3.3.2 Mix Design Calculations for cubes

For this investigation, as it is the common practice in Nigeria, a concrete design mix ratio of 1: 2: 4 was chosen and water/cement ratio of 0.5. This was used for the estimation of materials to be used for this project.

Volume of one cube concrete = $(0.15)^3 \times 2400kg = 8.1kg$

Weight of concrete [3 samples] = $8.1 \times 3 = 24.3kg$

Total weight of concrete = weight of concrete × No of curing days

$$= 24.3 \times 5 = 121.5kg$$

Weight of each concrete constituent;

1. **Cement:** $\frac{1}{7} \times 121.5kg = 17.36kg$
2. **Sand:** $\frac{2}{7} \times 121.5kg = 34.71kg$
3. **Granite:** $\frac{4}{7} \times 121.5kg = 69.43kg$
4. **Water Ratio:** $0.5 \times 17.36kg = 8.68kg$

Table 3.1: Mix design schedule for cubes

Proportion	Binder(kg)		Fine Aggregate	Coarse Aggregate	Water
(%)	Cement	EPO-FBA	(kg)	(kg)	(kg)
0	17.36	0	34.71	69.43	8.6
5	16.49	0.87	34.71	69.43	8.6
10	15.62	1.74	34.71	69.43	8.6
15	14.76	2.60	34.71	69.43	8.6
TOTAL	**64.23**	**5.21**	**138.84**	**277.72**	**34.4**

3.3.3 Mix Design Calculations for cylinder

Volume of concrete = $\frac{22}{7} \times (0.075)^2 \times 0.3 \times 2400kg = 12.7kg$

Weight of concrete [3 samples] = $12.7 \times 3 = 38.1kg$

Total weight of concrete = weight of concrete × No of curing days(i.e. 28 and 90days)

$= 38.1 \times 2 = 76.2kg$

Weight of each concrete constituent;

1. **Cement:** $\frac{1}{7} \times 76.2kg = 10.89kg$
2. **Sand:** $\frac{2}{7} \times 76.2kg = 21.77kg$
3. **Granite:** $\frac{4}{7} \times 76.2kg = 43.54kg$
4. **Water Ratio:** $0.5 \times 10.89kg = 5.45kg$

Table 3.2: Mix design schedule for cylinder

Proportion	Binder(kg)		Fine Aggregate	Coarse Aggregate	Water
(%)	Cement	EPO-FBA	(kg)	(kg)	(kg)
0	10.89	0	21.77	43.54	5.45
5	10.35	0.54	21.77	43.54	5.45
10	9.8	1.09	21.77	43.54	5.45
15	9.26	1.63	21.77	43.54	5.45
TOTAL	**40.23**	**3.26**	**87.08**	**174.16**	**21.8**

3.3.4 Estimates

Number of cement bag used = 105kg/50kg = 2.1 Bags, Approximately 2.5 bags of cement

Fine aggregate (Sand) used = 226kg

Coarse aggregate (Granite) used = 452kg

EPO-FBA used = 8.5kg

3.4 Casting of Specimens

The wooden moulds of dimension 150mm x 150mm x 150mm and cylindrical pipe of 300mm x 150mm was used, with an engine oil which is rub at the inner surface of the mould and cylindrical pipe so as to give a lubricating effect between the mould and the concrete after it has harden for easy removal. The mould and cylindrical pipe is put at a levelled and smooth surface so as to give the cubes a smooth base. Concrete was poured into the moulds and cylinder in two layers in such a way that each pouring will be approximately equivalent with the height of the mould divided into two. Then each layer poured is compacted using a tamping rod so as to give properly locking of the concrete and also to reduce the honeycomb due to improper compaction, using the tamping rod each layers of the concrete are given 25 blows each, equally distributed throughout the surface of the layer, the equally distributed blows are done for every layer. At the last layer the concrete is poured above the height of the mould and the cylindrical pipe before compacting it so as to provide a sufficient level of concrete, excess concrete is then scrape off from the surface using a hand trowel, so as to give a proper levelling with the top of the mould and cylinder pipe. The surface of the casted cube is then smoothening to provide a smooth surface. The proportion of the EPO-FBA present in the concrete and the date of casting is then inscribed on the concrete. The cubes are then removed after twenty-four hours to be cured for different day intervals. The casting of test specimens is shown in Plate 3.2(i) and Plate 3.2(ii) below;

Plate 3.2(i): Casting of the test specimens

Plate 3.2(ii): Casting of the tests specimen

3.5 Curing of specimen

After 24 hours of casting, Specimen were de-moulded and totally immersed in fresh water in a curing tank to ensure complete hydration. The number of days each concrete spent in the curing tank was based on the individual target strength (7, 14, 28, 60 and 90 days was used).

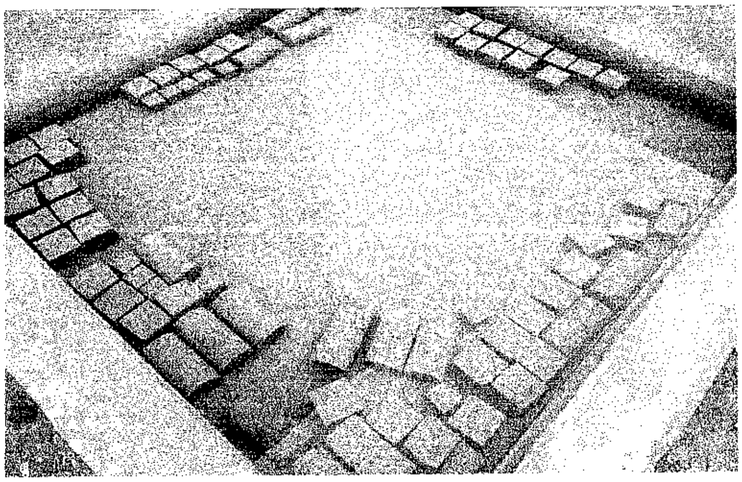

Plate 3.3: Curing of Concrete cube specimen

Table 3.3: Casting and testing schedule

DAYS	CASTING DATE	TESTING TEST
7	09/08	16/08
14	02/08	16/08
28	28/07	25/08
60	13/06	12/08
90	12/06	10/09

3.6 Experimental Investigations

The experimental investigation carried out in this research work can be classified into two which are listed below:

1. Preliminary Investigation
2. Main Investigations

3.6.1 Preliminary Investigations

The preliminary investigations performed on the ash were: fineness, specific gravity, consistency, setting time and chemical analysis.

i. Fineness

Fineness of cement is measured by sieving it on standard sieve. Fineness test is carried out on both the OPC and EPO-FBA using dry sieving method in accordance with BS 8110. The apparatus used are 90μm IS Sieve, Balance capable of weighing 10g to the nearest 10mg, A nylon or pure bristle brush, preferably with 25 to 40mm, bristle, for cleaning the sieve.

The procedure is as follows:

10g of cement was weigh approximately to the nearest 0.01g and it is placed on 90micron sieve. The sieve was agitated by swirling, planetary and linear movements, until no more fine material passes through it. The residue was weighed and express its mass as a percentage R1, of the quantity first placed on the sieve to the nearest 0.1 percent. The fine material was gently brush off the base of the sieve. Then the whole procedure was repeated using a fresh 10g of EPO-FBA sample to obtain R2.

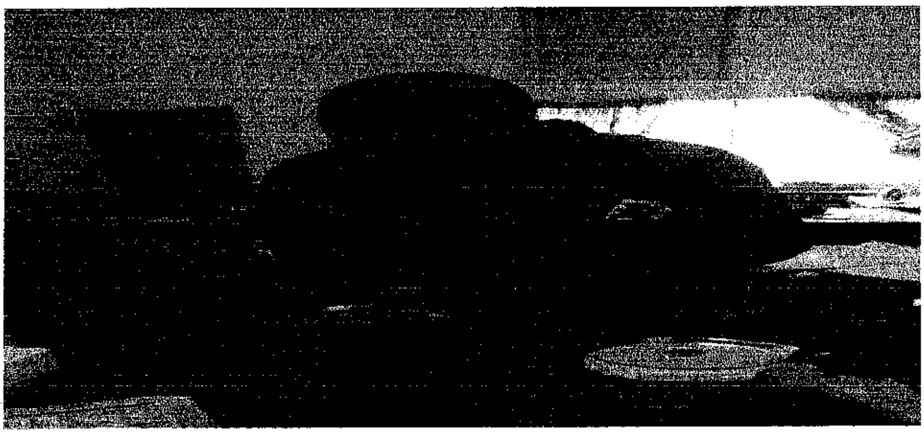

Plate 3.4: Fineness of cement experiment using 90micron sieve

ii. Specific Gravity

Specific gravity is also called the relative density and it is the ratio of the density of aggregate to the density of distilled water at a standard temperature. The specific gravity of EPO-FBA will be determined and compared with OPC in accordance with BS 1377 Part 2. The apparatus used are OPC (Ordinary Portland cement), EPO-FBA, Kerosene, Pycnometer of 100ml and weighing balance with 0.1gm accurate.

The procedure is as follows:

The weight of empty flask was measured (W1). The half of the flask was filled with sample one (Cement) and the weight with its stopper was measured (W2). Then the flask was filled with kerosene up to the top level of the flask. The cement and kerosene was mixed properly to remove air buddle from it and the flask with cement and kerosene was weighed (W3). The flask was empty and was filled again with kerosene up to the top of the flask. Then weigh the flask (W4). Then the whole procedure was repeated again using EPO-FBA instead of cement, for sample to obtain the specific gravity of EPO-FBA.

$$\boldsymbol{Specific\ Gravity\ (S_g) formular} = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)\ X\ 0.79}$$

iii. Consistency

This test is carried out to determine the percentage of water for consistency of a given sample of cement. Cement paste of normal consistency is defined as percentage of water by mass of cement to produce a consistency, which permits a plunger of 10mm diameter to penetrate up to a depth of 5 to 7mm above the bottom of a vicat mould. The apparatus used for carrying out the test are vicat apparatus, trowel, enameled trays, standard spatula, stopwatch, weight balance and measuring cylinder.

The procedure is as follows:

300gm of cement was weighed, accurately and was placed on the enameled tray. 25% of clean water was added and mixed by mean of a spatula. The mould was placed together with the non-porous glass plate under the plunger of vicat's apparatus. The indicator was adjust to show zero reading when the plunger just touches the bottom surface of the test mould. The vicat mould was then filled with the prepared paste, the mould resting on non-porous glass plate. Place the filled mould under the plunger with the surface of the paste just in contact with the plunger bottom.

Quickly release the plunger, allowing it to sink in to the paste. Another new trial pastes was prepared every time with varying percentage of water and test as described above until the plunger penetrates 5 to 7mm above the bottom of the mould. The amount of water was expressed as a percentage by weight (mass) of the dry cement.

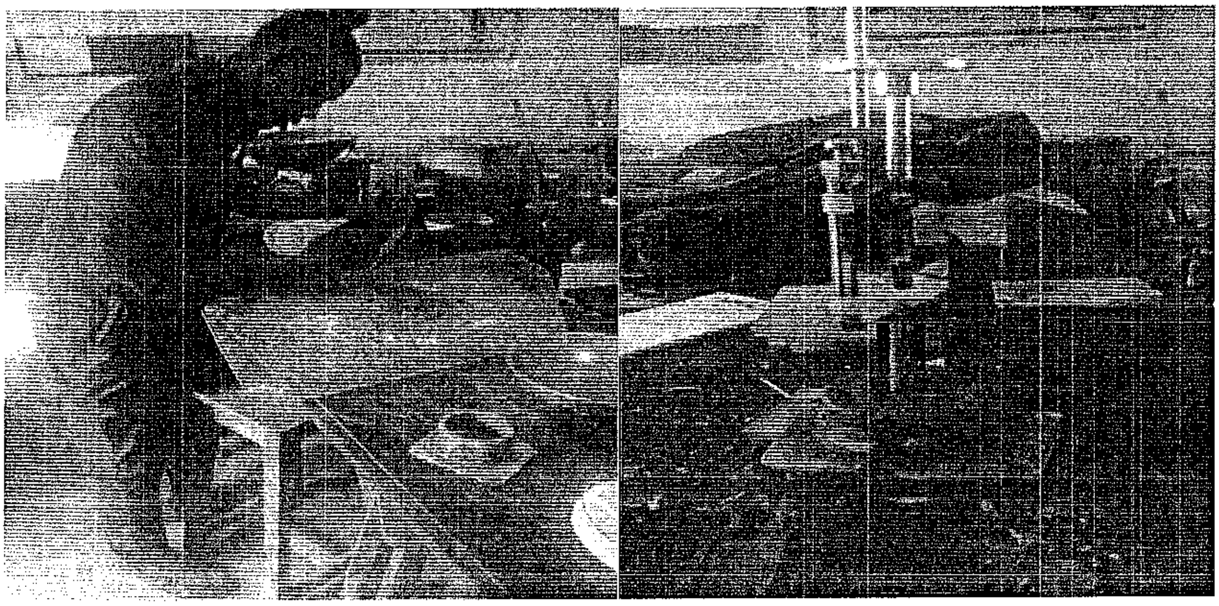

Plate 3.5: Consistency test experiment using vicat's apparatus

iv. Setting Times

This test is carried out to determine the initial and final setting times of cement for a given sample of cement and EPO-FBA. The term "setting" is used to describe the stiffening of the paste which begins to occur sometimes after the water is added to the cement i.e. the change from a fluid to a rigid state (loss of Plasticity).

The apparatus used for this experiments are ; Vicat apparatus with mould and non-porous plate and needle with annular cap. Weight balance with capacity of 1kg. Graduated measuring cylinder 100ml. trowel of about 210gm weight, enamel trays, standard spatulas. Stop watch and thermometer.

The procedure is as follows:

(A) TEST BLOCK PREPARATION

Before commencing setting time test, do the consistency test to obtain the water required to give the paste normal consistency (P). Take 300g of cement and prepare a neat cement paste with 0.85P of water by weight of cement. Gauge time is kept between 3 to 5 minutes. Start the stop watch at the instant when the water is added to the cement. Record this time (t). Fill the Vicat mould, resting on a glass plate, with the cement paste gauged as above. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared is called test block.

(B) INITIAL SETTING TIME

Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle. Lower the needle gently until it comes in contact with the surface of test block and quick release, allowing it to penetrate into the test block. In the beginning the needle completely pierces the test block. Repeat this procedure i.e. quickly releasing the needle after every 2 minutes till the needle fails to pierce the block for about 5 mm measured from the bottom of the mould. Note this time (t).

(C) FINAL SETTING TIME

For determining the final setting time, replace the needle of the Vicat's apparatus by the needle with an annular attachment. The cement is considered finally set when upon applying the final setting needle gently to the surface of the test block; the needle makes an impression thereon, while the attachment fails to do so. The time(t) is noted.

Plate 3.6: Setting time experiment using vicat's apparatus

3.5.2 Main Investigations

The main investigations that would be carried out are: Workability, Density, Compressive Strength and tensile strength. Concrete specimens will be prepared, using a mix ratio of 1:2:4 and water-cement ratio of 0.50. The Portland cement constituent of the mix will be subsequently replaced by EPO-FBA from 0 – 30% at 5% interval by weight. The samples without EPO-FBA served as the control. The density and compressive strength tests will be conducted on concrete cubes 150 x 150 x 150 mm moulds and 150 x 300mm cylinder moulds in accordance with BS 12350: Part 6 (2000) and BS EN 12390-3 (2009) respectively. The concrete specimens will be moist-cured and test after 7, 14, 28, 60 and 90 days.

i. Workability

The slump test is a means of assessing the consistency of fresh concrete. It was used indirectly as a means of checking that the correct amount of water has been added to the mix. The test was carried out in accordance with BS EN 12350-2, Testing fresh concrete (Slump test) this replaces BS 1881: Part 1 02. The steel slump cone was placed on a solid, impermeable, level base and filled with the fresh concrete in three equal layers. Each layer was rammer 25 times to ensure compaction. The third layer was finished off level with the top of the cone. The cone was carefully lifted up, leaving a heap of concrete that settles or 'slumps' slightly. The upturned slump cone was placed on the base to act as a reference, and the difference in level between its top and the top of the concrete was measured and recorded to the nearest 5 mm to give the slump of the concrete. When the cone was removed, the slump may take one of three forms. In a true slump the concrete simply subsides, keeping more or less to shape. In a shear slump the top portion of the concrete shears off and slips sideways. In a collapse slump the concrete collapses completely. Only a true slump is of any use in the test. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix.

Plate 3.7: Fresh Concrete Slump

ii. Density

The weight of concrete per unit volume will be determined using the concrete cube samples of 150mm x 150mm x 150mm size prepared for the compressive strength test in accordance with BS 12350: Part 6 (2000) and BS EN 12390-3 (2009) respectively.

iii. Compressive Strength

Since the major aim of this research was to determine the strength characteristic of the concrete with POEBA used as a replacement of cement and to check the strength variation between the two (that is, with POEBA in proportions and with the control which is with Cement only), hence this aspect is a major process or procedure in this research work. After the cubes has been cured for different day intervals which are 7, 14, 28, 60, and 90 days in portable water the cubes are then prepared for crushing by removing it from the water and allowed to be dried by air for about 30 minutes prior to the crushing process. The cubes are then tested for compressive strength using compression testing machine of 2000KN capacity. The maximum load at failure is taken. The average compressive strength of concrete and mortar specimens was calculated by using the equation stated below;

$$\textbf{Compressive strength } (N/mm^2) = \frac{\textbf{Ultimate compressive load (N)}}{\textbf{Area of cross section of specimen } (mm^2)}$$

The tests should then be carried out on the three cubes specified for the proportion and also the curing days so as to determine the average strength of the specimens and the average compressive strength values were taken.

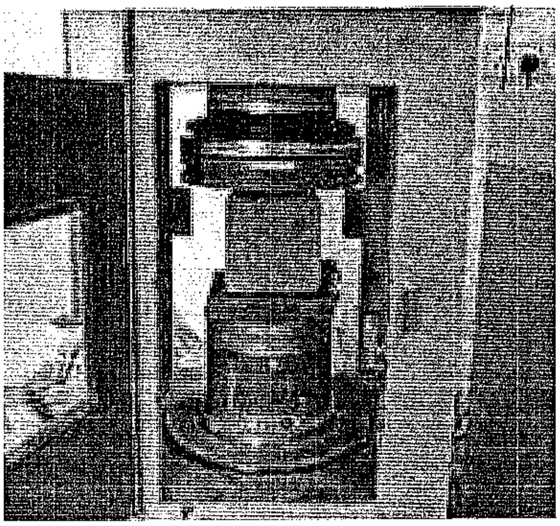

Plate 3.8: Concrete cube undergoing compression

iv. Tensile Strength

Tensile strength of a material is the maximum amount of tensile stress that it can take before failure, for example breaking. Concrete specimen of 150 x 300mm cylinder mould will be casted and cured for 28 and 90 days.

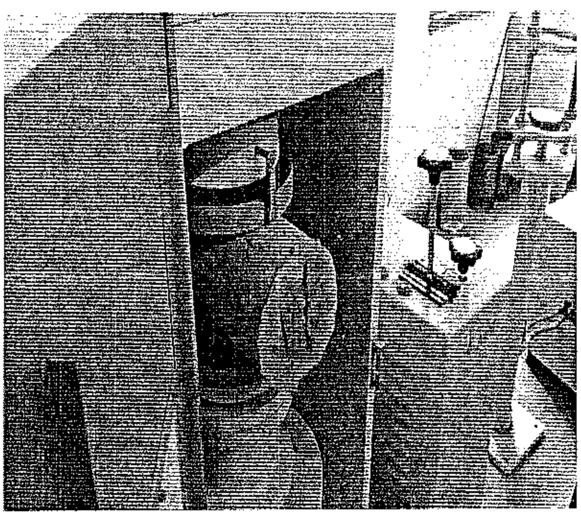

Plate 3.9: Tensile strength test

v. Durability

Durability is defined as the capability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties. It normally refers to the duration or life span of trouble-free performance. Different concretes require different degrees of durability depending on the exposure environment and properties desired. For example, concrete exposed to tidal seawater will have different requirements than indoor concrete. The durability properties that were tested on EPO-FBA concrete are water absorption and sorptivity.

A. Coefficient of Water Absorption

Coefficient of water absorption is suggested as a measure of permeability of water. This is measured by the rate of uptake of water by dry concrete in a period of 60m.

The concrete specimen was heated in an oven at 90°C – 100°C until constant weight is achieved. The concrete was then cooled at room temperature for 24hr. The four sides of the concrete specimen was then coated with silicone sealant to a height of 50mm while recording its mass. The sealed concrete specimen was then immersed in water in a shallow span to a depth of 5mm. After 60m, the concrete specimen was removed. Excess surface water was wiped out and the concrete was then reweighed. At the end of the test, the coefficient of water absorption was calculated using formulae.

B. Sorptivity

Sorptivity is a measure of the capillary forces exerted by the pore structure causing fluids to be drawn into the body of the material. The same procedure as that of water absorption was followed but the time at which the concrete specimen was taken out of the water differs. The concrete specimen was removed at selected times 4, 8, 10, 20, 30, 60, 90 and 120m. The sorptivity was also calculated using formulae.

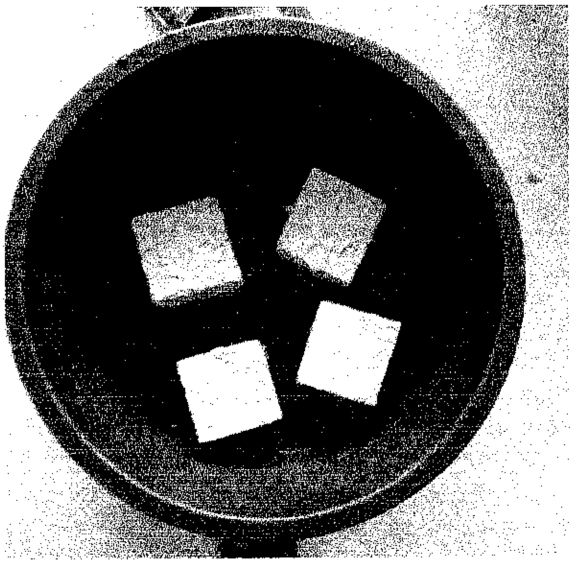

Plate 3.10: 100mm concrete cubes with 10mm depth in Water to test for sorptivity and water Absorption

Plate 3.11: Water absorption and sorptivity test

vi. Microstructure

Concrete has a heterogeneous microstructure, which consists of three components namely; cement paste, pore structure, and interfacial transition zone between the cement paste and aggregates. Improving these three components leads to enhance mechanical strength and durability of concrete.

Microstructural test will be carried out on broken sample of 28 days specimen of EPO-FBA Concrete. Scanning electron microscopy equipment was used to examine the morphological structures of the concrete containing Empty palm oil fruit bunch ash as partial replacement of Ordinary Portland Cement. This involves the characterization of the cement paste and the paste/aggregate interface. The equipment model ASPEX 3020 scanning electron microscopy (SEM) comes with energy dispersive spectrometer (EDS), allows high resolution identification of elements and compounds present in prepared 2-D cross sections of aggregate samples to be obtained.

All samples must be of an appropriate size to fit in the specimen chamber and are generally mounted rigidly on a specimen holder called a specimen stub. Several models of SEM can examine any part of a 6-inch (15 cm) semiconductor wafer, and some can tilt an object of that size to 45^0.

Samples are coated with platinum coating of electrically conducting material, deposited on the sample either by low-vacuum sputter coating or by high-vacuum evaporation. SEM instruments place the specimen in a relative high-pressure chamber where the working distance is short and the electron optical column is differentially pumped to keep vacuum adequately low at the electron gun. The high-pressure region around the sample in the ESEM neutralizes charge and provides an amplification of the secondary electron signal. Low-voltage SEM is typically conducted in an FEG-SEM because the field emission guns (FEG) is capable of producing high primary electron brightness and small spot size even at low accelerating potentials.

Embedding in a resin with further polishing to a mirror-like finish can be used for both biological and materials specimens when imaging in backscattered electrons or when doing quantitative X-rays microanalysis.

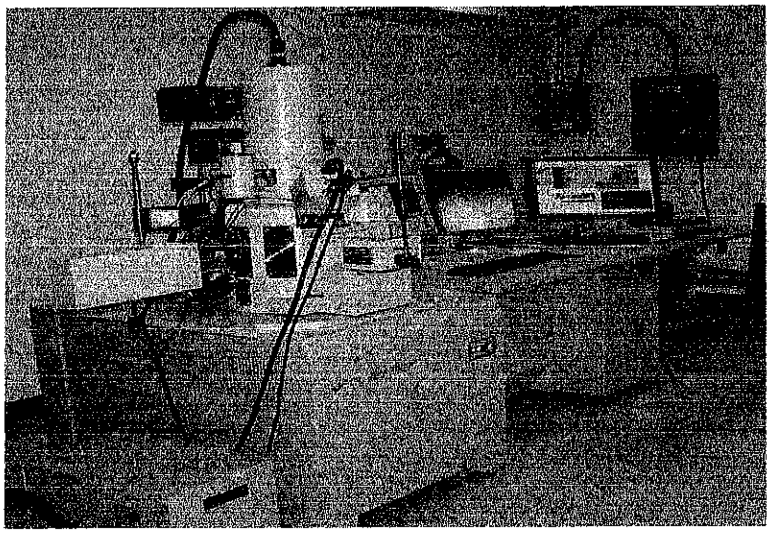

Plate 3.12: Scanning Electron Microscope Machine

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 General

The results from the preliminary tests (chemical composition, fineness of POEBA in relation to cement, consistency and setting time) as well as the concrete strength tests (Density, Compressive strength, tensile strength, durability test and microstructure) are discussed in this chapter. The tables and figures in this chapter shows the results of the preliminary tests. The details of the results are discussed below.

4.1 Preliminary Test

4.1.1 Chemical Analysis

Table 4.1: Chemical Composition of EPO-FBA and OPC

S/N	CHEMICAL COMPOSITION PARAMETERS	RESULT OBTAINED (%)	
		EPO-FBA	CEMENT
1	CaO	3.100	64.37
2	SiO_2	6.420	20.68
3	Fe_2O_3	6.640	3.62
4	MgO	4.100	1.81
5	Al_2O_3	12.700	5.41
6	SO_3	1.420	1.03
7	Na_2O	7.250	0.51
8	K_2O	1.860	0.47
9	P_2O_3	0.610	0.32
10	Mn_2O_3	2.620	0.007
11	LOI	44.600	0

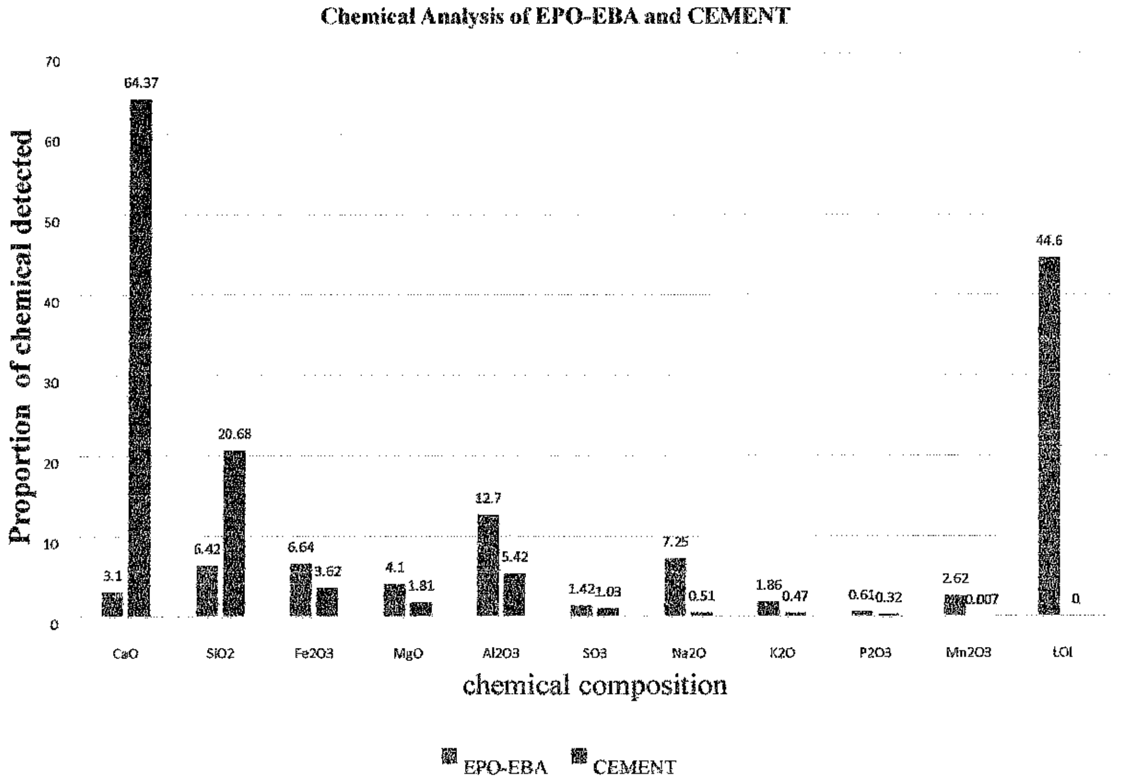

Figure 4.1: Comparison between Chemical composition of POEBA and Cement

The results of chemical composition analysis of the pozzolanic material used (EPO-FBA) and Ordinary Portland Cement are listed in Table 4.1 above. The result of composition of EPO-FBA and cement contained some low quantities of SiO_2+Al_2O_3, with an especially lesser amount of SiO_2. The chemical composition of natural pozzolan is limited to the minimum sum of SiO_2+Al_2O_3+Fe_2O_3 $\geq$70% in ASTM C 618 and the Turkey Standards (TS 25). The sample material which is EPO-FBA in our study have the sum of SiO_2+Al_2O_3 as 19.120% which is far lesser than the chemical requirement. But, since it will only act as a replacement for cement, therefore considering the aggregate composition of EPO-FBA with cement will give composition of SiO_2+Al_2O_3+Fe_2O_3 $\geq$25.76% which is low compared to the aggregate composition of

$SiO_2+Al_2O_3+Fe_2O_3 \geq 29.71\%$ for cement. A relatively low content of $SiO_2+Al_2O_3$ could also indicate the acidic nature of the pozzolanic material.

The concept had been declared that the most important composition of pozzolan is SiO2 and it can provide contributions to pozzolanic activity in non-crystalline form (Ahmet and Sukru 2007, Alp *et al.* 2009). The chemical composition of natural pozzolan is stated as 50–67% SiO2 in the German standards (DIN 51043). Because the EPO-FBA investigated contained a far lesser proportion of SiO_2 than required by this standard, which implies that they may hinder the potential for SiO_2 activity to actuate the pozzolanic activity during second hydration reaction. Rodriguez-Camacho and Uribe-Afif (2002) examined the performance of nine natural pozzolan in Mexican. They found that the pozzolan with 11.6-14.7% alumina was highly resistant to sulphate attack. In this regard, the material used in this study could be expected to produce a lesser resistance to sulphate attack when used as an admixture in the cement-based composite, but further tests should be performed to verify this assumption.

Also, the Loss of Ignition (LOI) present in the EPO-FBA is far greater than the LOI present in the cement. The loss on ignition, a measure of the extent of carbonation and hydration of free lime and free magnesia due to atmospheric exposure, of EPO-FBA is 44.6%. This value is far greater than the limits of 3.0% set by BS 12 (1996). The alkalis (K_2O and Na_2O), with a combined percentage of 9.110% is low, and thus reduce the possibility of the destructive alkali-aggregate reaction (Neville, A. M., 2003).

4.1.2 Fineness

The fineness of a material is responsible for the ratio of dehydration in the material. The fineness test is carried out on the Portland cement (Dangote Portland Cement) used in comparison with the pozzolanic material used which is POEBA and the result are analysed in a tabular form below in the table below.

Table 4.2: Fineness of Cement and EPO-FBA

Portland Cement (%)	EPO-FBA (%)
91	69

POEBA fineness can be expressed in terms of median particle size, percent mass collected in a 90μm sieve and the value being related to the fineness of the cement used.

Tay (1990) and Tangirapat et al. (2007), reported that large-sized pozzolanic materials has a low pozzolanic potential because of its large sized particles. Hence EPO-FBA is a low pozzolanic material with fineness of 69% by weight compared to the fineness of cement which is 91%.

4.1.3 Consistency

This test is carried out to determine the percentage of water for consistency of a given sample of cement. Cement paste of normal consistency is defined as percentage of water by mass of cement to produce a consistency, which permits a plunger of 10mm diameter to penetrate up to a depth of 5 to 7mm above the bottom of a vicat mould. It is necessary to determine the quantity of water to be mixed to prepare a cement paste of standard consistency for performing the tests for setting times, compressive strength and soundness. The quantity of the water to be added in each of the above mentioned experiments bear a definite relation with the percentage of water for normal.

Table 4.3: Consistency of EPO-FBA cement paste result

EPO-FBA (%)	CONSISTENCY (%)
0	27
5	32
10	34
15	39

4.1.4 Setting Times

The Initial and Final setting times obtained for each cement replacement level with EPO-FBA is as shown in Table 4.3. From Table 4.4, it can be seen that there is only a slight difference between the initial setting time of control cement paste and 5% replacement level, the initial setting time of the control paste is 80minutes while that of 5% replacement is 82minutes. For the 10% replacement level, there is a significant decrease in the initial setting time (27min) compared to 0% and 5%. The 15% replacement level was found to be 67min which is more than that of 10% replacement level. On the other hand, the final setting time of OPC was found to be 149min which is less than that of 5% which took the longest time to finally set. The final setting time decreases linearly with increase in EPO-FBA content from 10% to 15%. This result can be attached to the fact that EPO –FBA possess a very small specific surface area (Fapohunda et al. , 2017) which gave it the property of low water absorption rate and which in turn delayed the hydration process of the OPC/EPO-FBA paste.

Table 4.4: Setting times of EPO-FBA cement paste result

EPO-FBA (%)	INITIAL SETTING TIME (min)	FINAL SETTING TIME (min)
0	80	149
5	82	189
10	27	165
15	67	146

4.2 Main Investigation

4.2.1 Workability

Workability, in simplest language, is the ease with which freshly prepared concrete can be transported and placed for the job and compacted to a dense mass. Obviously, such a concrete should be a homogeneous mix having the desired consistency. It should be capable of spreading, easily and uniformly without inducing any segregation of the aggregates.

Table 4.5: Workability characteristics of concrete samples with EPO-FBA as partial replacement of OPC

Replacement (%)	Slump (mm)
0	30
5	20
10	20
15	20

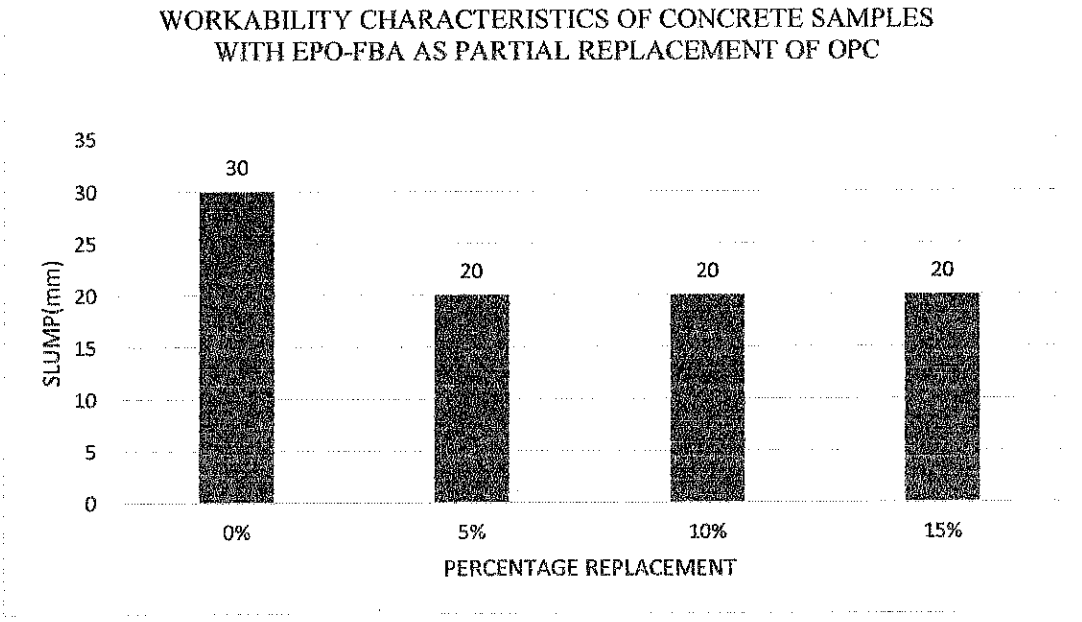

Figure 4.2: Workability characteristics of concrete samples with EPO-FBA as partial replacement of OPC

The result of the slump test for fresh concrete shows that the control mix, 30mm slump was achieved while the other percentage replacement (5%, 10% and 15%) gave 20mm slump. This result showed that EPO-FBA produces a harsh and lean mix as the replacement level increases. This result can then be attached to the fact that EPO-FBA possess a low percentage of fineness which in turn gave its large surface area characteristics. This means that large surface area of EPO-FBA is exposed for water to wet making the water to be insufficient as quantity of EPO-FBA increases. This in turn produces harsher mix which is less workable and which brings about the reason for a very low slump all through.

This result fall within the range of concrete classified as low workability (Neville, 2013). Due to the fact that all the samples indicate a cohesive mix and no segregation, the slump can be classified as true slump (Shetty, 2009). In the other hand, according to (Gambhir, 2013), such concrete is applicable in lightly reinforced sections and for mass concrete production.

4.2.2 DENSITY OF CONCRETE SPECIMENS WITH EPO-FBA

Table 4.6: Density of concrete with different proportion of EPO-FBA at various age

Curing Age	Proportion of EPO-FBA	Density (Kg/m^3)
7 Days	0	2441.5
	5	2417.8
	10	2414.8
	15	2405.9
14 Days	0	2483.0
	5	2483.0
	10	2432.6
	15	2423.7
28 Days	0	2488.9
	5	2483.0
	10	2474.1
	15	2474.1
60 Days	0	2509.6
	5	2500.7
	10	2462.2
	15	2456.3
90 Days	0	2485.9
	5	2491.9
	10	2483.0
	15	2488.9

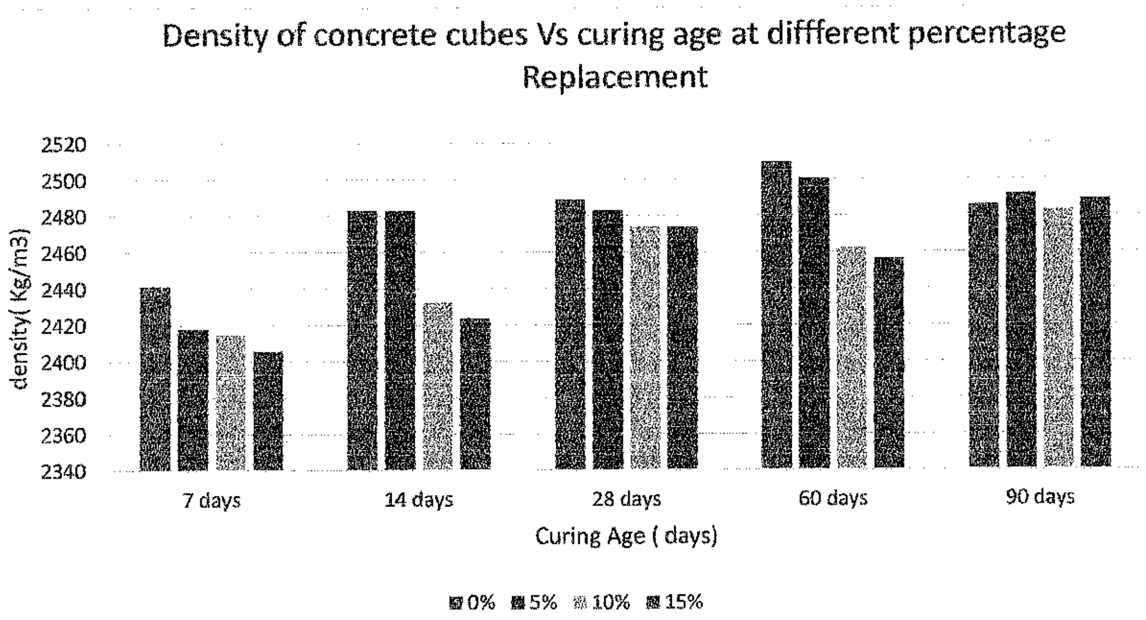

Figure 4.3: Density of concrete with different proportion of EPO-FBA

The density of concrete with different percentage replacement of Cement with EPO-FBA considered at different curing age are shown in the figure 4.3 above. It was found that the density increases with increase in the amount of EPO-FBA that replaces cement in the concrete and the minimum density is 2414.8kg/m^3 for 10% percentage replacement of cement with EPO-FBA at 7days and the maximum density which is 2509.6kg/m^3 occurs at 0% percentage replacement at 60days. The results also showed that the optimum content can be used for making the low initial strength concrete to ensure the economic benefits in constructions.

Also, considering the three types of concrete based on density which are: Lightweight, Normal weight and Heavy Weight Concrete, from the knowledge that concrete having densities in the range of 300 – 1950kg/m^3 are classified lightweight concrete; those in the range of 2200 – 2400kg/m^3 as normal weight concrete, and concrete with densities greater than 2500 kg/m^3 are regarded as heavyweight concrete (Falade et al., 2011), and since all the concrete with different proportion percentage with different age of curing ranges in densities between 2414.8kg/ m^3 and

2509.6kg/m^3 the concrete are classified as a heavyweight concrete and this helps in the optimization of concrete density to improve structural efficiency (the strength to density ratio), reduce transportation costs, and also enhance the hydration of high-cementitious concrete mixtures with low water-binder ratios (less than 0.40) is accomplished by replacing part of the normal-density aggregates (coarse aggregate, fine aggregate, or both) with comparable amounts of low-density aggregate.

4.2.3 COMPRESSIVE STRENGTH OF CONCRETE SPECIMENS WITH EPO-FBA

Table 4.7: Compressive strength of concrete of different proportion of EPO-FBA at various age

Curing Age	Proportion of EPO-FBA	Compressive Strength (N/mm^2)
7 Days	0	24.84
	5	24.96
	10	17.82
	15	15.82
14 Days	0	25.34
	5	24.82
	10	22.71
	15	18.85
28 Days	0	29.78
	5	26.42
	10	24.38
	15	22.24
60 Days	0	33.61

	5	**34.12**
	10	**30.75**
	15	**27.51**
90 Days	**0**	**35.28**
	5	**34.11**
	10	**32.90**
	15	**30.84**

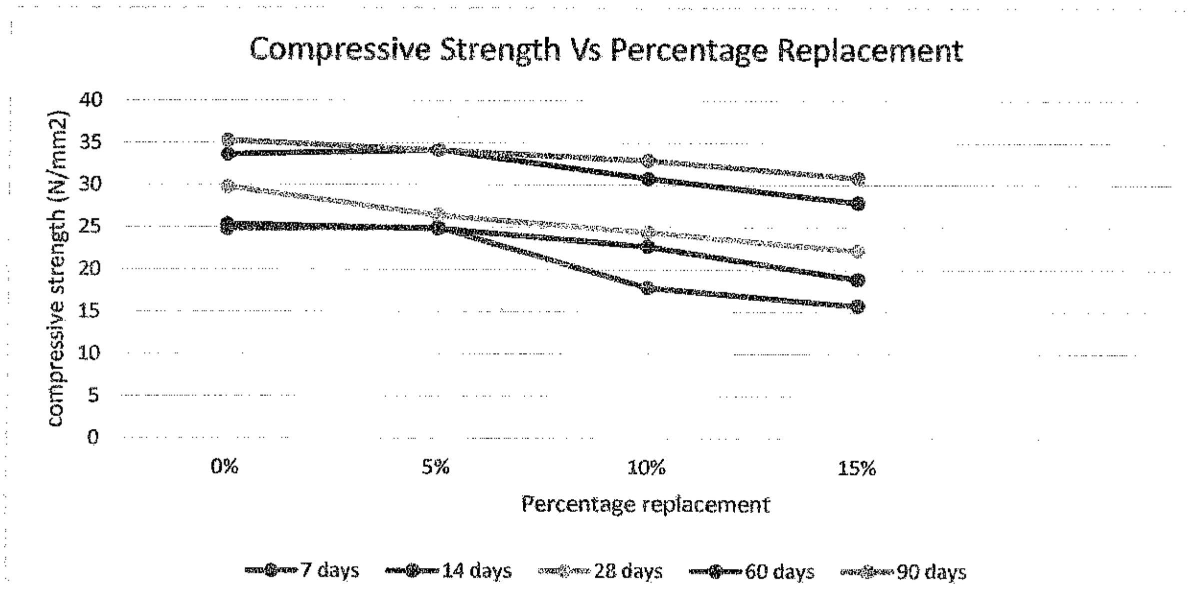

Figure 4.4: Compressive strength of concrete with different proportion of EPO-FBA

In figure 4.4 shown above, the change in the compressive strength for concrete with different proportion of EPO-FBA as a partial replacement of cement is presented and the following observations are made, the compressive strength of the concrete decreases as the proportion of the EPO-FBA is increased in the concrete with the compressive strength occurring at the least proportion which is 5% replacement of cement with EPO-FBA. Also an increase is shown at 5% replacement at 60 days of curing before a decrease is noted as the proportion of EPO-FBA is further increased. Hence, up to 5%, there is no significant difference in the compressive strength compared with the control.

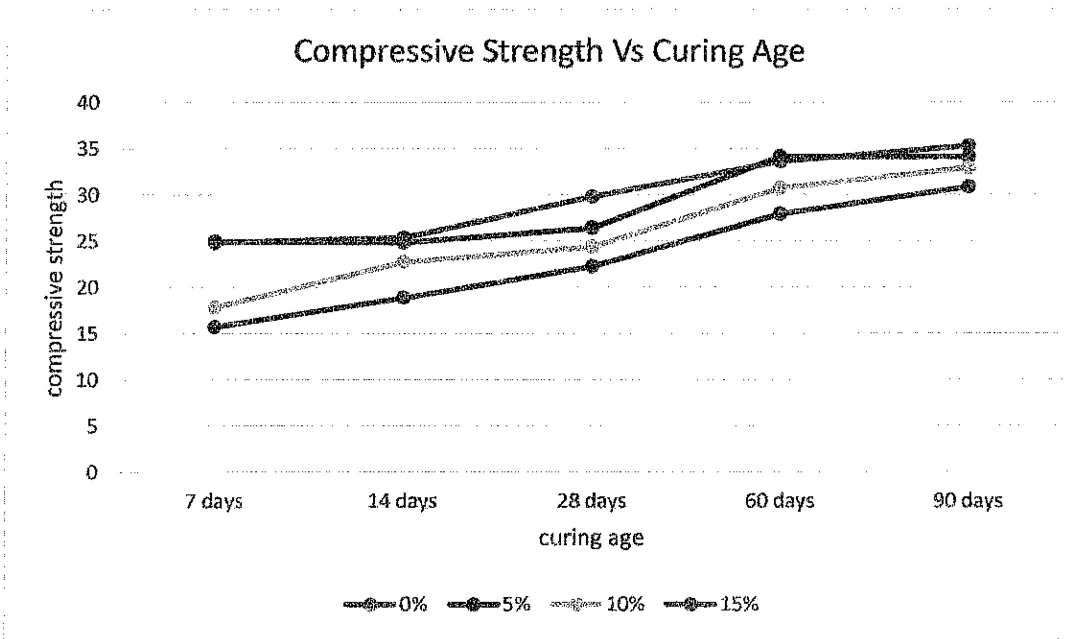

Figure 4.5: Compressive strength of concrete at different curing age

Figure 4.5 depicts the variation of compressive strength with curing age of concrete with different proportion of EPO-FBA for all the various series of mixes considered. The compressive strengths obtained for concrete mixes with proportion of EPO-FBA between 10% to 15% increases with increase in curing age but 5% proportion of EPO-FBA shows a different trend of compressive strength increment as the strength drop at curing age of 60 days and later increases at 90 days. Also comparing other proportion to the control mix which also shows an increase in compressive strength with increase in curing days shows a similar trend of compressive strength increase.

The maximum strengths occur at 90 days of curing with the control mix having the maximum compressive strength follow by the 5% proportion of EPO-FBA which is very close to the maximum compressive and hence shows little or no significant change and an increase in compressive strength is noticed with increase in age.

Table 4.8: Determination of the Pozzolanicity of Empty Palm Oil Fruit Brunch Ash (EPO-FBA) through Strength Activity Index (SAI)

% of (EPO-FBA) in the Mix	Compressive Strength, CS (N/ mm^2) and Strength Activity Index, SAI (%)									
	Curing Ages (days)									
	7		14		**28**		60		90	
	CS (N/mm^2)	**SAI (%)**	CS (N/mm^2)	SAI (%)	**CS (N/mm^2)**	**SAI (%)**	CS (N/mm^2)	SAI (%)	CS (N/mm^2)	SAI (%)
0	**24.84**	**100**	25.34	100	**29.78**	**100**	33.61	100	35.28	100
5	**24.96**	**100.50**	24.82	97.95	**26.42**	**88.72**	34.12	101.52	34.11	96.68
10	**17.82**	**71.74**	22.71	89.62	**24.38**	**81.87**	30.75	91.49	32.90	93.25
15	**15.82**	**63.69**	18.85	74.39	**22.24**	**75.00**	27.51	81.85	30.84	87.41

The strength activity index is measured by calculating the strength developed by the blend of the suspected pozzolan relative to the control. For any material to be classified as a pozzolan, the strength of the blended sample at 7-days and/or 28-days must not be less than the 75% of the strength of control specimens.

From Table 4.8, it can be seen that at 7-days only the sample with 5% of cement replaced with empty palm oil fruit brunch ash (EPO-FBA) met the criterion of pozzolanicity. However, at 28-days curing, all the mixes exhibited pozzolanic traits because the 28-days strengths of specimens containing empty palm oil fruit brunch ash (EPO-FBA) were all more than 75% of the strength of specimens without EPO-FBA, that is, the control specimens. It can thus be concluded that EPO-FBA is pozzolanic.

4.2.4 TENSILE STRENGTH OF CONCRETE SPECIMENS WITH EPO-FBA

Table 4.9: Tensile strength of concrete of different proportion of EPO-FBA

Proportion (%)	Curing Age (N/mm^2) 28 Days	90 Days
0	3.10	3.22
5	2.91	2.82
10	2.72	2.81
15	2.72	2.78

The results of tensile strength of concrete mixes with and without EPO-FBA measured at 28 days and 90 days are given in Table 4.9 above. Test results indicate that the tensile strength reduces as the percentage of EPO-FBA increase from 0% to 15%. When the replacement of EPO-FBA is increased, strength goes on decreasing. However, for 10% at 28days ash added, the tensile-strength development was the same as the 15%. These results are represented graphically below in Figure 4.9.

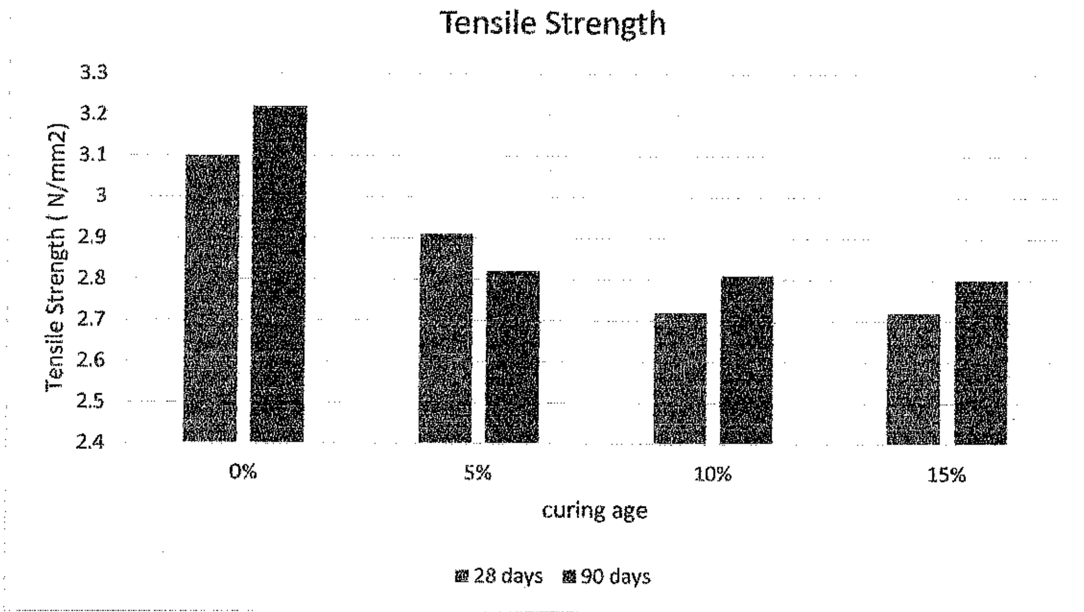

Figure 4.6: Tensile strength of concrete of different proportion of EPO-FBA

4.2.5 DURABILITY OF CONCRETE SPECIMENS WITH EPO-FBA

The result of durability performance of Concrete with EPO-FBA as partial replacement of OPC assessed by testing for water absorption and sorptivity after 28 and 90 days of curing are as shown in Table 4.10 and Figure 4.7. From the result, it can be seen that both the sorptivity and water absorption of all the tested samples showed the same pattern. The water absorption rate increases with increase in quantity of EPO-FBA. This result can be connected to the withdrawal of mixing water from the mix as EPO-FBA content increases which then leads to the formation of unhydrated compounds without the product of hydration (C-S-H). This left some pores within the concrete structure which then led to the increase in water absorption. In the other hand, the result of water absorption rate and after 90-Days curing is less than that of 28-Days. This result can be due to the fact that more hydration product (C-S-H) was produced at later curing ages which are responsible for filling the pores in the concrete structure and which in turn reduces the water absorption rate. The hydration products can also bring about a state of discontinuity of pores in the internal matrix, thereby making the material impervious (Fapohunda et al., 2017).

Table 4.10: Water absorption results for 28-Days and 90-Days Curing Ages

Replacement Level (%)	Water Absorption (m^2/s) of concrete specimens with respective curing ages	
	28 Days	90 Days
0	2.32×10^{-9}	1.11×10^{-9}
5	4.08×10^{-9}	2.34×10^{-9}
10	1.81×10^{-9}	3.80×10^{-9}
15	8.05×10^{-9}	5.03×10^{-9}

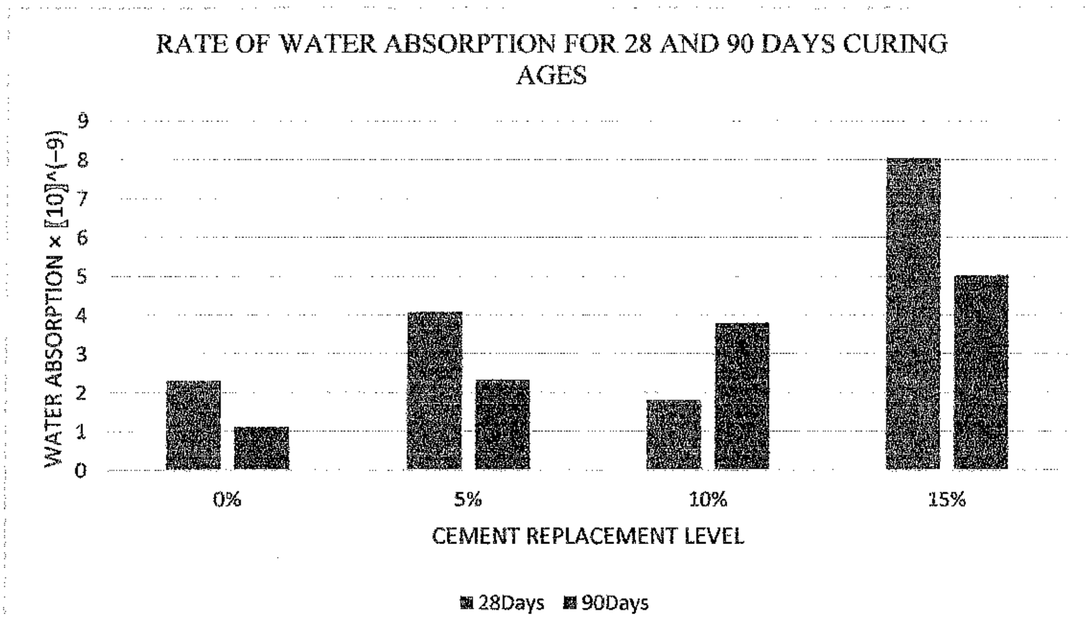

Figure 4.7: Water absorption results for 28-Days and 90-Days Curing Ages

4.2.6 Microstructure

The microstructural examination of selected samples was conducted to analyse the bond between the concrete aggregate and cement paste at the microscopic level. According to (Mindess et al., 2003) the bonding between the aggregate and binder is considered vital for better transfer of stresses between the binder and aggregates especially at the interfacial zone, which influences the concrete strength. The main source of strength in concrete is the adhesion between the solid products of hydrated cement paste. This adhesion can be attributed to the van der Waals forces of attraction with a degree of adhesive depends on the extent and the nature of the solid surfaces involved. Some of hydrated products, such as C-S-H crystals, calcium sulfoaluminate hydrates, and hexagonal calcium aluminate hydrates, possess vast surface areas and adhesive capability. Therefore, they tend to adhere strongly to each other and at the same time to solids with low surface areas fine and coarse aggregate particles (Just et al., 2013).

The SEM analyses were conducted on selected concrete samples at replacement level 0%, 5%, 10% and 15% cured for 28 days. Figure 4.9 shows the SEM micrograph taken on the fractured surface of concrete without EPO-FBA. This Diagram shows a well-developed aggregate–cement paste interface and the hydration product C-S-H (Calcium Silicate Hydrate) can be seen as honeycombs structure with some surrounding pores but no crack. In the other hand, from Figure 4.10, the 5% replacement level with EPO-FBA shared similar characteristics with that of the control sample. The strength forming product of hydration C-S-H can be seen surrounding the whole aggregate structure with no cracks and little pores compared to that of 0% replacement. This later age development of the strength forming hydration product C-S-H can be connected to the promising result of compressive strength in the 5% replacement with EPO-FBA which is very close to the strength of Control sample.

It can be observed from the remaining (as shown in Figure 4.10 to 4.11 below), 10% and 15% respectively, as the quantity of EPO-FBA increases, the pores reduces and the structure became densely packed. This can be connected to the fact that there is reduction in the quantity of strength forming hydration product C-S-H as the quantity of EPO-FBA increases which makes the remaining unreacted EPO-FBA particle to fill the pores in the structure. This shows that EPO-FBA possess micro-filling ability and explains the low result of compressive strength at 28Days especially at larger replacement with EPO-FBA. In the other hand, the increase in the content of unreacted EPO-FBA shows the reason why the rate of water absorption increases with increasing EPO-FBA.

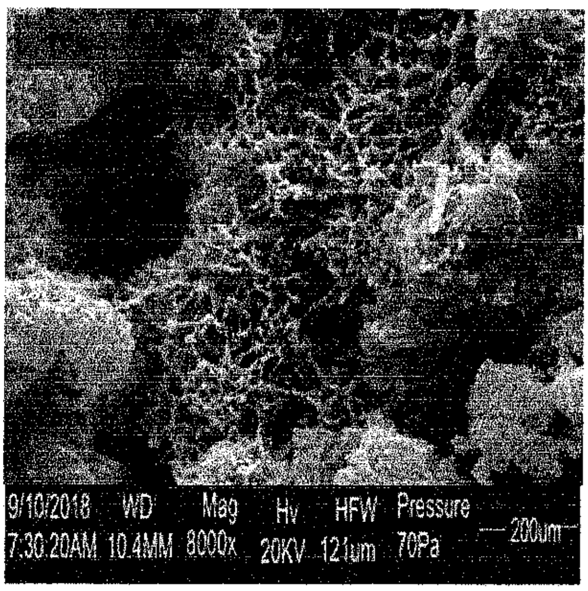

Figure 4.8: SEM microghraph of concrete with 0% EPO-FBA

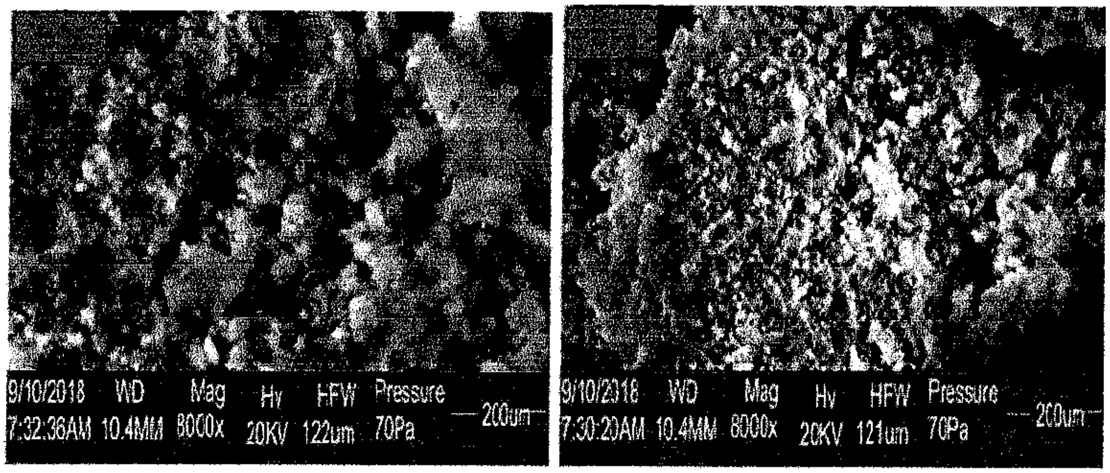

Figure 4.9: SEM microghraph of concrete with 5% EPO-FBA

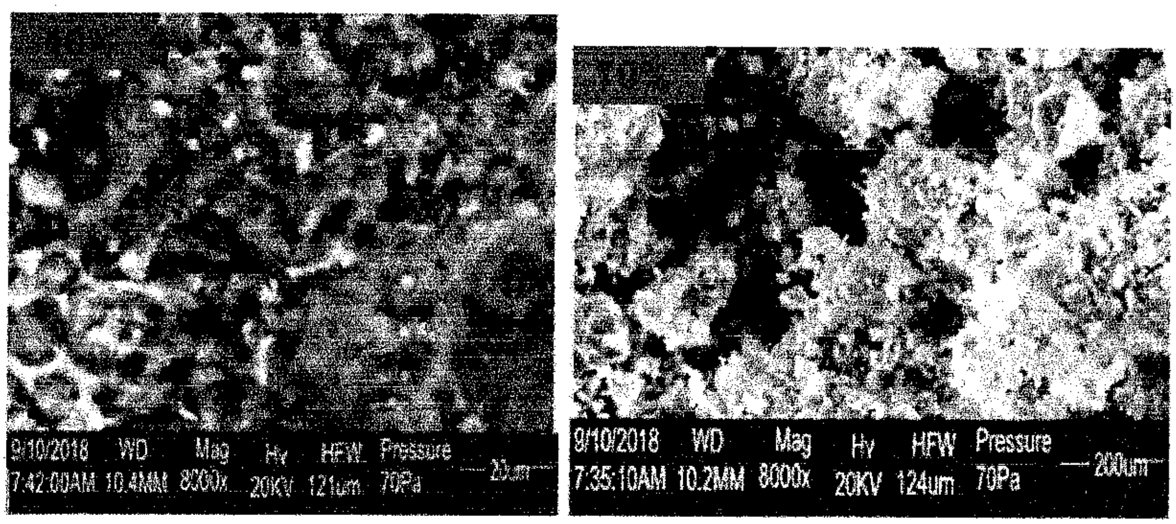

Figure 4.10: SEM microghraph of concrete with 10% EPO-FBA

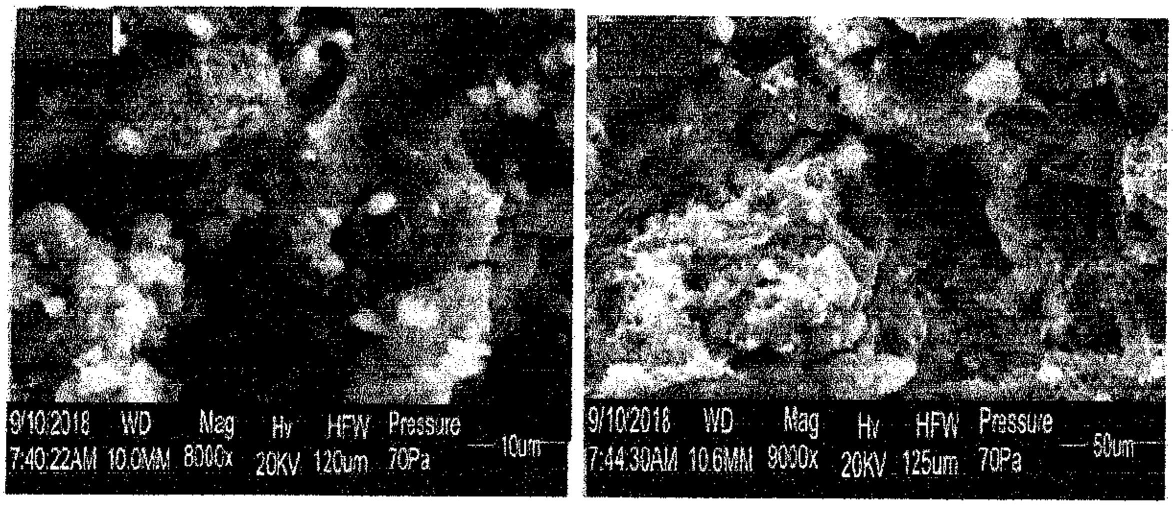

Figure 4.11: SEM microghraph of concrete with 15% EPO-FBA

The EDX spectrums of the concrete samples are shown in Figure 4.12 to 4.15. It can be seen that the count of Silicon and Calcium which are the main element responsible for the strength forming and bonding of concrete structure decline with increasing EPO-FBA. This contributes to the reason why there is decrease in the compressive strength of concrete with increasing EPO-FBA.

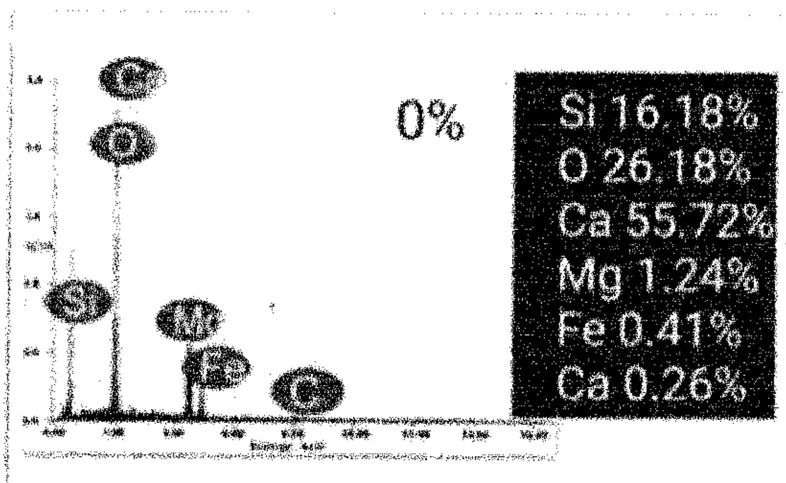

Figure 4.12: EDX spectrum of concrete with 0% EPO-FBA

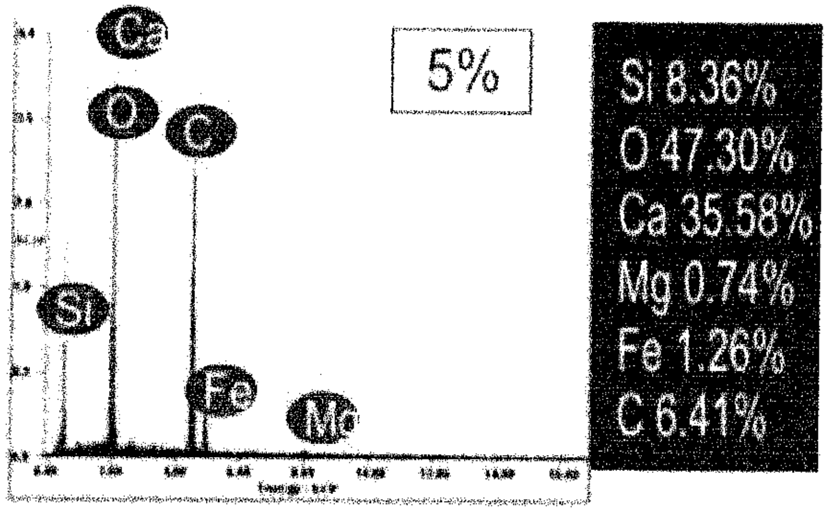

Figure 4.13: EDX spectrum of concrete with 5% EPO-FBA

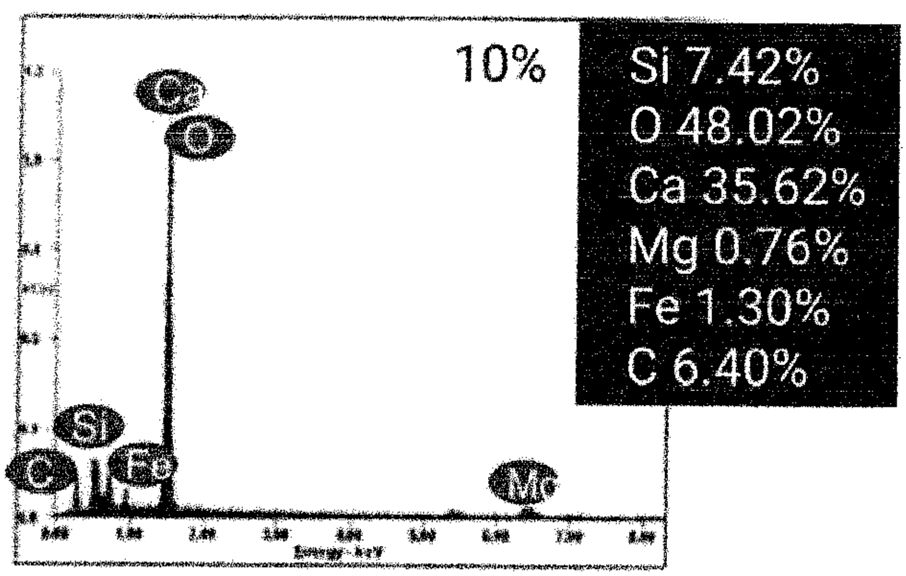

Figure 4.14: EDX spectrum of concrete with 10% EPO-FBA

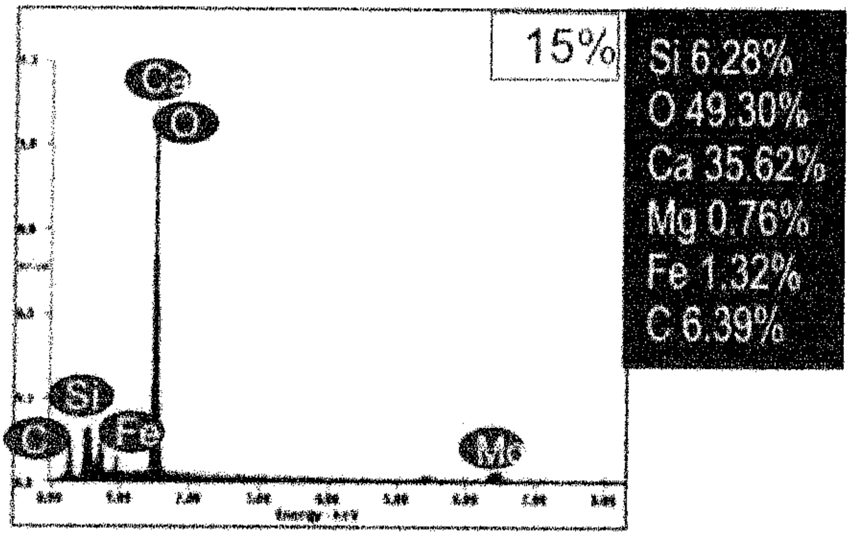

Figure 4.15: EDX spectrum of concrete with 15% EPO-FBA

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

From the results of this investigation, the following conclusions are drawn:

1. Compressive strength of the concrete decreased as the proportion replacement of cement with EPO-FBA increased. This is because of the low pozzolanic reactivity and high water demand of EPO-FBA that reduced the workability and strength of the concrete.
2. The workability of EPO-FBA decreased with increase in percentage of EPO-FBA. The compaction factor has been decreased with increase in percentage of EPO-FBA.
3. Fineness and consistency test result of EPO-FBA were found to be lower than those of normal OPC concrete.
4. Results suggest that EPO-FBA can be added to cement concrete as partial replacement of cement up to 5% without any significant reduction in any of the property of concrete. This will result in reduction in the cost of concrete to some extent.
5. EPO-FBA produces a little effect on the microstructure of concrete samples at later age (28 days). The improvement of microstructure occurred mostly in the pore structure and a little in the interfacial transition zone.
6. The sorptivity of concrete specimen at later ages (28 and 90 Days) increases with increase in percentage replacement of Ordinary Portland Cement (OPC) with Empty Palm Oil Fruit Bunch Ash (EPO-FBA). This implies that introduction of EPO-FBA as partial replacement of OPC in concrete production increases the required capillary forces for the pore structure to draw fluid into the body of the concrete specimen.
7. The water absorption of concrete specimen after 28 and 90 Days curing increases with increase in percentage replacement of Ordinary Portland Cement (OPC) with Empty

Palm Oil Fruit Bunch Ash (EPO-FBA). This implies that the replacement of OPC with EPO-FBA increases the pore volume which is occupied by water in saturated condition of hardened concrete.

8. The use of EPO-FBA in the production of concrete will help to clean the environment of potentially hazardous wastes, reduce the amount of cement used in concrete production thereby bringing down cost of cement and reduction in consumption of non-renewable resources.

5.2 Recommendations

On the basis of the test results, observation and conclusions, the following recommendation are being proffered.

1. Based on the study, the processing method of EPO-FBA needs to be checked, improved and monitored so as to enhance its quality and there is a definite need to study other properties such as plastic shrinkage, shear characteristics and flexural strength so as to make a better recommendation on the effective strength of EPO-FBA as a partial replacement of OPC.
2. More studies need to be carried out on the microstructure and durability of concrete containing EPO-FBA as partial replacement of OPC as only a few literatures were noticed.
3. In order to alter workability, setting times and some other related properties, the effect of chemical admixtures needs to be included in the study.
4. So as to increase the quantity of effective EPO-FBA at the same time improve the strength of the concrete samples, the type of cement used could be changed.

5. The above study should not only be limited to concrete. Effect of EPO-FBA as partial replacement of OPC in mortal could also be investigated.

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