SOME LATER DAYS STRUCTURAL PROPERTIES OF CONCRETE CONTAINING PALM OIL EMPTY BUNCH ASH (POEBA) AS PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

By

SHITTU, Ahmed Olanrewaju

(CVE/11/0378)

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ABSTRACT

In an attempt to reduced 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 POEBA as partial replacement of cement in the production of structural concrete.

This research work is carried out to determine the properties of Palm Oil Empty Bunch Ash (POEBA) when used as partial replacement for Ordinary Portland Cement (OPC) in concrete. The test being carried out include the test for the Chemical properties, fineness and specific gravity of the POEBA and also tests for consistency, density, and compressive strength was carried out on concrete whose composition of cement is being proportioned and replaced with 5% interval of POEBA by weight up to 50%. The mix design used for the concrete mix is 1:2:4 and the Water/cement ratio used is 0.75. The concrete cubes were cured in water for 60, 75 and 90 days so as to attain its maximum attainable strength due to the process of hydration. The curing method implemented is moist curing.

Based on the test results it was observed that workability of the concrete was improved due to addition of POEBA because of its increased water demanding property. The compressive strength of the concrete is observed to decrease as the addition of POEBA in proportions was increased but there is 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 normal weight concrete based on the density range of the whole cube with different proportion of POEBA which are all within the range of 2240 and 2400Kg/m^3.

And from the above test results it was concluded that POEBA may be used as replacement materials of cement in concrete up to 5%.

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Finally, to my parent Mr. and Mrs. Shittu. I pray they live long to reap their fruit of labour.

DEDICATION

This report is dedicated to Almighty Allah for being a source of knowledge and inspiration.

CERTIFICATION

This is to certify that this proposal was prepared by Shittu, Ahmed Olanrewaju (CVE/11/0378) under my supervision, in partial fulfillment of the requirements for the award of a Bachelor of Engineering (B.Eng) degree in Civil Engineering, Federal University Oye Ekiti. Ekiti State Nigeria.

28-9-2016	
Shittu, Ahmed Olanrewaju (Student)	Date
	28-9-2016
Dr. C.A. Fapohunda (Project Supervisor)	Date
Prof. J.B. Adeyeri (Head of Department)	Date

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing Materials
RHA	Rice Husk Ash
GRH	Grinded Rice Husk
POFA	Palm Oil Fuel Ash
PFA	Pulverize Fuel Ash
EPOB	Empty Palm Oil Bunch
POEBA	Palm Oil Empty Bunch Ash
OPC	Ordinary Portland Cement
SQS	Sandstone Quarry Sand
GGBS	Ground granulated blast furnace slag
CRP	Crushed Rock Powder
RAC	Recycled Aggregate Concrete
MIP	Mercury Intrusion Porosimetry
CKD	Cement Kiln Dust
GCHA	Guinea Corn Husk Ash
MK	Metakaolin
BS	British Standard

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CHAPTER ONE

INTRODUCTION

1.1 General Background

Most of the ancient structure and historical buildings had been constructed with lime concrete. With the advent of cement, the use of lime concrete has been confined to making bases for concrete foundations and roof terracing. 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

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 haying micro porous structure (Penta,1954). Volcanic pozzolan which gets deposited and later on exposed due to weathering action is called compact materials or tuffs. Weathering cause either zeolitisation (Conversion into zeolite which is a natural or synthetic hydrated alumino-silicate with an open three-dimensional crystal structure, in which water molecules are held in cavities in the lattice) or argillation (weathering of aluminum silicates) which turns the glass of pozzolan either into zeolitic minerals or clay minerals. This phenomenon depends on intensity of chemical and physical changes to the deposits as well as their duration. Zeolitisation improves the pozzolanic activity while argillation reduces it (Sersal, 1958) & Malquori (1962).

1.1.3 Pozzolan as Cement Substitute

Separately from industrial waste, ashes from agricultural source like rice husk, coconut husk, palm oil husk, cassava peel ash, pulverized bone, peanut shell or fiber shell etc. have been used for making cement substitutes (Bentur et al., 1986). Among them, rice husk ash (RHA) is highly rich and has been distinguished as the most active pozzolan in making high performance concrete and cement products. Previously, numerous works have been carried out to look into the various aspects of ashes with pozzolanic behavior, and in many parts of the world these materials have already been known as supplementary cementing materials. Presently various types of by-product materials, such as Fly ash, Blast furnace slag, silica fume, Rice husk ash, and others have been widely used as pozzolanic materials in concrete.

Their utilization not only improves mortar properties, but also preserves the environment. Fly ash can improve concrete Properties such as workability, durability and ultimate strength in hardened concrete

The pozzolanic activity expresses the reactivity of pozzolan (pozzolanic supplementary cementing material) for pozzolanic reaction. It can be determined by testing the compressive strength of 50-mm mortar cubes with and without pozzolan. The pozzolanic activity of supplementary cementing material depends on its silica content, particle size distribution, and surface fineness. The pozzolanic activity of POFA can be improved by increasing the fineness of ash through a grinding process. Therefore, ground POFA possesses a good pozzolanic activity index (Samarin et al., 1983).

1.1.4 Applications of Pozzolan in Concrete

Most of the concrete produced today are a multi component product containing one or more admixtures in addition to the four basic components which is cement, water, fine and coarse aggregate. For every component, one usually has several choices that could influences, 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. (Bentur et al., 1986).

Incorporation of this pozzolanic material involving replacement of a part of the Portland cement with excess weight of fly ash, replacing also part of the aggregate would to creation a more economical concrete (Samarin et al., 1983). The contribution of pozzolanic material in concrete towards improvement of concrete durability has also been highlighted (Mehta, 1988) and (Hoff, 1992) who reported that the incorporation of pozzolanic material such as fly, ash, silica flume, and natural pozzolan in concrete contribute to the formation of the denser binder which inhibits the migration of the sea water into concrete. Other researcher Awal & Hussin (1996) proved that adding POFA for production of concrete would be able to increase the resistance of concrete toward sulphate and acid attack. The role of pozzolan towards improving the properties of concrete has become significant to the extent whereby there are researchers such as (Dunstan, 1986) who stated that fly ash should be considered to be the fourth ingredient in concrete, that is in addition to the aggregate, cement and water, and not as a replacement of the cement. Conclusively, whatever is the mode of application all the methods can result in a significant improvement and optimization of certain properties of both fresh and hardened concrete.

1.1.5 Pozzolanic Reaction and Its Significance

It is well known that pozzolanic reaction can only take place with the existence of calcium hydroxide that is produced from hydration process reacting with pozzolanic material in the presence of moisture. The extent of the pozzolanic reaction depends on the fineness of the pozzolanic material as well as the amount of silica in this material. In this studies, integration of pozzolanic material as a cement replacement for production of concrete improves the properties of the concrete in terms of strength or durability.

A pozzolan is a siliceous or alumino-siliceous material, which is highly vitreous and independently shows few/fewer cementitious properties. But in the presence of a lime-rich medium like calcium hydroxide, shows better cementitious properties towards the later day strength (> 28 days).

On overall, application of this material for construction material able to reduce cost of the material and also provides mean of using this pozzolanic material which might end up in landfill if it is not put to any use. (Bentur et al.,1986).

The basic of the pozzolanic reaction stands with a simple acid-base reaction between calcium hydroxide, also known as Portlandite, or ($Ca(OH)_2$), and silica acid (H_4SiO_4, or $Si(OH)_2$). The pozzolanic reaction is representing as below:

$$Ca(OH)_2 + H_4SiO_4 \Rightarrow Ca^{2+} + H_2SiO_4^{2-} + 2\,H_2O \Rightarrow CaH_2SiO_4 \cdot 2\,H_2O \qquad \text{(Eq. 1.1)}$$

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 Aims and Objective of Study

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

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

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

1.4 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 Palm Oil Empty Bunch Ash (POEBA) as a partial replacement of cement by weight. Investigations into other properties are outside the scope of this work.

1.5 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 Palm Oil Empty Bunch Ash (POEBA) 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.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter presents an overview of literature on the various experiments conducted by many authors on the partial replacement of cement with supplementary waste materials as a pozzolanic material, thereof highlighting the significance of using supplementary waste pozzolanic material for replacing the cement in concrete.

2.2 Literatures Review on Partial Replacement of Cement

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:

According to Funso Falade, et al (2013) the structural properties of foamed aerated concrete with and without pulverized bone is being studied and properties of the concrete such as workability, plastic and testing densities, compressive strength, and tensile strength are studied at the design density of 1600kg/m^3. The tensile strength was evaluated by subjecting 150 x 150 x750mm unreinforced foamed concrete beams to flexural test and 150x300mm cylinder specimens were subjected to splitting test. 150mm cube specimens were used for the determination of both the compressive strength and the testing density of the foamed aerated concrete.

The plastic density was investigated using a container of known volume, and its workability determined using the slump test. The pulverized bone content was varied from 0 to 20% at interval of 5%. The specimens without the pulverized bone served as the control. At the designed density of 1600kg/m^3, the results for the control specimens at 28-day curing age are 15.43 and 13.89N/mm for air- and water-cured specimens respectively. The modulus of rupture and splitting tensile strength are 2.53 and 1.63N/mm^2 respectively. The results for specimens with pulverized bone did not differ significantly from the specimens without pulverized bone. From the results of this investigation, it can be concluded that foamed aerated concrete used for this study has potential for structural applications. Also pulverized bone can be used to reduce (partially replace) the quantity of cement used in aerated concrete production; thus ridding our environment of potentially harmful wastes, as well as reduce the consumption of non-renewable resources.

The research work on the properties of Rice Husk Ash (RHA) when used as partial replacement for Ordinary Portland Cement (OPC) in concrete is carried out. OPC was replaced with RHA by weight at 0%, 5%, 10%, 15%, 20% and 25%. 0% replacement served as the control. Compacting factor test was carried out on fresh concrete while Compressive Strength test was carried out on hardened 150mm concrete cubes after 7, 14 and 28 days curing in water. The results revealed that the Compacting factor decreased as the percentage replacement of OPC with RHA increased. The compressive strength of the hardened concrete also decreased with increasing OPC replacement with RHA. It is recommended that further studies be carried out to gather more facts about the suitability of partial replacement of OPC with RHA in concrete. (Obilade, I.O.,2014)

Patagundi and Patil (2002) conducted experiments to investigate the properties of concrete when cement was partially replaced by fly ash and natural sand by crusher stone powder simultaneously. The compressive strength and flexural strength were studied. The behaviour of concrete when subjected to heat cycles was also studied. The replacement of sand was from 0- 40% at increments of 10%. Using OPC the design mix of 1: 1.2: 2.4 was prepared with water cement ratio 0.30. To facilitate the flow of concrete a super plasticizer was used. In temperature resistance test, the concrete cube specimen was subjected to heat cycles say 8 hours of heating at 60°C followed by 16 hours of cooling at 25°C. Two heat cycles say 15-day cycle and 30-day cycle were adopted. From test results it was observed that 28-day compressive strength was maximum at 30% sand replacement and this was due to the fact that crusher powder fills up the maximum voids to get dense concrete and fly ash liberates strength during later periods. Similarly, flexural strength was also maximum at 30% replacement itself. Due to heat cycle there will be some loss in compressive strength as well as flexural strength. The maximum resistance to heat was developed at 30% sand replacement. From the above test results it was concluded that quarry dust and fly ash may be used as replacement materials in concrete.

In his work, Vasumathi (2003), investigated the properties of concrete when cement is replaced by fly ash and sand by quarry dust separately and simultaneously. Tests were conducted on workability at fresh state and compressive strength at hardened state at the age of 7, 14 and 28 days. The sand was replaced from 0 to 25% at increment of 5%. From the test results it was observed that workability was decreased due to addition of quarry dust. Better result on 28 days compressive strength was obtained on replacement of fly ash, quarry dust, fly ash and quarry dust at 5%, 15% and 10% respectively. It was concluded that replacement of cement with fly ash and sand with quarry dust resulted economical construction and also a solution for reducing the environmental pollution.

Investigation conducted by Lamb (2005) confirmed that the Sandstone Quarry Sand (SQS) can be used as a cement substitute, subject to the end user requirements and material's availability. The leachate results showed a significant increase in lime, when SQS was added to the mortar, which might cause efflorescence on concrete products. Even though the pozzolanic results were positive, it was found that this material contains a very high insoluble residue, which limits its use in cement only as filler.

The use of fly ash and quarry dust as partially replacement materials for cement and sand in concrete is researched, where sand was replaced by quarry dust from 0 to 45% at increment of 15%. Cement was replaced by fly ash at 0%, 15% and 30%. Using M30 mix with OPC the strength was determined at the age of 3, 7 and 28 days. From the test results it was observed that the use of 15% fly ash leads to a reduction in early strength of concrete. This effect was eliminated by addition of 30% quarry dust. Using of quarry dust leads to the reduction in the workability of concrete. Therefore, the concurrent use of crushed rock material and fly ash in concrete will lead to the benefits. (Chaturanga et al., 2008).

Also Venu-Malagavelli and Rao (2010) studied about the characteristics of M30 concrete with partial replacement of cement with Ground granulated blast furnace slag (GGBS) and sand with the ROBO sand (crusher dust). 43 grade OPC was used to prepare concrete mix. Sand was replaced by crusher dust from 0-30% at increment of 5% and cement by GGBS 40-60%. The cubes and cylinders were cast and tested for both compressive and tensile strength. Admixture also added to enhance the required workability. The w/c ratio was fixed as 0.42. From the test results it was found that if sand only replaced by crusher dust then maximum compressive and tensile strength was obtained at 30% replacement. For GGBS in place of cement and crusher dust for sand used simultaneously then maximum strength was obtained at 50% and 25% materials respectively. It was concluded that GGBS and ROBO sand can be utilized as partial replacement materials.

According to Anupama et al (2010), the use of metakaolin in cement mortar as a partial replacement for cement with quarry dust as fine aggregate. 43 grade OPC was used to prepare cement mortar 1:3 mix. They cast specimens using metakaolin as partial replacement of cement by 5 to 15% and quarry dust as fine aggregate. The specimens were tested at the age of 3, 7, 28, 56 and 90 days. From the test results it was observed that the compressive strength was decreased with increase in metakaolin content for a given water binder ratio. The drop in compressive strength was disappeared in mixes made of higher water binder ratio. Mix with 15% metakaolin was superior in all water/binder ratios investigated.

The effect of crushed rock powder (CRP) as fine aggregate and partial replacement of cement with admixtures subjected to different curing methods was studied by Rajendra Prasad et al (2011). Sand was replaced by CRP in 0%, 10%, 20%, 40%, 60%, 80% and 100% and cement replaced by 10% Rice husk ash (RHA). 53 grade OPC was used to prepare M30 concrete with water cement ratio 0.45. From the test results it was observed that 10% RHA with 20% quarry dust replacement combination gave better compressive strength. Other than 20% replacement obtained lesser compressive strength compared with control concrete. This was due to the voids present in the concrete mixes with higher amount of CRP. It was concluded that quarry dust can be utilized in concrete replacing sand.

Arundeb-Gupta (2012) conducted experiments to study the 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.

Further, Chandana Sukesh et al. (2012) 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.

The properties of concrete containing Guinea Corn Husk Ash (GCHA) as partial replacement of Ordinary Portland Cement (OPC) was investigated by Ndububa et al. (2015). The percent replacement levels by weight were 5%, 10%, 15%, 20% and 25% in 1:2:4 concrete mix with 0.65 water - cement ratio. The chemical constituents of the GCHA were SiO_2 (78.19%), Al_2O_3 (1.36%), Fe_2O_3 (0.84%), CaO (3.34%), MgO (3.76%), K_2O (7.67%), P (2.95%) and Na_2O, TiO_2, SrO, Cl, MnO, $S0_3$ in trace quantities. Since SiO_2, Al_2O_3, and Fe have a combined constituent percent in excess of 70% (i.e. 80.39%), GCHA meets the requirement of a pozzolana in accordance the relevant standards. The GCHA concrete gave compressive strength in the range of 9.5 N/mm2 for 25% ash and 26.3 N/mm2 for 5% ash at 28 days curing period. The 5% value was higher than that of plain concrete which was 25.5N/mm2. The trend shows that 10% GCHA should not be exceeded for a competitive value for compressive strength. The density of GCHA-cement concrete slightly reduced with increase of GCHA, for example it reduced by 2.27% for 25% ash at 28days curing. However, it slightly increased at 5% replacement level again. Further work on the Water Absorption Capacity, permeability and durability parameters of GCHA cement concrete is recommended.

In their work, Amitkumar et al. (2013) who investigate that the ceramic industry inevitably generates wastes, irrespective of the improvements introduced in manufacturing processes and about 15%-30% production goes as waste. They stated that these wastes pose a problem in present-day society, requiring a suitable form of management in order to achieve sustainable development. In their research study, they replaced (OPC) cement by ceramic waste powder accordingly in the range of 0%, 10%, 20%, 30% 40%, & 50% by weight for M-25 grade concrete & the wastes employed came from ceramic industry which had been deemed unfit for sale due to a variety of reasons, including dimensional or mechanical defects, or defects in the firing process. They concluded that the use ceramic masonry rubble as active addition endows cement with positive characteristics as major mechanical strength and the economic advantages and reuse of this kind of waste has advantages economic and environmental, reduction in the number of natural spaces employed as refuse dumps.

Khatib et.al (2012) studied the compressive strength, density and ultrasonic pulse velocity of mortar containing high volume of Metakaolin (MK) as partial substitution of cement. In this paper up to 50% of MK was used to replace cement in increment of 10. After De-molding, specimens were cured in water at 20°C for a total period of 28 days. The density seems to reduce with the increase of MK content especially at MK content above 30%. The strength increases as the MK content increases up to about 40% MK with a maximum strength occurring at 20% where the strength is 47% higher. At 50% the strength start reducing, 10% and the 30% MK mixes exhibit an increase in strength of around 37%.

In their research, Shirule et.al (2012) described the feasibility of using the marble sludge dust in concrete production as partial replacement of cement. The Compressive strength of Cubes & Split Tensile strength of Cylinders are increased with addition of waste marble powder up to 10% replaced by weight and it was also observed that 10% replacement gave optimum percentage of strength.

Investigation conducted by Sudhir S. *et al.* (2013) concluded that concrete plays the key role and a large quantum of concrete is being utilized in every construction practices. They also studied that natural river sand is one of the key ingredients of concrete, is becoming expensive due to excessive cost of transportation from sources & also large scale depletion of sources creates environmental problems & to overcome these problems there is a need of cost effective alternative and innovative materials. They studied deeply & stated that Quarry dust is as waste obtained during quarrying process & it has very recently gained good attention to be used as an effective filler material instead of fine aggregate & also, the use of quarry dust as the fine aggregate decreases the cost of concrete production in terms of the partial replacement for natural river sand. They formed the design mix of M25grade concrete with replacement of 0%, 20%, 25%, 30%, and 35% of quarry dust organized as M1, M2, M3, M4 and M5 respectively have been considered for laboratory analysis viz. slump test, compaction factor test, compressive strength, split tensile strength and flexural strength of hardened concrete. They investigated the hardened properties of concrete using quarry dust.

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 28day 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. (Hyung-Min Lee et al., 2010)

According to Amitkumar et al., (2005) who investigated that the ceramic industry inevitably generates wastes, irrespective of the improvements introduced in manufacturing processes & about 15%-30% production goes as waste. They stated that these wastes pose a problem in present-day society, requiring a suitable form of management in order to achieve sustainable development. In their research study, they replaced (OPC) cement by ceramic waste powder accordingly in the range of 0%, 10%, 20%, 30% 40%, & 50% by weight for M-25 grade concrete & the wastes employed came from ceramic industry which had been deemed unfit for sale due to a variety of reasons, including dimensional or mechanical defects, or defects in the firing process. They concluded that the use ceramic masonry rubble as active addition endows cement with positive characteristics as major mechanical strength and the economic advantages & reuse of this kind of waste has advantages economic and environmental, reduction in the number of natural spaces employed as refuse dumps.

2.3 Palm Oil Empty Bunch Ash as a New Pozzolanic Material

Palm Oil Empty Bunch Ash is a product of the incineration process of empty palm oil fruit bunch and hence a new pozzolanic material whose effect on concrete has not been investigated. Hence, this research work will provide the stance to study the effect of palm oil empty bunch ash as a partial replacement of cement in concrete.

Hence, the literature survey encompasses many studies with waste products used as a supplementary cementing material in concrete. This reflects a growing interest in academic and industrial research in this area. Even though various studies have been conducted on partial replacement of cement, there is no in depth study or no study on using Palm Oil Empty Bunch Ash to optimize their replacement level of cement in concrete.

CHAPTER THREE

MATERIALS AND 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.

$$2C_3S + 6H \Rightarrow C_3S_2H_3 + 3CH \quad (1)$$

$$2C_2S + 4H \Rightarrow C_3S_2H_3 + CH \quad (2)$$

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.

$$\text{Pozzolans} + CH \Rightarrow C\text{-}S\text{-}H \quad (3)$$

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 Experimental Investigations

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

1. Material Characterization (Preliminary)
2. Major Investigations
    a) Chemical Analysis
    b) Pozzolanic Test
    c) Consistency Test
    d) Setting time tests
    e) Density
    f) Compressive strength

3.3 Materials and Equipment

The material used for this study were Palm Oil Empty Bunch Ash which was derived from burnt Empty Palm Oil Fruit Bunch in a kiln or a furnace into ashes. The source of the Empty Palm Oil Fruit Bunch was from piled up palm oil waste, which was gotten from the local palm oil milling site at Ikole Ekiti.

3.3.1 Palm Oil Empty Bunch Ash

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 until it turns to ash.

Plate 1: Empty Palm Oil Fruit Bunch

3.3.2 Cement

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).

3.3.3 Fine Aggregate

The material, which passes 3/16" B.S. sieve size, is termed as fine aggregate. 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

3.3.4 Coarse Aggregate

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 maximum size may be 20 cm (9") for mass concrete work, such as dams etc, and 62.5mm (2.5") for plain concrete work. For R.C.C. Construction, the maximum is (1") although 20mm (0.75") of aggregate is commonly adopted.

3.3.5 Equipment

The equipment for the various tests include Compressive strength machine, set of sieves, moulds and rammer, weighing balance, Vicat apparatus, cans, Mechanical Shaking Machine, Shovel and Head-pan.

3.4 Methods

The methods used for this work were:

1. Collection and pilling up of empty palm oil fruit bunch;
2. Preparation of the Palm Oil Empty Bunch Ash;
3. Preparation of fine aggregate, coarse aggregate and cement;
4. Mixing of the concrete using a mix ratio of 1:2:4 and water-cement ratio of 0.5;
5. Mixing of concrete constituent with the Palm Oil Empty Bunch Ash (POEBA) as a partial replacement of cement in proportion of 5% interval

by weight of cement up to 20% and using 0% of POEBA in the concrete as a control sample;

6. Determination of the workability, density, setting time of the fresh concrete
7. Casting of the concrete with different proportion of POEBA in a mould
8. Removal of the concrete from the mould after 24 hours;
9. Curing of the concrete using moist-curing for curing age of 7, 14, 21, 28, 60 and 90 days;
10. Determination of the compressive strength of the concrete and other necessary properties.

3.5 Mixing and Proportioning of Concrete

3.5.1 Preliminary Information

Mix ratio ⇨ 1:2:4

Water cement ratio (W/C) ⇨ 0.7

No of cubes per sample = 3

No of curing Days = 6 (i.e. 7, 14, 21, 28, 60, 90 days)

No of proportioning = 11 (i.e. 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%)

No of cubes to be casted per day = $3 \times 6 = 18$ (for different proportions)

3.5.2 Mix Design Calculations

Volume of 18 cubes = $(0.15)^3 \times 18 = 0.061m^3$

Mass of 18 cubes of concrete = Density of concrete × Volume of 18 cubes

$$= 2400kg/m^3 \times 0.061m^3 = 146.4kg$$

Weight of each concrete constituent;

1. **Cement:** $\frac{1}{7} \times 146.4kg = 20.91kg \approx 21kg$

2. **Sand:** $\frac{2}{7} \times 146.4kg = 41.8kg \approx 42kg$

3. **Granite:** $\frac{4}{7} \times 146.4kg = 83.7kg \approx 84kg$

The proportion by mass of each constituent of the concrete and water used by weight is detailed in table 3.1.

Table 3.1: Mix design schedule

Proportion (%)	Binder(kg)		Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (kg)
	Cement	POEBA			
0	21	0	42	84	10.5
5	19.95	1.05	42	84	10.5
10	18.9	2.1	42	84	10.5
15	17.85	3.15	42	84	10.5
20	16.8	4.2	42	84	10.5
TOTAL	**94.5**	**10.5**	**210**	**420**	**52.5**

3.5.3 Estimates

Number of cement bag = 94.5/50 = 1.89 Bags, Approximately 2 bags of cement

Number of Bag of Sand (cement bag) = 210/55 = 3.8 Bags, Approximately 4 bags

Number of Bag of Granite = 420/65 = 6.5 Bags.

3.6 Casting of Specimens

The wooden moulds of dimension 150mm x150mm x 150mm was used, with an engine oil which is rub at the inner surface of the mould so as to give a lubricating effect between the mould and the concrete after it has harden for easy removal. The mould is put at a levelled and smooth surface so as to give the cubes a smooth base. Concrete was poured into the moulds in three layers in such a way that each pouring will be approximately equivalent with the height of the mould divided into three. 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 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. The surface of the casted cube is then smoothening to provide a smooth surface. The proportion of the POEBA 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 2 below;

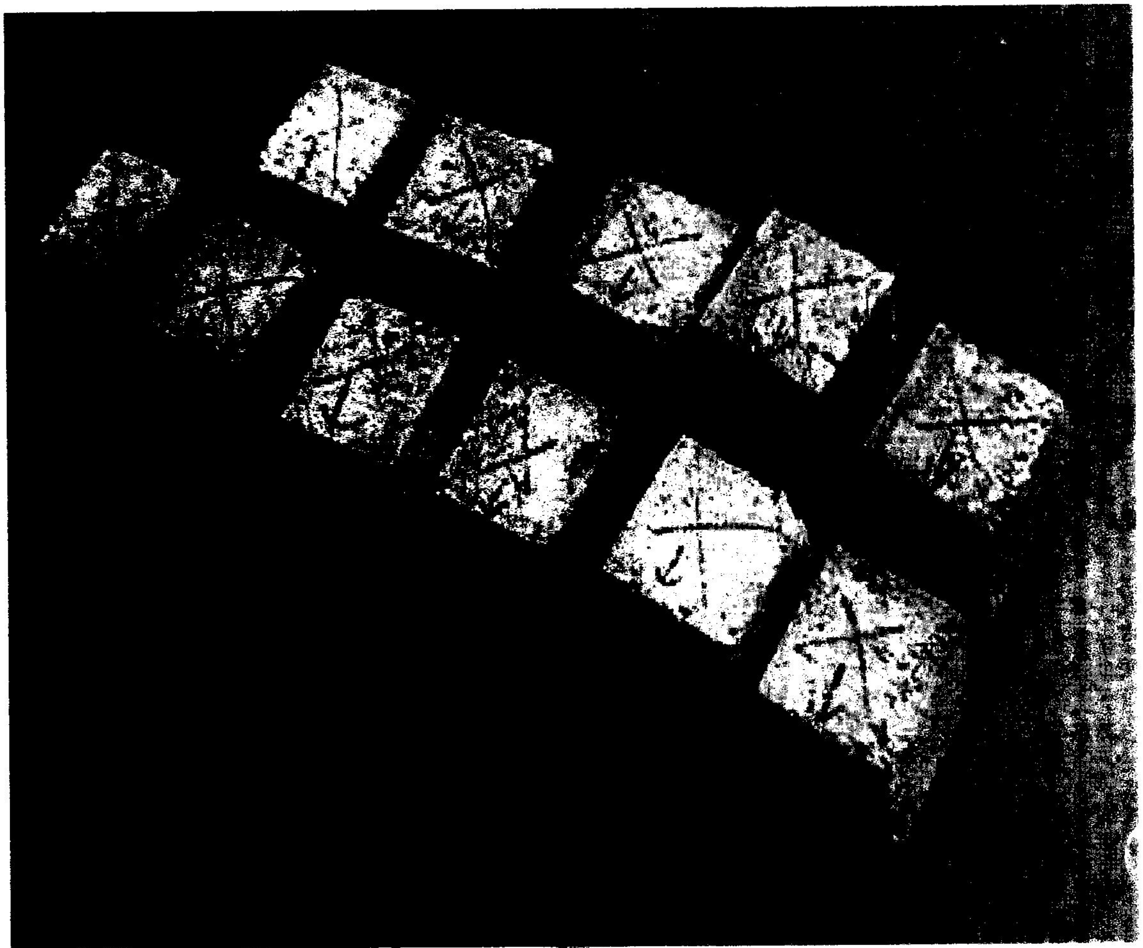

Plate 2: Typical example of cubes to be cast

The schedule of casting with the number of cubes to be casted in each casting date is shown in Table 3.2.

Table 3.2: Casting schedule of the cubes

DAY	PROPORTION	DATE	NO. OF CUBES
1	0%	16/05	18
2	5%	18/05	18
3	10%	20/05	18
4	15%	24/05	18
5	20%	26/05	18

3.7 Compressive Strength Test of Cubes

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 60, 75 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;

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

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.

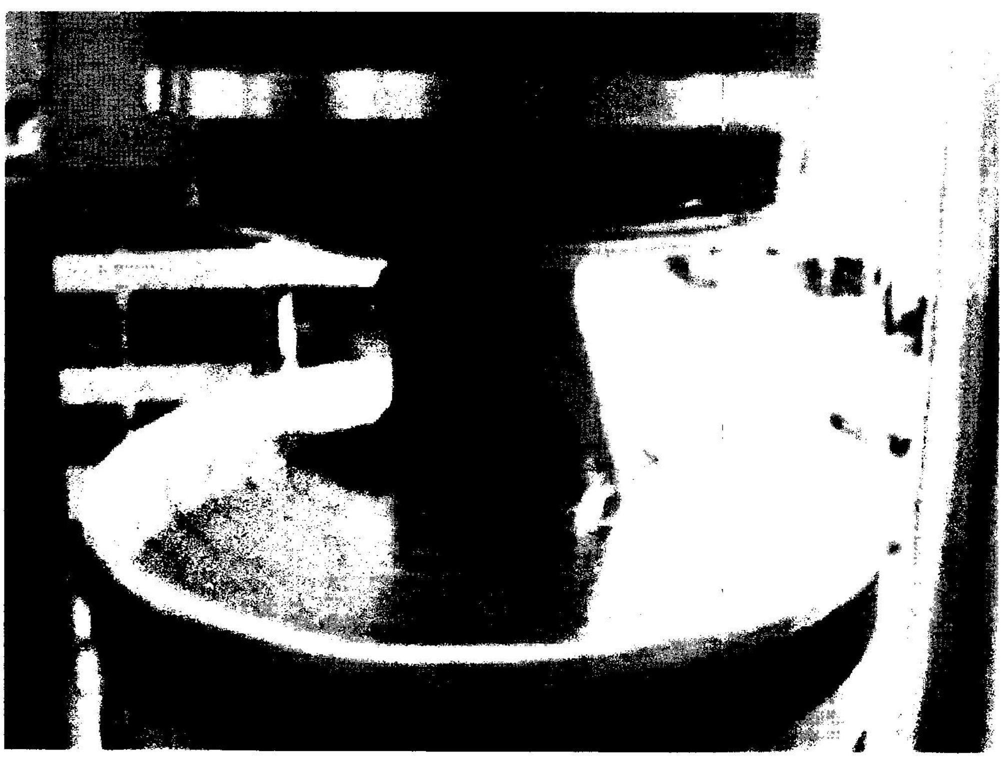

Plate 3: Concrete cube undergoing compression

Table 3.3: Casting and testing schedule

Proportion (%)	Casting Date	Testing Dates		
		60	75	90
0	16/05	15/07	30/07	14/08
5	18/05	17/07	01/08	16/08
10	20/05	19/07	03/08	18/08
15	24/05	23/07	07/08	22/08
20	26/05	25/07	09/08	24/08

3.8 Workability (Slump test)

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.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 General

The results from the preliminary tests (fineness of POEBA in relation to cement, specific gravity, bulk density) as well as the concrete strength tests (Density and Compressive strength test) 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.

4.2 Chemical Analysis

The result of the different percentage of different chemical constituent of POEBA and cement is presented in Table 4.1.

Table 4.1: Chemical Composition of POEBA and Cement

S/N	CHEMICAL COMPOSITION (%)	LEVELS DETECTED	
		POEBA	CEMENT
1	SiO_2	0.002	19.720
2	Al_2O_3	0.005	4.940
3	Fe_2O_3	0.003	0.710
4	CaO	18.670	64.220
5	MgO	1.540	2.190
6	Na_2O	0.510	0.670
7	K_2O	0.220	0.450
8	SO_3	0.000	1.030
9	MnO	0.000	0.000
10	BaO	0.000	0.000
11	Moisture	0.000	0.000
12	L O I	64.200	0.002

The results of chemical composition analysis of the pozzolanic material used (POEBA) and Ordinary Portland Cement are graphical represented in Figure 4.1 shown above. The

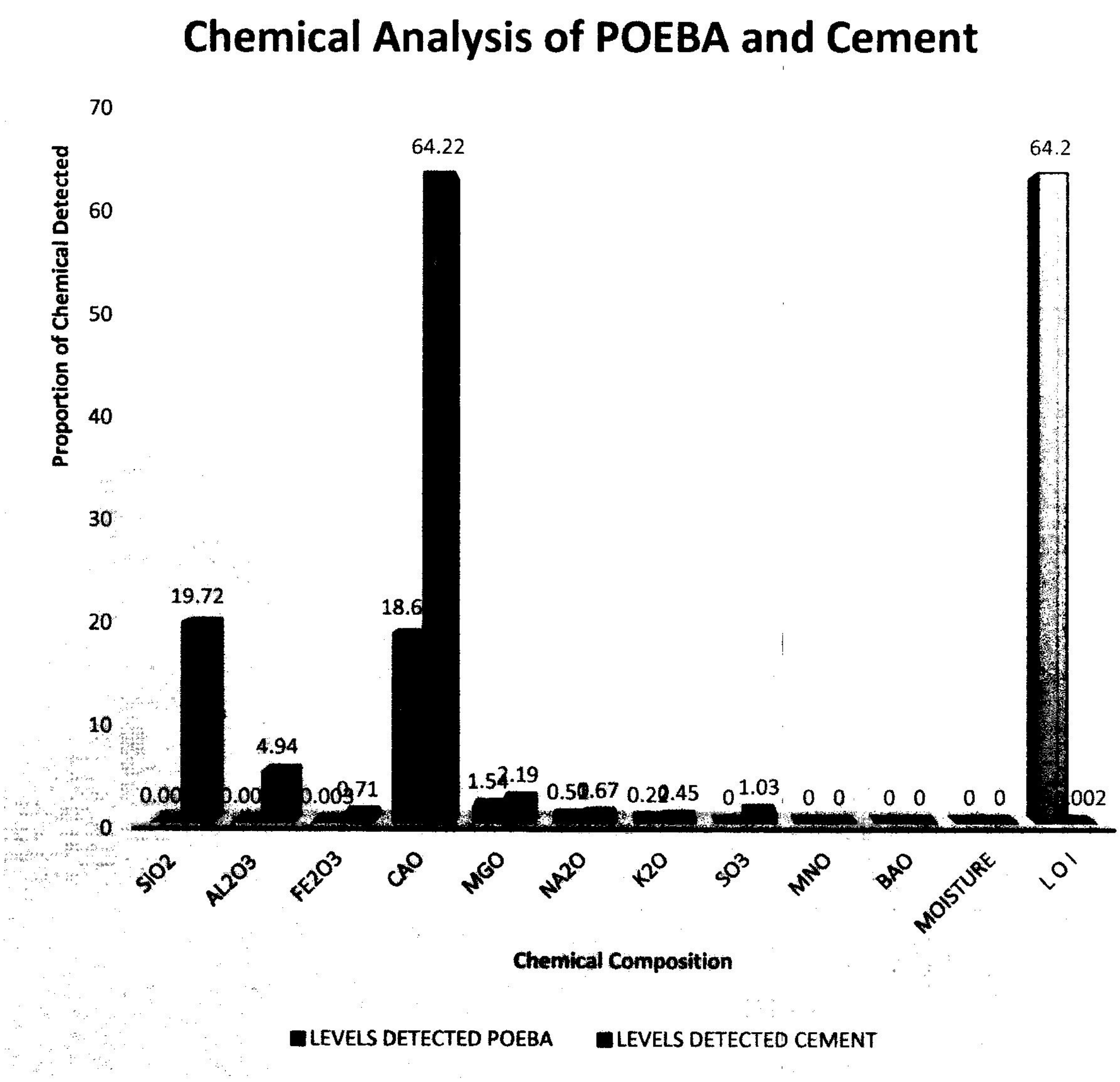

Figure 4.1: Comparison between Chemical composition of POEBA and Cement

result of composition of POEBA 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 POEBA in our study have the sum of $SiO_2+Al_2O_3$ as 0.007% 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 POEBA with cement will give composition of $SiO_2+Al_2O_3+Fe_2O_3$ $\geq 0.010\%$ which is very low compared to the aggregate composition of $SiO_2+Al_2O_3+Fe_2O_3$ $\geq 25.36\%$ 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 POEBA 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 to 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 POEBA 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 POEBA is 64.2%. 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 0.73% is low, and thus reduce the possibility of the destructive alkali-aggregate reaction (Neville, A. M., 2003).

4.3 Some Physical Properties of the Materials

4.3.1 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 4.2.

Table 4.2: Fineness of Cement and POEBA

Fineness of Material	Portland Cement (%)	POEBA (%)
Sample A	90	25
Sample B	89	28

POEBA fineness can be expressed in terms of median particle size, percent mass collected in a 45μm 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 POEBA is a low pozzolanic material with an average fineness of 26.5% by weight compared to the average fineness of cement which is 89.5%.

4.3.2 Specific gravity

Bulk density of POEBA is analysed below using a container of known volume of $0.003375m^3$ and the weight of sample as 1.590kg hence giving a bulk density of $471.11Kg/m^3$. Hence, the specific gravity of the solid particle is 0.471. V. Sata (2004) found that after the grinding process, the specific gravity of POFA increased because of a decrease in porosity. The specific gravity of POEBA is 0.471, which is lower than the specific gravity of OPC (3.14). Therefore, cement particles are heavier and denser than those of POEBA.

4.4 Workability Test

The fresh concrete which may be expected to give the best results must possess the property of workability. This most important property of fresh concrete is considered to be the sum total of qualities like plasticity, mobility, slump and compatibility. 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.

Plate 4 shows the nature of the slump after the removal of the cone which denote a true slump of the concrete.

Plate 4: Fresh Concrete Slump

The result of the slump test for fresh concrete with 20% replacement of cement with POEBA gives a true slump of 30mm. This implies that the increase in replacement proportion increases the workability of the concrete. Several studies have reported the effects of POFA on the workability of fresh concrete. Tay and Show (1995). investigated the workability of POFA concrete by compacting factor. They found that with the increasing POFA replacement level, workability decreased.

4.5 Density of Concrete Specimens with POEBA

The result of the density of concrete with different proportion of POEBA at various age is presented in Table 4.3.

Table 4.3: Density of concrete with different proportion of POEBA at various age

Curing Age	Proportion of POEBA	Density (Kg/m^3)
50 Days	20	2311.11
60 Days	0	2301.23
	5	2330.86
	10	2350.62
	15	2301.23
	20	2340.74
75 Days	0	2320.99
	5	2301.23
	10	2241.97
	15	2281.48
	20	2400.00
90 Days	0	2311.11
	5	2320.99
	10	2291.36
	15	2330.86
	20	2355.56

The density of concrete with different percentage replacement of Cement with POEBA considered at different curing age are shown in the figure 4.2.

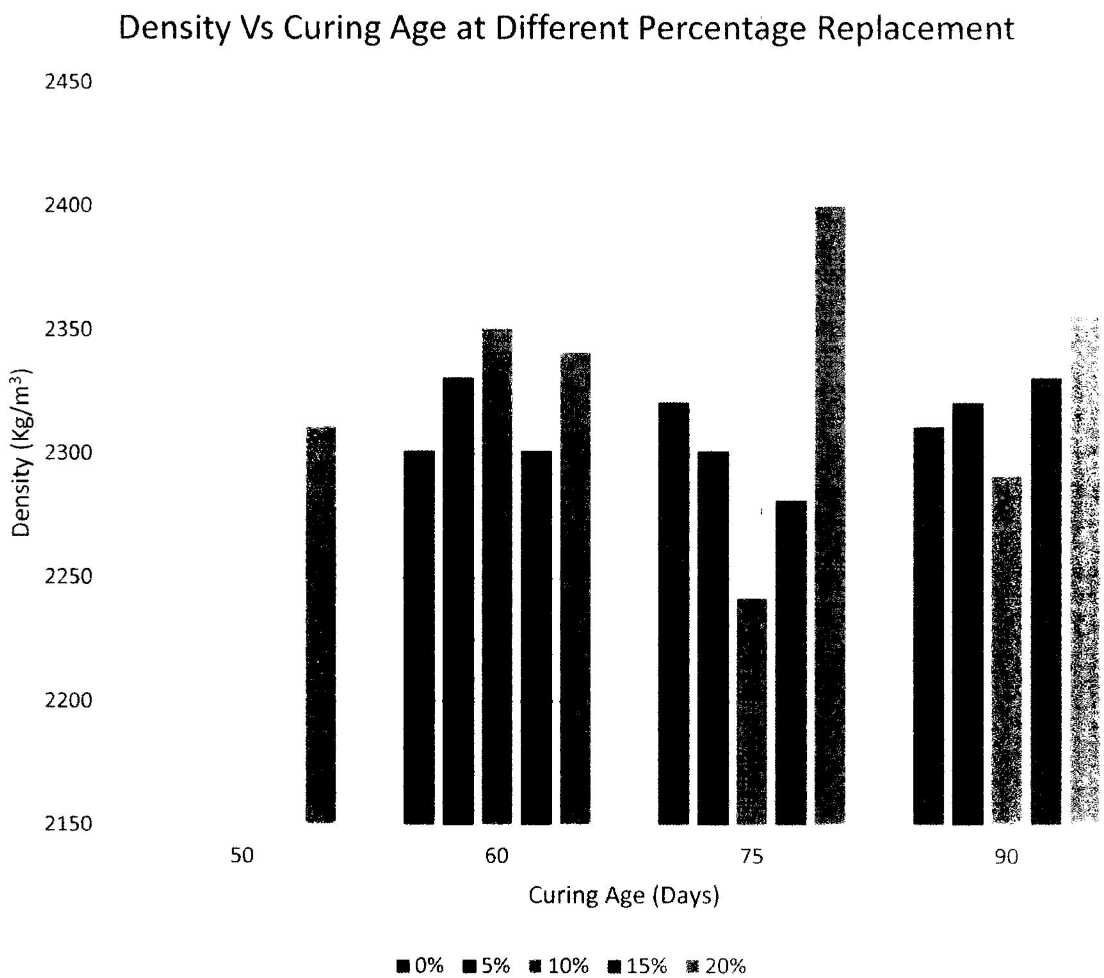

Figure 4.2: Density of concrete with different proportion of POEBA

It was found that the density increases with increase in the amount of POEBA that replaces cement in the concrete and the minimum density were 2241.97 and 2291.36kg/m^3 for 10% percentage replacement of cement with POEBA and the maximum density which is 2400kg/m^3 occurs at 20% percentage replacement. 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 2240 and 2400kg/m^3 the concrete are classified as a Normal weight 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.

4.6 Compressive Strength of Concrete Specimens with POEBA

The result of the Compressive strength of concrete of different proportion of POEBA at various age is presented in Table 4.4 shown below.

Table 4.4: Compressive strength of concrete of different proportion of POEBA at various age

Curing Age	Proportion of POEBA	Compressive Strength (N/mm^2)
60 Days	0	15.18
	5	17.55
	10	10.30
	15	8.52
	20	8.89
75 Days	0	16.59
	5	16.22
	10	12.29
	15	11.56
	20	10.66
90 Days	0	17.78
	5	17.48
	10	12.96
	15	12.44
	20	11.26

In figure 4.3 shown above, the change in the compressive strength for concrete with different proportion of POEBA 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 POEBA is increased in the concrete with the compressive strength occurring at the least proportion which is 5% replacement of cement with POEBA.

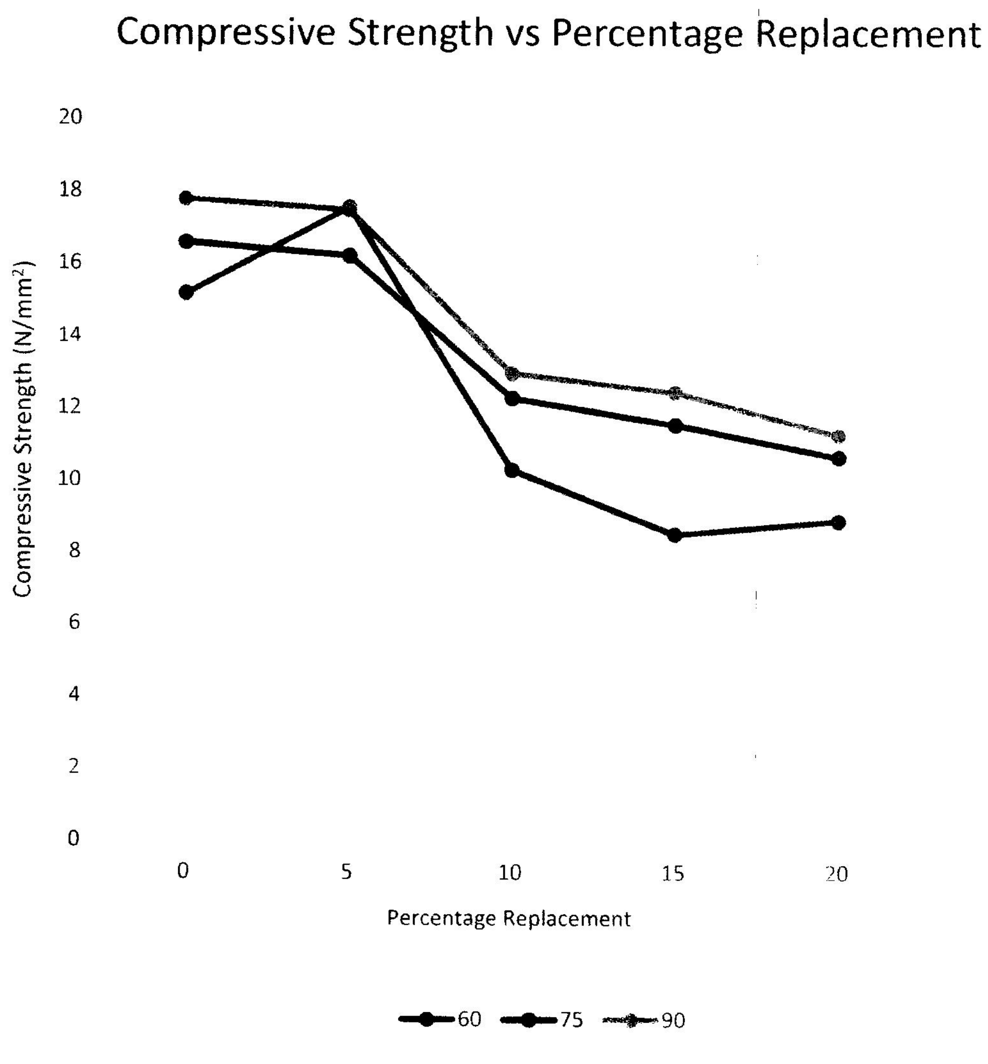

Figure 4.3: Compressive strength of concrete with different proportion of POEBA

Also an increase is shown at 5% replacement at 65 days of curing before a decrease is noted as the proportion of POEBA is further increased. Hence, up to 5%, there is no significant difference in the compressive strength compared with the control.

Figure 4.4 depicts the variation of compressive strength with curing age of concrete with different proportion of POEBA for all the various series of mixes considered.

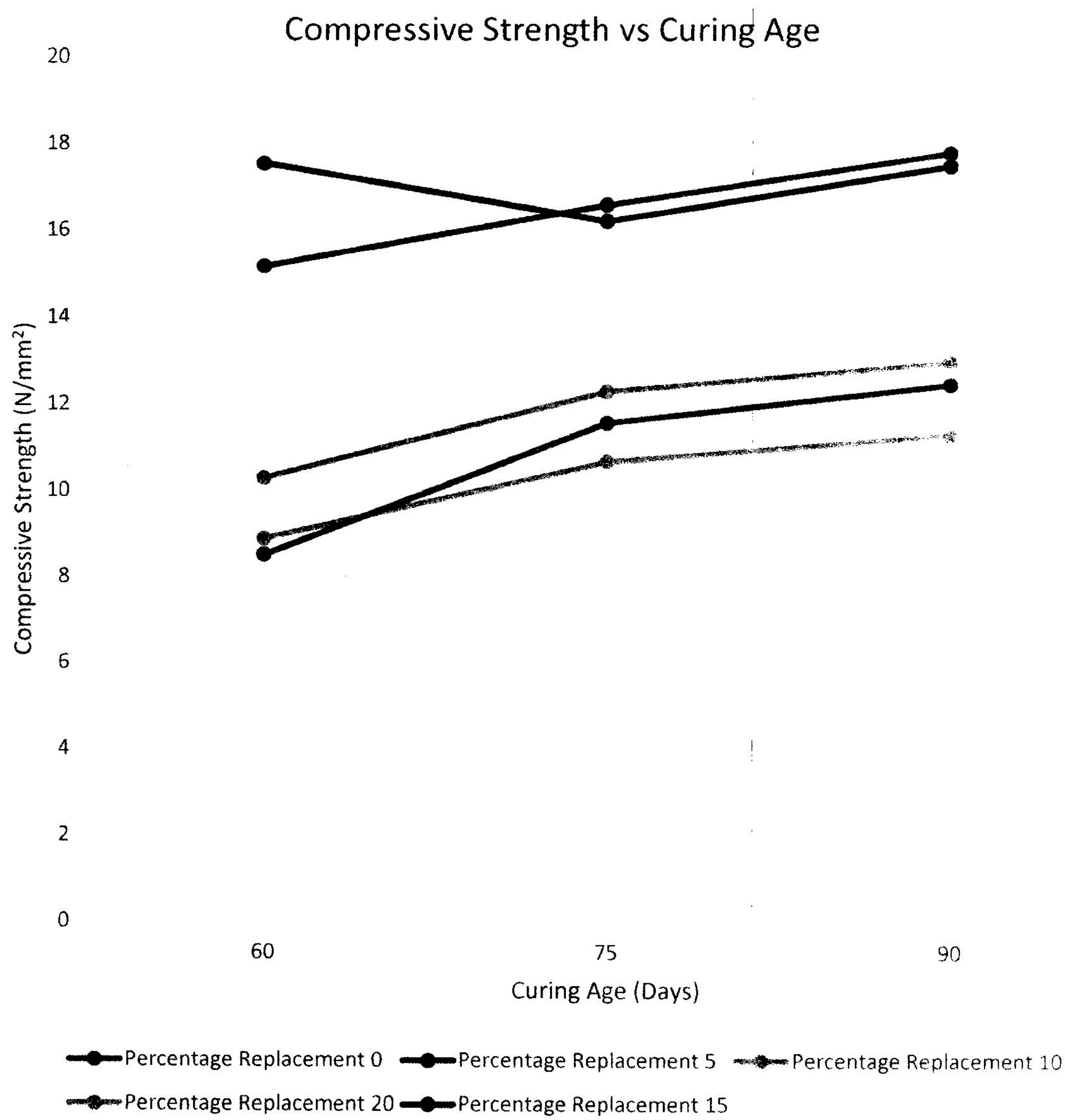

Figure 4.4: Compressive strength of concrete at different curing age

The compressive strengths obtained for concrete mixes with proportion of POEBA between 10% to 20% increases with increase in curing age but 5% proportion of POEBA shows a different trend of compressive strength increment as the strength drop at curing age of 75 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 POEBA 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.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The following conclusions are drawn:

1. Compressive strength of the concrete decreased as the proportion replacement of cement with POEBA increased. This is because of the low pozzolanic reactivity and high water demand of POEBA that reduced the workability and strength of the concrete.
2. After grinding process, fineness and pozzolanic reactivity of POEBA significantly increased. By using 26.5% fine POEBA by weight, high-strength concrete can be produced with lower drying shrinkage, lower water permeability and higher resistance to chloride and sulfate attack than OPC concrete.
3. The concrete replaced by different proportion of cement by POEBA ranges between densities of 2240 and 2400kg/m^3 and are classified as a Normal weight 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.
4. Results suggest that 5% replacement of POEBA could be the optimum level for the production of concrete because strength of concrete reduced gradually beyond this replacement level.
5. The use of POEBA 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

Based on this research work very few studies have reported on the use of POEBA in mortars and concrete for properties such as plastic shrinkage, and flexural strength. Therefore, there is a definitive need to study these properties. Also a thorough evaluation of OPC mortars and concrete that contain POEBA should be performed regarding their short-term performance and durability characteristics. And finally, the pozzolanic reactivity of ternary blends, i.e., mixtures of OPC, POEBA and other abundantly available local pozzolanic materials, such as fly ash and rice-husk ash, must be studied.

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