COMPARATIVE STUDIES ON THE PARTIAL REPLACEMENT OF CEMENT WITH SELECTED ASHES IN CONCRETE PRODUCTION USING BIDA NATURAL STONES

BY

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ABSTRACT

This research work investigated the possibility of utilizing Rice Husk ash and Bone Powder ash blended with cement in the production of concrete having sufficient qualities for construction. Two different ashes were separately used as partial replacement of cement in concrete production which includes rice husk ash (RHA) and Bone Powder ash (BPA). Mix design of 1:2:4 were adopted. The ashes were obtained through open air burning. Sieve analysis, Specific gravitytests, Bulk density, Moisture content, AIV and ACV were carried out on the aggregates. Concrete mix were prepared at 100% OPC as control, three trial mix each of RHA and BPA at cement replacement of 5%, 10%, 15%, 20% and 25%. Workability were carried out on fresh concrete containing the two ashes RHA and BPA to ascertain the consistency of the fresh concrete containing ashes as partial replacement for cement. Crushing test were also conducted on the hardened concrete to determine the compressive strength of the concrete at 7, 14, 21 and 28 days. The result showed that 5% RHA has compressive strength is close to control in concrete at 28days while that of 5% BPA was not too close to the control at the 28days. Also from the results obtained it was observed that the partial replacement of cement by RHA and BPA is advantageous, particularly for areas at which the concrete can utilize such as columns, slab, foundation and beam at 5% replacement.

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ABBREVIATIONS, GLOSSARIES AND SYMBOLS

AASHTO	American Association for State Highway and Transportation Officials
ACI	American Concrete Institute
ACI	Aggregate Crushing Value
ASTM	American Society for Testing and Materials
AIV	Aggregate Impact Value
BS	British Standard
BPA	Bone Powder Ash
FA	Fly ash
Gs	specific gravity
GHG	greenhouse gases
GSA	Groundnut Shell Ash
LOI	Loss on ignition
NCRI	National Cereal Research Institute
W	Weight
OPC	Ordinary Portland Cement
RHA	Rice Husk Ash
SCM	Supplement Cementitious materials
V_s	Volume of mould
ρ_b	Bulk density
M C	Moisture Content

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Concrete is extensively used building material these days. Concrete is obtained by means of mixing of cement materials, water, aggregate as well as admixtures in right proportions. Its properties to a great extent depend on properties of its constituents. While cement is most important component of concrete and has comparatively low unit cost (BS 1377, 1990).

Choice of its suitable type and use has critical importance in obtaining stability of its preferred properties in cost-effective means for any concrete mix. Concrete is the most widely used man-made construction material in the world. The Ordinary Portland Cement is one of most important ingredients which is used for production of concrete and has no substitute in civil construction. However, the production of cement involves release of huge amounts of carbon-dioxide gas into atmosphere, main provider for greenhouse effect as well as global warming. Hence it is expected moreover to search for a different material or partially replace it by means of some other material. The search for such material, which is used as a choice for cement, must guide to global sustainable expansion as well as small environmental impact. Several studies were made for improvising the properties of concrete by means of adding of new materials; which might be natural materials or else recycle materials or else synthetic materials. The extra material can be replacing aggregate or else cement or else just as additive. Fly ash, rice husk ash, bone powder ash and silica fume are some of pozzolanic materials which are used in concrete as partial substitute of cement. The strength, stability as well as other features of concrete will depend on properties of its ingredients, quantity of mix, technique of compaction as well as other controls during the process of placing as (Mamlouk and Zainiewski, 2006) well as curing (Oyekan, 2007).

The World's demand for concrete over the last three decades have sky-rockected since concrete as become the material of choice for the construction and development of physical infrastructure, this is because of the higher flexibility oferred by the use of concrete and it slow cost to strength ratio compared to wood and steel (Mamlouk and Zainiewski, 2006). Concrete production requires large volume of earth materials, the continous exploration or excavation of which depletes the earth and causes ecological strain (Sagar *et al.,* 2019). In recent times, the use of aggricultural, industrial and agro-industrial waste in concrete production as partial or full replacement of the convenntional concrete ingredients (cement, river sand and stones) has become attractive to environmental and material sceintistsand researchers all over the world (Asma *et al*., 2015). The cement reacts chemically with water and other ingredients to form a hard matrix which binds all the materials together into a durable stone-like material that has many uses in construction industry. Often, additives (such as pozzolanas) are included in the mixture to improve the engineering properties of wet or the finished material ASTM C618, (2008). The use of complement binders that are less pollutant could impact the construction industry towards the production of concrete with less environmental impact.

The production of cement, the conventional cementitious agent in concrete production is usually accompanied with the release of enormous greenhouse gasses (GHSs) into the atmosphere. Sreenivasa *et al*. (2017) reported that cement production alone account for about 7% of the world's carbon dioxide discharge into the air. Hence, the need to find greener and cheap alternativesor atleast limit the use of cement in concrete production cannot be overstated. Amongst the industrial and agricultural wastes which have receive the most attention as partial replacement of cement in concrete production are fly ash, blast furnace slag, rice husk ash, silica fume, bone powder ash and saw dust due to their pozzolanic properties (Chennakesava, 2019; Sagar *et al*., 2019). Coarse aggregate are particles retained on No.4 (4.5mm) sieve, but generally it sizes ranges from 5mm to 150mm. The maximum size of course aggregates used for structural members is about 25mm. For mass concrete used for dams or deep foundations, the maximum size can be as large as 150mm (Mohammed, 2016). Aggregate that pass a 4.75mm sieve (No.4) and predominantly retained on a No. 200 (75µm) sieve are classified as fine aggregate (Karthic *et al.*, 2014). This study intends to evaluate the effects of bone powder ash and rice husk ash on the compressive strength of concrete made with Bida natural stone and whose cement is partially replaced with bone powder ash and rice husk ash.

1.2 Statement of the Research Problem

The world's manufacture of concrete for use in infrasture projects was estimated to be more than 1.6 billion tons by Mehta (2001) and the implication is that more than 1.6 billion tons of earth materials are used up in concrete production. The continuous removal or excavation of this huge volume of earth material from the crust may depletes the earth and causes ecological strain (Sagar *et al.*, 2019) and this will have negative impacts on men.

Heightening industrial activities, urbanization and infrastructural development increases the level of development and the standard of living of any Nation, but also hosted new economic and environmental challenges like waste generation and management (Rishi *et al.*, 2017). Despite other waste associated with the cement production, cement production alone accounts for about 7% of the World's carbon dioxide release into the athmosphere (Sreenivasa *et al*., 2017). Also, the activities of the industrial and agricultural sector leads to the genration of large volume of waste and the careless disposal of which is detrimental to our environment (Dawei, 2012).

For instance bone powder, rice husk and their ashes are by-product of cattle bone and rice processing respectively. Bone powder ash and rice husk ash are pozzollanic and have been re-used and re-cycled in the production of concrete as partial replacement of cement (Chennakesava, 2019; Sagar *et al*., 2019). However, this study is set out to determine the percentage replacement of bone powder ash and rice husk ash on the compressive strength of concrete cube (150 by 150 mm) made with Bida natural stone and whose cement is partially replaced with bone powder ash and rice husk ash.

1.3 Aims and Objectives

The aim of the study is to determine the compressive strength of concrete with partial replacement of cement with bone powder ash and rice husk ash in concrete production. The specific objectives of this study is to

i. Determine the physical and mechanical properties of the aggregates.
ii. Determine the workability of the resulting fresh concrete
iii. Determine the compressive strength of the hardened concrete at 7, 14, 21 and 28 days of curing.

1.4 Justification of the Study

Bone powder ash and rice husk ash are pozzollanic and have been re-used and re-cycled in the production of concrete as partial replacement of cement (Chennakesava, 2019, Sagar *et al.*, 2019). However, this study is set out to determine the percentage replacement of bone powder ash and rice husk ash on the compressive strength of concrete cube (150 by 150 mm) made with Bida natural stone and whose cement is partially replaced with bone powder ash and rice husk ash.

Rice husk ash and bone powder ash in under review in this study as pozzolana and partial replacement of cement.

The production of cement is usually associated with the release of carbon dioxide and other greenhouse gases in the air.

1.5 Scope of the Study

The scope of this research involves the collection of samples, determination of physical and mechanical properties of aggregate which include, moisture content, sieve analysis, bulk density, specific gravity, aggregate impact value, aggregate crushing value etc. The scope also includes determination of workability by using slump test, compacting and uncompacting factor test. And lastly, the determination of compressive strength of hardens concrete.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Background to the Study

In recent times, for the concrete production, the majority of the commonly used cement is ordinary Portland cement (OPC). As a consequence, the cost of cement is continuously increasing and natural resources are reducing (such as clinker i.e. cement raw material). Cement (OPC) is the main ingredient for the production of concrete, and a such the demand of cement is increasing day by day. During the cement production process, clinker is burnt at about 1450^0C (Neville, 2004) consequently huge amount of CO_2 is emitted to the atmosphere. Hence the temperature of the globe is increasing which is one of the reasons for climate change. About 7% of world's CO_2 is produced from the manufacturing of cement. In consequence, global warming is increasing continuously (Mehta, 2001). To solve these, researches in cement and concrete technology have been concentrated on the use of waste material as a potential alternative to cement in the construction industry.

2.2 Sustainability and sustainable concrete

Today, sustainability is a key issue for the global concrete industry. Achieving sustainability has become more and more important question all over the world during the last decade. It is well known that sustain means to support or to maintain a process going, and the objective of sustainability is that life on the universe can be sustained for the projected future. Environment, economy, and society are the components of sustainability. At the present time, the environment is probably the most important component, and an engineer or architect exercises sustainability to reduce negative impact on the environment. Thus, the word sustainable tends to be identical with environmentally sound or friendly and green (Leslie and Jonathan 2004). Large amounts of low cost building materials (Portland cement concrete) is required for the construction of infrastructure due to rapidly industrializing world and this trends will be continued. The unlimited use of natural resources and huge amounts of environmental pollution is a principal caution for the preservation of the life-sustaining environment on the globe. Why the problem of sustainable industrial development has recently considered enormously significant? A difficult question that we have to identify is how a sustainable development will be executed (Mehta, 1999). The various related concerns which lead us to the way of sustainable development that are mentioned below (Meyer, 2002):

i. Previous mistake could be cured by purifying the polluted water and soil.
ii. Reducing the global warming by neglecting the contamination of air, water and soil, as well as CO_2 emission.
iii. Balancing between consumption and generation of natural resources (material or energy).
iv. Searching for equilibrium between economic development and preservation of the environment (upgrading social life and the living standard by avoiding the disturbance of environment as much as possible).

However, for developing sustainability and sustainable concrete, engineers who are related to the concrete construction have to perform active responsibility in this area. They have professional duty to inform and teach clients, the public and fellow engineers about: the current building codes and laws, the long-term benefits from using new environmentally-friendly technology and higher quality, durable designs. Engineers also take the following special responsibility to develop a world view in problem solving which considers the effects of infrastructure decisions on the earth and on all living things (Fredrik, 1999):

i. For the conservation and preservation of present resources, engineers should to be aware and responsible.
ii. Environmentally friendly technology could be implemented by their direct participation in order to execute a more sustainable future; and,
iii. They must apply a valuable leadership in this domain.

Concrete is one of the most widely used artificial construction material and its manufacturing process requires large amounts of raw materials (cement, sand, aggregates, and water). As a result, the concrete construction can make significant negative impacts over the environment. The sustainable concrete is associated with reduction of the amount of polluting and CO_2 gases emitted during the concrete production, use of waste material in more efficient way, development of low-energy, long-lasting, flexible buildings and structures exploiting the thermal mass of concrete in a structure to reduce energy demand (Sustainable Concrete, 2011). Two main actions that meet the needs for sustainable construction development are: a sensible use of natural resources that can be achieved by the use of by-products and reusable materials, and a lower environmental impact that will be gained through reduced carbon dioxide emission and reduced natural resources extraction from quarries.

For performing the goal of sustainable development, one of the solutions suggests the possibility of using the industrial by-products of thermoelectric plants (Carlos and Patricia, 2001). By designing for durability as well as undertaking life cycle analyses of construction projects, the cement replacement materials such as fly ash in concrete, a better sustainable way is possible to direct the construction industry, and particularly the concrete production (Fredrik, 1999). Therefore, the other industrial by product (slag) and the biogenic waste (POHA, RHA, and AFT) that are available in Nigeria will make an important and active role in these regards.

2.2.1 Pozzolanic activity of waste materials

Pozzolans are such fine materials, containing silica and/or alumina, and do not exhibit any cementing properties of their own; in the presence of calcium oxide (CaO) or calcium hydroxide ($Ca(OH)_2$), silica and alumina in the pozzolans react and form cementitious materials. Palm oil fuel ash contains the silica oxide that can react with calcium hydroxide ($Ca(OH)_2$) generated from the hydration process; and the pozzolanic reactions produce more calcium silicate hydrate (C-S-H) gel compound as well as reducing the amount of calcium hydroxide (Eldagal, 2008). POHA is an agro-waste ash that contains a large amount of silicon dioxide and has high potential to be used as a cement replacement. For producing high-strength concrete, POHA can be used as a pozzolanic material; it improves the durability, reduces cost due to less use of cement. It will also be beneficial for the environment with respect to reducing the waste disposal volume of landfills (Tangchirapat, 2009). The siliceous glass is the primary contributor from the fly ash to pozzolanic reaction in concrete since it is the amorphous silica that combines with free lime and water from calcium silicate hydrate (C-S-H), the binder in concrete (ACI, 1996).

For the same chemical composition, the activity of fly ash (FA) is greater due to the higher proportion of vitreous matter (Fu, 2002). The reaction between RHA and $Ca(OH)_2$ solution was investigated by Yu *et al.* (1999) and they suggested that in the presence of water, a kind of fine C-S-H gel is formed after their reaction. The same opinion was found in a study of (Feng, 2004). Amorphous silica could be found in some pozzolanic materials which react with lime more eagerly than those of crystalline form (Lin *et al.* 2003). As a result of this pozzolanic characteristic, RHA is an extremely reactive pozzolanic material and it is suitable to be used in lime-pozzolan mixes and Portland cement as a supplement. It is well known that the utilization of mineral admixtures (such as FA, slag, RHA, POHA) has a positive effect on the quality of the concrete by binding the $Ca(OH)_2$ (Papadakis and Tsimas, 2002; Mehta, 1983). Therefore, due to their pozzolanic action all these waste materials could be used in concrete as replacement of cement. In consequence, they could execute a vital task for the SC construction compressive strength and enhancement of the durability of concrete (Bhatty, 1995; Azmar International; 2000; ACI, 2001).

2.2.2 Pozzolanic activity of pozzolans

Cement hydration is the result of chemical reactions that occur between water and the chemical compounds of Dicalcium Silicate (C_2S) and Tricalcium Silicate (C_3S) producing calcium silicate hydrate (C-S-H) and Ca(OH) plus water produced: $CaO.SiO_2.H_2O$+ Ca $(OH)_2$. The addition of the pozzolan to the hydrating cement (Pozzolana + $Ca(OH)_2$ + H_2O) produces the gel of the cementitious substance of C-S-H; $3CaO.SiO_2$ – $2CaO.SiO_2$ + H_2O $CaO.SiO_2.H_2O$ + $Ca(OH)_2$.

This process of the gel formation as asserted by Neuwald (2004) is the pozzolanic reaction of the Pozzolan. The formation of the C-S-H gel prevents water soluble compounds from migrating out of the concrete and thus makes the cement paste denser; and invariably a reduction in the permeability of the concrete is enhanced (Zhanng *et al.,* 1996) averred that the pozzolanic reaction of the pozzolan continues with the production of additional gels of C-S-H; and that this continuous the reaction of $Ca(OH)_2$ with the pozzolan is termed, the pozzolanic activity of the pozzolana. The Pozzolanicity of a pozzolan is thus, the degree of the chemical reactions of the active constituents of the pozzolan at ordinary temperatures with $Ca(OH)_2$ from cement hydration, producing the cementitious compounds (Neville, 1998, Massazza, 1993, Zhanng *et al.*, 1996).

2.2.3 Pozzolanic materials in concrete production

Pozzolanas are natural materials containing silica and alumina oxides which on their own have little or no hydraulic properties, but when mixed with lime in the presence of water will set and harden like Portland cement (Alp, 2009).

According to ASTM C618, (2008), pozzolanas are natural or artificial siliceous or aluminous materials which in themselves possess little or no cementitious value, but will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. Pozzolana can be divided in to two groups: natural and artificial, depending on the source of the material. Natural pozzolanas include volcanic ash and diatomite and so on. artificial pozzolanas include calcium clay, by-products from industrial processes such as fly ash, ground granulated blast furnace slag, silica fume, and ash from burnt agricultural waste such rice husk, bagasse, corn cob ash, groundnut ash etc. apart from the cost benefit of use of pozzolanas with ordinary Portland cement, other advantages of pozzolanas as reported in Neville (2004) include; improved workability improve water retention/ reduced bleeding, improved sulphate resistance, improved resistance to alkali aggregate reaction, low heat of hydration and enhanced long term strength. The only disadvantage of blended pozzolanic cement as reported in Neville (2004) and many other researches is that their early strength gain is slightly lower. However, the only benefits can be achieved with a good pozzolana. According to ASTM C618, (2008), good pozzolanas are those rich in silica and aluminum, with a combined silica, alumina and ferric oxide content of not less than 70% and 50% for class F and C pozzolanas respectively.

ASTM C618 (2008) specification for fly ash and raw or calcined natural pozzolana for use as mineral admixture in Portland cement concrete is a standard with which all pozzolanic materials properties are compared. This specification is presented in table 2.5. ASTM C618 (2008) categorizes natural pozzolanas and fly ashes in to the following three categories; Class N: Raw or calcined natural pozzolanas such as some diatomaceous earth, opaline chert and shale, stuffs, volcanic ashes and pumice, calcine caoline clay and laterite shale. Class F: fly ash normally produced from burning anthracite, bituminous coal. This class of fly ash exhibits pozzolanic properties but rarely, if any, self-hardening property.

Class C: fly ash normally produced form lignite or sub-bituminous coal. This fly ash has both pozzolanic and varying degree of self-cementitious properties. Most class C fly ashes contain more than 15% calcium oxide CaO), but some may contain as little as 10% CaO (ASTM C618, 2008).

Tsado *et al.* (2014) carried out a study on the comparative study of artificial pozzolana and reported that, addition of pozzolana will improves the properties of concrete and consequently, there will be a fall in the cost of conventional cement due to the affordability of a pozzolanic material at a cheaper rate.

According to BS EN 197-1 (2000), Pozzolanic materials do not harden in themselves when mixed with water but, when finely ground and in the presence of water, they react at normal ambient temperature with dissolved calcium hydroxide ($Ca(OH)_2$) to form hydrated calcium silicate and calcium aluminate compounds. In this view pozzolana consist mainly of reactive silicon dioxide (SiO_2) and aluminum oxides (Al_2O_3), and the remains contain part of iron oxide (Fe_2O_3) and other oxides.

Natural pozzolans are usually materials of volcanic origin or sedimentary with a high content of sum of (SiO_2 and Al_2O_3) not greater than 80% (≥80%), but a low content of MgO and SiO_3generally exhibit a high pozzolanic activity (Alp, 2009). The main constituent of bone is calcium, hence its abundance in the bone ash gave it the required advantage as pozolana (Akinyele, 2016).

Coker and Ninalowo., (2016) highlighted some of the procedures involve in the pozzolanic reaction; as water is added to the Portland cement, the tricalcium silicate (C_3S) and dicalcium silicate (C2S) react to form calcium silicate hydrates (C-S-H), which is largely responsible for the strength development, together calcium hydroxide $Ca(OH)_2$ mostly refer to hydrated lime as illustrated in equation (2.1).

$$2Ca_3SiO_3 + 7H_20 \rightarrow 3CaO.2SiO_2.4H_2O + 3Ca(OH)_2 \qquad (2.1)$$

Table 2.1: ASTM C618 Chemical Requirement

	Class		
Properties	N	F	C
Silicon dioxide (SiO_2)+ Aluminum oxide (Al_2O_3)+ iron oxide(Fe_2O_3),Min, (%)	70	70	50
Sulphur trioxide ((SO_3), max, (%)	4	5	5
Moisture content, max, (%	3	3	3
Loss on ignition, max, (%)	10	6[A]	6
As the use of class F pozzolan containing up to 12% loss on ignition may be approved by the user if either acceptable records or laboratory test result are.			

(Source: ASTM C618, 2008)

Table 2.2: ASTM C618 Physical Requirement

	Class		
Properties	N	F	C
Fineness: Amount retained when wet-sieved on 45 Micron (No. 345) sieve, max, (%)	34	34	34
Strength activity index: With Portland cement at 7days, min, percentage of control	75	75	75
With Portland cement at 28days, min, percentage of control	75	75	75
Water requirement, max, percentage of control.	115	105	105
Soundness: Autoclave expansion or contraction, max, (%)	0.8	0.8	0.8
Uniformity requirements: The density and fineness of individual samples shall not vary from average established by ten preceding test, or by all preceding tests if the number is less than ten ,by more than:			
Density, ma variation from average, (%)	5	5	5
percentage retained on 45 micron (No. 325) sieve, max variation, percentage points from average	5	5	5

(Source: ASTM C618, 2008)

Table 2.3: Chemical Requirement for Pozzolana as Per ASTM C618

	Class		
Properties	N	F	C
Silicon dioxide (SiO2) + Aluminium oxide +iron oxide (Fe2O3), min .(%)	70	70	50
Sulphure trioxide (SO3), max. (%)	4	5	5
Moisture content, max, (%)	3	3	3
Loss on ignition, max, (%)	10	6[A]	6

(Source: ASTM C618, 2008)

Table 2.4: Physical and Chemical Requirement for Pozzolana ASTM C618

Property	ASTM Requirement
Silicon divide (SiO2) + Aluminum oxide (Al2O3)	70
Pozzolanic activity index with Portland cement at 28 days. Max. Percent	75
Magnesium oxide (MgO) max. percent	5.0
Loss on ignition. Max percent	120
Water requirement. Max percent	115

(Source: ASTM C618, 2008)

2.2.4 Sustainability and environmental benefits

The concentration of CO_2 emissions in the atmosphere, resulting from OPC manufacturing varied from 5% to 10% of the greenhouse gases (GHGs) (Obada, 2008) The World Business Council for Sustainable Development (WBCSD) thus in 2002 recommended the reduction of CO_2 emissions from cement manufacture processes by 30% by 2020; and 60% by 2050. These levels of CO_2 emissions obviously make the cement manufacturing unsustainable. Horst (2001), Lynne and Adam (2000) attested that these emissions problems are real; as every ton of Portland cement produced, the CO_2 released to the atmosphere by the burning fuel is between 1 to 1.25 tons. Econoler International (2009) reported that the cement industry accounts for about 5% of the annual global anthropogenic carbon dioxide emissions; representing about 1,800 million tons of CO_2 emissions in 2005 from the use of fossil fuels. Thus, a reduction in OPC production directly reduces the emissions of CO_2 to the atmosphere from the cement manufacturing. Consequently, a reduction of the OPC in concrete mixes will create a substantial reduction of the greenhouse gases (GHG) emissions.

The sustainability theory for the use of Supplement Cementitious materials (SCMs) such as the pumice is that even if, it is a small reduction of the OPC in concrete uses per ton of concrete produced; the resultant environmental benefits are large because of the enormous quantity of concrete consumed daily worldwide (Altwair and Kabir, 2010). Thus, a replacement of any quantity of the OPC directly reduces the emissions of CO_2 to the atmosphere. The use of SCMs will consequently lessen the burden of the green gasses release cement calcinations.

2.3 Cement as Concrete Material

Cement can be defined as a material that can bind solid particles such as gravel, sand, in to a compact whole. Different form of materials exhibits cementitious properties. Ordinary Portland cement has the ability to set and harden in the presence of water. They are usually produced from calcareous raw material containing silicate, aluminate and iron oxides (Neville, 2004). The process of manufacture of cement consist of essentially of grinding the raw materials mixing them intimately in certain proportions and burning in a kiln at 1400-1450^{o}C to form predominantly clinker. The clinker is cooled and ground to a fine powder with some gypsum added and the resulting product yields the commercially produced Ordinary Portland cement widely used throughout the world (Alp, 2009). Ordinary Portland cement is the most common type of cement used in construction application. Since the cost of cement is volatile and demand is so high, other cheap inorganic materials with cementitious properties can be used as partial replacement of Portland cement in concrete production (Alp, 2009).

2.3.1 Properties of ordinary portland cement

The most commonly used binding materials in building and civil engineering works are considered as that which will set and harden under water, as such, are often called Ordinary Portland cement (Neville, 1981). Others are the slag-containing cements, high alumina cements, and the fly ash cements but most importantly of these is the Ordinary Portland cement.

2.3.2 Physical properties of portland cement

Ordinary Portland cement is capable of setting, hardening and remains stable under water. It is composed of calcium silicates and some amount of gypsum. ASTM C150 and BS EN 197-1 (2000) gives the physical properties of Portland cement to includes setting time, soundness, consistency, fineness, strength, heat hydration, etc. and their impact on the performance of cement in concrete.

2.3.3 Setting time of portland cement

The setting time of Portland cement is in two stages; initial setting time and final setting time. The initial setting time which is the beginning of a noticeable stiffening in the cement paste and it is measured from when water is poured for mixing of paste of standard consistency to time when a needle with a diameter 1.13-0.05mm penetrates the paste not deeper than 51mm from the bottom. The final setting time is measured from the moment when mixing water was added to the cement. This is when the needle gently lowered to the surface of the paste; penetrate it to a depth of 0.5mm but the circular cutting edge fail to make an impression on the surface of the paste. BS12 (1978) recommends initials and final setting times to be not more than 45 minutes and 2 hours respectively.

American Concrete Institute defines setting of a concrete as a measure of the rate of release of hydration. The compound gypsum added to clinker in the production of cement serves as a retarder. Setting characteristics of concrete is highly important part in the field of concrete construction (Brooks *et al*, 2000). It helps in the preparation of different stages of concreting operations which includes transporting, placing, consolidating and finishing. Placement of concrete in formworks depends on the setting time of concrete which make the concrete strong and rigid (Niragi, 2016).

The setting time are the initial and final setting which are to be determine accordance to BS 12 (1996) and BS 4550 part 3.1 (1978). Setting time is the stiffening of the cement paste or the change from the plastic state to a solid state and this is achieved due to selective hydration of cement compounds. The two first to react are C_3A and C_3S. The setting time of cement decreases with a rise in temperature. The setting times indicate that a paste is or is not undergoing normal hydration reactions. Sulfate (from gypsum or other sources) in the Ordinary Portland cement regulates setting time, but setting time is also affected by cement fineness, water-cement ratio, and any admixtures that may be used (ASTM C 191 and AASHTO T 131). The importance of setting in concrete works comes from the importance to keep the fresh concrete in the plastic stage for enough time necessary to complete its mixing and placing under practical conditions (this is the purpose from initial setting time). But, from the economical side, it is important that the concrete hardens at convenient period after casting. (ASTM C191 and AASHTO T131).

2.3.4 Soundness of ordinary portland cement

Soundness is a physical property of cement paste, which determines the ability of the cement paste to retain its volume after setting is completed. The expansion after setting is caused by the slow of hydration or other reactions which may result to unsoundness of the cement (ASTM C151). The unsoundness is due to the presence of free CaO (lime) and free MgO (magnesia) in cement. These constituents hydrate very slowly after setting of cement. Since $Ca(OH)_2$ and $Mg(OH)_2$ occupy larger volume, expansion takes place.

Most specifications for Portland cement limit the magnesia content and the maximum expansion as measured by the autoclave expansion test. Since adoption of the autoclave expansion test ASTM C151, (2002) in 1943, there have been exceedingly few cases of abnormal expansion attributed to unsound cement. BS 4550: part 3 limitation specified for various Portland cements require that the measured expansion in the test be not more than 10mm.

2.3.5 Consistency of portland cement

Consistency is the percentage of mass of water to cement required to produce cement paste of desired consistency. It is used in the determination of the initial and final setting times and soundness of cement (BS EN 197-1, 2000 and Neville, 2004). The consistency is measured by the Vicat apparatus, and it is defined as that consistency which will permit a Vicat plunger having 10 mm diameter to penetrate the paste to a point (6 ± 1 mm) from the bottom of the mould. BS 197-1 (2000) specified 26% - 33% as percentage mass of for a standard paste. Mortars are mixed to obtain either a fixed water- cement ratio or to yield a flow within a bed range. The flow is determined on a flow table as described in ASTM C230 (AASHTO M 153) and ASTM C143.

2.3.6 Fineness of ordinary portland cement

The fineness of cement affects heat released and the rate of hydration. The increase in the cement fineness (smaller particle size) increases the rate at which cement hydrates and thus accelerates strength development. The effects of greater fineness on paste strength are manifested principally during the first Seven days (ASTM C204 or AASHTO T153). The fineness of cement is a property that must be carefully controlled during the manufacturing process. The total specific surface of the cement represents the surface area available for hydration. Various methods are in use to measure the specific surface of cements. For most purposes air permeability methods produce accurate and repeatable results. The cement fineness is usually measured by the Blaine air-permeability test that indirectly measures the surface area of the cement particle per unit mass. Cements with finer particles have more surface area in square meters per kilogram of cement.

2.3.7 Strength of ordinary portland cement

The compressive strength of hardened cement is the most important of all the properties for structural use. The strength of mortar or concrete depends on the cohesion of the cement paste, and its adhesion to the aggregate particles and to certain extends on the strength of the aggregate itself. The last factor is not considered at this stage, and is eliminated in tests on the quality of cement by the use of standard aggregates. Strength tests are not made on a net cement paste because of difficulties of moulding and testing with a consequent large variability of test results. Cement sand mortar and, some cases, concrete of prescribed proportions are made with specific materials under strictly controlled conditions, and used for the purpose of determining the strength of cement. In general, cement strengths cannot be used to predict concrete strengths with a great degree of accuracy because of the many variables in aggregate characteristics, concrete mixtures, construction procedures, and environmental conditions in the field. Compressive strength of cement is influenced by the cement type and the compound composition and fineness of the cement. The ASTM C1157 has both minimum and maximum strength requirements while ASTM C150 set only a minimum strength requirement. It should not be assumed that two types of cement meeting the same minimum requirements will produce the same strength of mortar or concrete without modification of mix proportions.

2.3.8 Heat hydration of portland cement

The raw material used in the manufacture of Portland cement consists of lime, silica, alumina and iron oxide. These compounds interact with one another in the kiln to form a series of more complex products. The relative proportions of these compounds are responsible for influencing the various properties of cement. Four compounds are usually regarded as the major constituents of cement. They are tricalcium silicate, dicalcium silicate tricalcium aluminate and tetra calcium alumino ferrite. Anhydrous cement does not bind the fine and coarse aggregate. It acquires and adhesive property only when water is mixed with it. The chemical reaction that takes place between cement and water is referred as hydration of cement.

2.3.9 Loss on ignition of portland cement

Ignition loss (LOI) represents the % weight loss suffered by a sample of cement after heating to 1832 F. Any water bonded to hydrated cement particles is expelled above this temperature. The higher the LOI, the less strength the cement will develop. ASTM limits the LOI to 4.0%, this indicates the pre-hydration or carbonation due to prolonged or improper storage. LOI is the loss of the weight of a cement sample when heated at 1000^{o}C. i.e. LOI of 4%. Loss on ignition of Portland cement is determined by heating a cement sample of known weight to between 900°C and 1000^{o}C until a constant weight is obtained. The weight loss of the sample is then determined. Normally, a high loss on ignition is an indication of pre-hydration and carbonation, which may be caused by improper or prolonged storage or adulteration during transport (ASTM C114).

2.3.10 Chemical properties of portland cement

The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. These oxides interact with one another in the kiln at high temperature to form more complex compounds. The relative proportions of these oxide compositions are responsible for influencing the various properties of cement; in addition to rate of cooling and fineness of grinding.

Table 2.5: Approximate Oxides Composition Limits of Ordinary Portland Cement

Oxide	Percentage content
CaO	60.0-67.0
SiO_2	17.0-25.0
Al_2O_3	3.0-8.0
Fe_2O_3	0.5-6.0
MgO	0.1-4.0
Alkalies (K_2O, Na_2O)	0.4-1.3
SO_3	1.3-3.0
Insoluble residue	0.3-5.0
Losson ignition	1.0-1.5

(Source: Neville, 2004)

The calculated quantity of the compounds in cement varies greatly even for a relatively small change in the oxide composition of the raw materials. To manufacture a cement of stipulated compound composition, it becomes absolutely necessary to closely control the oxide composition of the raw materials. SO_3 also appear in cement analysis which comes from adding gypsum (4 – 6)% during clinker grinding. The Iraqi and British specification for normal high rapid Portland cement pointed that SO_3 content must be between (3 – 2.5)% according to type of cement and C_3A content. The percentage of MgO in cement which comes from Magnesia compounds in raw material is about (4 – 10%) and 5% as maximum range to control expansion from hydration of this oxide in hard concrete. An increase in lime (CaO) content beyond a certain value makes it difficult to combine with other compounds and free lime will exist in the clinker which causes unsoundness in cement. Insoluble residue is that part of the Cement that is not soluble in hydrochloric acid HCl and arise mainly from non-active silica to form cement compounds dissolved in this acid therefore it expresses the completeness of the chemical reactions inside the rotary kiln. The tricalcium silicates are the primary bonding agents within Ordinary Portland cement today, yet many of the chemical compositions for pre-regulated Ordinary Portland cement existed in the same chemical form as natural cement. For the past 100 years there have been important changes in the production of Ordinary Portland cement. Where early Ordinary Portland cement was typically burned once, modern Ordinary Portland cement undergoes several complex processes including burning of the stone through a rotating kiln, the addition of additives, like gypsum, within the actual cement clinker to increase the consistency of the final product, and finally through a similar, but slightly more complex grinding process which produces an extremely fine powder able to pass through sieves that would retain water (Mehta, 2001).

2.3.11 Types of Cement

Portland cement is a closely controlled chemical combination of calcium, silicon, aluminum, iron and small amounts of other compounds, to which gypsum is added in the final grinding process to regulate the setting time of the concrete. Some of the raw materials used to manufacture cement are limestone, shale, and chalk or marl, combined with shale, clay, slate or blast furnace slag, silica sand, and iron ore. Lime and silica make up approximately 85 percent of the total mass. The (ASTM C618, 2008) has designated five types of Portland cement, designated Types IV., physically and chemically, these cement types differ primarily in their content of C_3A and in their fineness. In terms of performance, they differ primarily in the rate of early hydration and in their ability to resist sulfate attack. The general characteristics of these types are listed in Table 2.6.

Table 2.6: General features of the main types of Portland cement

Cement Type	Classification	Characteristics	Applications
Type I	General purpose	Fairly high C_3S content for good early strength development	General construction (most buildings, bridges, pavements, precast units, etc)
Type II	Moderate sulfate resistance	Low C_3A content (< 8%)	Structures exposed to soil or water containing sulfate ions
Type III	High early strength	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV	Low heat of hydration (slow reacting)	Low content of C_3S (< 50%) and C_3A	Massive structures such as dams. Now rare.
Type V	High sulfate resistance	Very low C3A content (< 5%)	Structures exposed to high levels of sulfate ions
White	White color	No C_4AF, low MgO	Decorative (otherwise has properties similar to Type I)

(Source: ASTM C150, 2005)

2.3.12 Cement blending

American Society for Testing and Material (ASTM C150, 2005) defined Blended Cements (BC) as cement mixtures containing Portland cement and one or more Supplementary cementitious materials (SCMs); with the potential benefits of reducing the overall concrete costs, improving concrete workability, durability and long-term strengths. Horst (2001) elucidated further that BC as a technical term, often refers to cement products that are factory blended by cement companies while on the site mixing with the OPC is referred to as 'partial replacements'. As stated earlier in this report pozzolans are utilized as SCMs in cement blending or partial replacements of the OPC in concrete mixes.

2.4 Necessity and Opportunity of Sustainable Concrete Using Waste Materials

Since global warming is known as the most crucial environmental issue at present time and sustainability is becoming an important issue of economic and political debates, and for the next developments in the concrete industry will not be the new types of concrete - produced with expensive materials and special methods - but low cost and highly durable concrete mixtures containing largest possible amounts of industrial and agricultural waste/by products that are suitable for supplementary use of Portland cement, virgin aggregate, and drinking water (Mehta, 2004).

Besides, huge energy is required for burning of clinker during the production of cement, for these a large amount of CO_2 is produced and released to the atmosphere. Approximately, one ton of CO_2, a greenhouse gas, is delivered into the atmosphere for each ton of cement production. Worldwide, the cement industry is responsible for about 1.4 billion tons in 1995, which caused the emission of as much CO_2 gas as 300 million automobiles - statistically for almost 7% of the total world production of CO_2 (Malhotra, 2000). Hence environmental pollution and global warming is increasing continuously and, natural resources and energies are being reducing day by day. On the other hand, huge amount of biogenic wastes (POFA, RHA, AFT) are being produced in the developing countries, Nigeria is the best example. Industrial by-products (slag and fly ash) are generated from the developed as well as developing countries. In fact, in spite of their technical and financial benefits, till now there is no potential example of using these ashes, they are only used as landfill purposes.

Consequently, environmental pollution is observed, huge land area is covered and become useless, and resulting in to soil contamination. Moreover, addition of waste material in cement could reduce the releasing rate of CO_2 to the atmosphere. The embodied CO_2 emission feature long with waste material and without its contribution to cement production. It can easily be understood that, due to incorporation of waste material into cement, the embodied CO_2 emission is reduced significantly. For example, with addition of 50% slag, embodied CO_2 emission is reduced by 56 kg/ton (36.6%). This feature has a similar trend for the total CO_2 emission into the atmosphere during the cement manufacturing. For 50% slag addition, total CO_2 emission is reduced to 53.3%: for CEM I, CO_2 emission is 1011 kg/ton but for 50% slag, this value is dropped down to 539 kg/ton.

Evidently it can be said that utilization of waste material in cement production in Nigeria would be a potential step for restriction of CO_2 emission as well as reservation of energy. Waste materials could be used as effective construction materials and have the ability to satisfy the design specifications provided that it would be processed properly. In fact, many by-products and solid waste material can be used in concrete mixtures as replacement of aggregates or cement, depending on their chemical and physical characteristics. The capacity of concrete for incorporating these secondary raw materials is very wide and the main limit is their availability.

Fly Ash is a by-product of coal combustion that is collected in smoke stacks; it is a lower cost cementitious substance that has been used for about or more than a century as a better environmentally benign substitute for some of the Portland cement content in concrete; it saves money, has some superior performance characteristics, and in terms of sustainability, fly ash preserves raw materials and reduces CO_2 emissions. There are unlimited supplies of good quality fly ash worldwide, and these ashes have been used in concrete as supplement of cement in different study: new concrete technology such as high-volume fly ash concrete has been developed, superplasticizers and supplementary cementing materials used in combined, leading to economical high-performance, crack-resistant concrete with improved durability (Mehta, 1999; Malhotra, 1986; Malhotra and Mehta, 2002). Therefore, this is the optimum time of producing Sustainable Concrete using waste material as concrete ingredients, as a supplement of cement or direct incorporation into concrete. This process would be useful and meaningful simultaneously for the following multiple advantages: minimization of waste disposal, environmental pollution, saving raw materials as well as energy, and reduction of CO_2 emissions. There is great opportunity to perform this step in Nigeria and it could be successfully implemented here because the country produces a large amount of biogenic and industrial wastes.

2.5 Benefits of Using Waste Material in Concrete

Recently, the use of supplementary cementing materials from other sources has become significant for technical, environmental and economic reasons. Re-utilisation of industrial by-products (slag, fly ash, ash from timber, agricultural waste-RHA, POHA, ceramic waste, kiln dusts, sludge, concrete demolition waste, incinerator ash, and others) and post-consumer waste (glass, plastic, tires, steel, fibres) as supplementary material, reinforcing agents, or as aggregates could have a beneficial effect on concrete's total embodied energy as well as on long-term performance and durability. A concrete containing waste material (fly ash, slag, POHA, RHA) is an example of sustainable construction development which is feasible with satisfactory performance, in terms of both safety and serviceability of structures, at lower costs and with environmental advantages over ordinary concrete, as stated in different literatures.

Moreover, when recycled materials are appropriately used in concrete, some important properties of the hardened concrete such as ductility and durability can be improved (Moriconi, 2002). There are more advantages of using waste material in cement and concrete as mentioned below:

i. Incorporation of rice husk ash improves compressive strength (Safiuddin,*et al*., 2010) flexural strengths of concrete (Coutinho, 2002, Ismaila and Wahinddin, 1996) and split tensile strength (Habeeb and Fuyyadh, 2009, DeSensale, 2006).
ii. Rice husk ash shows better durability of concrete (Coutinho, 2002).
iii. Addition of rice husk ash improves resistance to sulfate attack (Chatveera and Lertwattanaruk, 2009, Sakr, 2006, Chindaprasirta *et al*., 2007).
iv. Strength increases (Chatveera and Lertwattanaruk, 2009) with increasing amount of fly ash up to an optimum value of 40% of cement (Oner *et al*., 2005).

2.6 Rice Husk Ash (RHA)

Rice husk Ash Rice husk is the waste obtained from shell of rice grains during the processing of rice grains. Rice husk is a waste material which creates environmental pollution. Because of low nutrition it is unsuitable for edible purpose. In a few countries; it is used as fuel in rice processing plants and electricity generation plants, in order to reduce volume of rice husk waste. About one tonne of husk is produced from five tonnes of rice paddy and it has been estimated that some 120 million tonnes of husk could be available annually on a global basis for pozzolana production. Nagrale, (2016). As the ash content by weight is about 20%, there are potentially 24 million tonnes of RHA available as pozzolana. Rice is grown in large quantities in many Third World countries including China, the Indian sub-continent, South-east Asia and, in smaller quantities, in some regions of Africa and South America. Production is likely to be more than doubled in most of these countries by the year 2020.

Traditionally, rice husk has been considered a waste material and has generally been disposed of by dumping or burning, although some has been used as a low-grade fuel.

Nevertheless, RHA has been successfully used as a pozzolana in commercial production in a number of countries including Columbia, Thailand and India.

Research and pilot projects have been undertaken in most of the major rice-growing countries of the world. However, it has been estimated that the total world production of cement based on RHA is only 30,000 tonnes per year, mainly undertaken in small-scale village production units. It is clear therefore that considerable potential exists to expand production on both a small and large scale (Coker and Ninalowo, 2016).

2.7 Cattle Bone Ash Use in Concrete Production

Bone can be described as a strong, hard, fibrous material in mammalian which gives shape and support to the animal body. They are sourced from animal after slaughtering them, and removing out all the flesh from the bone structures (John, 2014).

Cow-Bone causes a severe disposal problem and continues to gather at increasing rate, which if not properly managed, the bone will create increasing environmental problems (Mahmud, 2016). For this reasons, recycling of bone as sustainable material in concrete production would aid to preserve natural resources in cement production and protect against ecological problems (Mahmud, 2016). John (2014), in his study concluded that fired bones when made in to fine and coarse aggregate could be used as 50% replacement of all aggregate concrete. He also observed that the density decreases with the increase bone content in the concrete, which implies that fired bones are suitable for light weight concrete.

According to Akinyele (2016), at 10%, bone ash can partially replace cement in concrete at 28 days comprehensive strength value. Ahmad (2016), carried out an experimental investigation to study the effect of cattle bone ash on the properties of concrete. The result shows that the CBA contained high percentage of lime (CaO) of 60.7% against 61% of ordinary Portland cement, it was also observed that all concrete produced attained a strength ranging between 14-30Mpa at 28 days. Tsado (2017), in his study effectiveness of powdered cow bones as pozzolana in concrete production observed that powdered cow bones requires less amount of water to achieved the same consistency with the same amount of ordinary Portland cement, and that powdered cow bones can be incorporated with ordinary Portland cement at partial replacement to produce concrete provided the replacement is not more than 10%.

2.8 Workability of Fresh Mortar/Concrete

American Concrete Institute (ACI, 1990b) defines workability as that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which concrete can be mixed, placed, compacted and finished. With the addition of natural pozzolans, there was a decrease in volume expansion of the fresh mix by 74 – 87% (Alp, 2009).

Dhanalakshmi (2015), concluded that there was increase in workability with the addition of fly ash to optimum egg shell powder concrete. Coker and Ninalowo, (2016), carried out a study into the properties of lightweight formed concrete by partially replacing Portland cement by rice husk ash. It was observed that 0.4 water/binder was capable of producing structural lightweight concrete with a compressive strength of 18.5N/mm^2 at 28 days.

2.9 Durability and Workability

American Concrete Institute defines concrete durability as its ability to resist weathering actions, chemical attack, abrasion and other degradation process. Durability of concrete varies depending on the exposure environment and properties desired. Oyekan (2011) carried out an investigation into the engineering properties of sandcrete block made with rice husk-blended cement. It was observed that the presence of mineral admixture improved the strength, durability and workability of cementitious product. Dhanalakshmi (2015), carried out a comparative study on effect of egg shell concrete properties by partially replacing ordinary Portland cement by fly ash. It was observed that there was an increase in workability with respect to the addition of fly ash to optimum egg shell powder concrete.

2.10 Compressive Strength of Concrete

Shetty (2005), define the compressive strength of concrete as its resistance to crushing load applied directly, this implies the maximum compressive load the concrete can carry per unit area. The strength of concrete is influenced by water cement ratio, aggregate cement ratio, grading, surface texture, shape, strength and stiffness of aggregate particles, and maximum size of aggregate. Concrete for cast-in-situ pile shall have an ultimate compressive strength of not less than 20N/mm^2 at the age of 28 days. Tsado *et al.* (2014) carried out a comparative analysis of properties of some pozzolana concrete. It was observed that there was a decrease in compressive strength for each ash beyond 20% replacement. Mahmud (2016) performed an experiment on probability based design approach of concrete mixed with cow bone ash admixed cement. It was also concluded that, higher comprehensive strength was achieved at both 7 and 28 days. Akinyele (2016), in his study, effect of bone ash and wood ash in concrete observed that 10% of bone ash can partially replace cement in concrete at 28 days comprehensive strength.

3.1 Related Works on Combined Effects of CBA and RHA in Concrete Production

Research on waste is on the rise and the subject is attracting global commendation due to its functional benefit in reducing constructional cost considerably (Tsado, 2017).

Experimental study on a review of partial replacement of cement with some agro wastes revealed that Only GHA and RHA satisfied pozzolanic material requirement with the sum of SiO_2, $Al2O_3$ and $Fe2O_3$ being greater than 70%. WA, AHA and BGSA, had values lower than 70%, and can be considered as non pozzolanic material. BPA is also a non pozzolanic material with moderate CaO composition and lower SiO_2 component. The result indicated that only the use of 10% BPA to replace cement has shown promising result in the replacement of cement with agro-wastes (Manasseh, 2010).

A study on the characteristics strength of groundnut shell ash (GSA) and ordinary Portland cement blended concrete in Nigeria was carried out, and it was concluded that the compressive strengths of the control (0%) and those of other percentage combinations increased with curing age but decreased with increased GSA percentage. Though, characteristics strengths revealed that the OPC/GSA concrete of 10% replacement performed better in comparison to the acceptable standard and would be more suitable for mass concrete production (Buari *et al*., 2013). Similarly, (Mahmoud *et al.,* 2012) carried out an extensive research on Ground shell ash (GSA) in low cost production, and the result obtained at optimum reveals that the strength activity of the ordinary Portland cement/Groundnuts ash showed decreases with increase of cement above 20% replacement. (Mahmoud *et al.,* 2012) suggested an optimum replacement level of 20% of GSA with OPC as a partial replacement of cement in sandcrete block to achieve a satisfactory compressive strength at percentage of the binder quantity. Abdullahi (2006) carried out a study on the rice hush ash in low-cost sandcrete block production, and the results obtained shows that the compressive strength of the OPC/RHA sandcrete blocks increases with age at curing and decreases as the percentage of RHA content increases. The study finally suggested an optimum replacement level of 20%. (Breuge, *et al.,* 2018), suggested from his study of ultra-high performance concrete made with rice husk ash that, due to the ability of RHA particles to reduce the autogenous shrinkage in low water-cement mixtures. This low cost material is an excellent alternative for expensive silica fume for production of ultra-high performance materials. It was shown from the result that Autogenous shrinkage measurement on RHA modified mixtures showed that ashes with a mean particle size of 5.6μm reduced the autogenous more that ashes with a smaller (3.6μm) or larger (9.0μm) mean particle size. In the same vein, a study on the structural properties of rice husk ash concrete has been carried out, and it was concluded that the compressive strength and workability tests suggest that RHA could be substituted for OPC at up to 25% in the production of concrete with no loss in workability or strength. Rice husk ash was suggested for structural concrete at 10% replacement level.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

The composition of materials used for this research includes fine aggregate (River sand), coarse aggregate (Bida Natural stones) according to BS 882: 1992, and water. Ordinary Portland cement, Dangote 3X in accordance with codes of practice ASTM C150 (2005) and BS 812, (1996) for the production of concrete in addition to rice husk ash (RHA), and Bone powder ash (BPA) ashes.

3.1.1 Cement

Dangote brand of 3X Ordinary Portland cement in 50Kg sourced within Minna was used for this research. The physical properties of the cement are presented in Appendixes. The specific gravity of the cement (3.14) was conducted in accordance with BS EN 197-1:2000, using the gas jar method. Test for fineness of cement was conducted in accordance with ASTM C184 (1994) method using 75um British Standard sieve.

3.1.2 Fine aggregate

The fine aggregate used was cleaned sharp sand sourced from River Chanchanga in Minna, Niger State. The sieve analysis of the fine aggregate was done in accordance with BS 812 Part1:1975 and the particle size distribution. Table is shown in the Appendix A1.

3.1.3 Coarse aggregate

The coarse aggregate used was Bida natural stones of nominal size 10-14mm sourced at kata Eregia long Bida Minna Niger state. It has a specific gravity of 2.68 and average impact value of 42.65 percent. The sieve analysis of the coarse aggregate was done in accordance with BS 812 Part1:1975 and the summary of the particle size distribution preserved is details in the Appendix A2.

Plate I: Bida natural stones

3.1.4 Water

Clean drinkable water free from any organic or inorganic impurity having 7.0 pH value which was available in the Department of Civil Engineering Federal University of Technology Minna laboratory was used for mixture and cured of concrete samples. The water used was in conformity to BS 3148 (1980).

3.2 Method

3.2.1 Rice husk ash production

Rice Husk Ash-Rice husk was sourced from a local rice mill at Bida Niger state, Nigeria. The Rice husk is a by-product of the rice milling process. When subjected to combustion, almost 20% of the husk becomes ash with high silica content. RHA used in this experiment has a specific gravity 1.87. The rice husks were burnt using open combustion. The fully burnt rice husk ash was later grounded and sieved with sieve 75µm to ensure proper fineness of the ash. The colour of RHA is black and it's odourless. It's smooth when touch and cool before use. When small quantity is thrown in a bucket of water it does not sink but flow on the surface.

Plate II: Rice husk ash

3.2.2 Bone powder ash production

Bone Powder ash is a by- product of waste bones collected from abattoirs in Minna Niger state. The waste bones were sun-dried after careful separation from flesh, tissues, and fats. The sizes were gradually reduced by mortar and the ash was obtained through closed incineration at the temperature of 650^{o}C at National Cereal Research Institute (NCRI) Baddegi Bida Niger State, the ash was sieved through various sieve sizes.

Plate III: Bone powder ash

3.2.3 Method of grading the aggregates

The aggregates were graded in accordance to the British standard (BS 882: 1992) using sieves analysis. Coarse aggregate are particles retained on No.4 (4.5mm) sieve, but generally it sizes ranges from 5mm to 150mm, while the Aggregate that pass a 4.75mm sieve (No.4) and predominantly retained on a No. 200 (75µm) sieve are classified as fine aggregate.

3.2.4 Water absorption test for coarse aggregate

Two tests were carried out to ascertain the average water absorption for the coarse aggregates. The test was in conformity to BS 4550, Part 3 (1978).

3.2.5 Density test

The density of fresh concrete was obtained by weighing the compacted concrete in a standard container of known weight and volume. The test was in conformity to BS 4550, Part 3 (1978).

3.2.6 Bulk density test on aggregates

The test was carried out as compacted and un-compacted on the samples, as illustrated in Appendix A9 and A10. The test was in conformity to BS 4550, Part 3 (1978).

3.2.7 Specific gravity test

Two tests were carried out to ascertain the specific gravity of fine aggregate (River sand), coarse aggregate (Bida natural stones), bone powder ash, rice husk ash, and the average value on each case was determine. The test was in conformity to BS 4550, Part 3 (1978).

3.2.8 Aggregate impact value (AIV)

The test was carried out as compacted and un-compacted on the samples, as shown in Appendix A11. The test was in conformity to BS 4550, Part 3 (1978).

3.2.9 Aggregate crushing value (ACV)

The test was carried out as compacted and un-compacted on the samples, as shown in Appendix A12. The test was in conformity to BS 4550, Part 3 (1978).

3.2.10 Concrete mix design for aggregates content

The design mix adopted was Absolute Volume Method mix proportioning. The cement was partially replaced with Rice Husk Ash (RHA) and Bone Powder Ash (BPA) separately. A total number of six (6) batches were prepared with mix proportions by weigth-1:2:4 and a water cement ratio of 0.5 was adopted. Twenty-four (24) numbers of cubes were produced for each batch. Three cubes samples of each mixed were tested for compressive strength at 7, 14, 21, and 28, days curing periods respectively.

Table 3.1: Measurement for batching

RHA (%)	0	5	10	15	20	25
BPA (%)	0	5	10	15	20	25

3.2.11 Workability test on fresh concrete mixes

Concrete is characterized by filling ability, passing ability and resistance to segregation. There are two major method of measuring workability these are slump test and compacting factor test. These tests were conducted to assess the properties of the freshly mixed concrete (Control mixes) and those with cement partially replaced by ashes at 5%, 10%, 15%, 20% and 25%. The test was in conformity to BS 1881, Part 108 (1983).

a) Compaction factor test

The inverse approach of the degree of compaction achieved by a standard amount of work done in achieving full compaction is called the compaction factor and is measured by the density ratio. The apparatus consists of two hoppers and one cylinder. The hoppers have hinged doors at the bottom and are cleaned, oiled and set before carrying out the test as detailed below; The is filled with concrete gently. The bottom door of the hopper is then realized and the concrete falls into the lower hopper. This lower hopper is smaller than the upper hopper and was therefore filled to overflowing and this always contains the same amount of concrete in a standard state. The bottom door of the lower hopper was released also and the concrete falls into the cylinder. Excess concrete was cut and or trimmed and the net mass of concrete in the known volume cylinder is determined.

The weight of the concrete in the cylinder referred to as compacted concrete. It was found by refilling the container in layers of approximately 50mm each and each layer being compacted 25 blows using the standard compaction rod trowel, the concrete was then trimmed. The concrete in the cylinder was weighed again and the compacted weight was recorded. The higher the value of the compacted weights in comparison with that of un-compacted weight, the greater the workability (BS 1881, part 108, 1983).

b) Slump test

Slump Test: The slump test was carried out in accordance with BS1881-108:1983 using apparatus which consist of slump cone and tamping rod.

3.2.12 Tests on hardened concrete

Compressive strength test was conducted at the Department of Civil Engineering Concrete laboratory, Federal University of Technology Minna, Niger State on the hardened concrete samples for both control mixes and those with cement partially replaced by ashes with their respective density (unit weight) computed using the concrete cubes samples.

a) Density unit weight

The density of the hardened concrete was established from the cube samples after 7, 14, 21 and 28 days of standard curing in accordance with BS1881: part 114:1983.

b) Compressive strength of the concrete using test cubes

Compressive strength of concrete is the measurement of its resistance to crushing load applied directly; this implies the maximum compressive load the concrete can carry per unit area. The test was in conformity to BS 1881, Part 108, (1983).

Plate IV: Curing of concrete cubes

Plate V: Crushing of concrete cubes

3.2.13 Mix Design for concrete

The mix design used for preparing the concrete was based on an Absolute volume method in accordance with BS 5328: Part 2: 1991. A mix ratio of 1:2:4, water/cement ratio of 0.5, characteristic strength of $25N/mm^2$ at 28 days (Grade 25 Concrete) with Target strength of $30N/mm^2$ was used for the concrete mix design which can be used for columns, slab, foundation and beam if possible at 5% without any chemical additive.

Mix design by Absolute Volume Method

The purpose of mix proportioning is to produce the required properties.

$V_{cement} + V_{water} + V_{f.agg} + V_{c.agg} + V_{air} = 1.0m^3$ (1)

$V_{water} + V_{f.agg} + V_{c.agg} + V_{RHA} + V_{air} = 1.0m^3$ (2)

$V_{water} + V_{f.agg} + V_{c.agg} + V_{BPA} + V_{air} = 1.0m^3$ (3)

Where each of this parameters are C: Required quantity of cement, W: Required quantity of water, F.agg: Required quantity of fine aggregate; C.agg: Required quantity of coarse aggregate (Bida Natural Stone).

S_{Gc}, S_{Gs}, S_{Gg} are specific gravity of cement, fine aggregate and coarse aggregate

$S_{Gc} = 3.15$; SGs = 2.65; $S_{Gg} = 2.68$

Void space = 5%

$$\text{Density}\left(\frac{kg}{m3}\right) = \frac{mass\ (kg)}{volume\ (m3)}$$

$$Specific\ gravity\ (S.G) = \frac{Density}{Density\ of\ water}$$

$$\frac{M_w}{1000} + \frac{M_c}{1000ec} + \frac{M_{f.agg}}{1000ef.agg} + \frac{M_{c.agg}}{1000ec.agg} + V_{air} = 1.0m^3$$

$$\frac{M_w}{1000} + \frac{(1-X)M_c}{1000ec} + \frac{XM_{rha}}{1000erha} + \frac{M_{f.agg}}{1000ef.agg} + \frac{M_{c.agg}}{1000ec.agg} + V_{air} = 1.0m^3$$

$$\frac{M_w}{1000} + \frac{(1-X)M_c}{1000ec} + \frac{XM_{bpa}}{1000ebpa} + \frac{M_{f.agg}}{1000ef.agg} + \frac{M_{c.agg}}{1000ec.agg} + V_{air} = 1.0m^3$$

Using mix ratio of 1:2:4

Fine agg. To cement ratio 2: F = 2C

Coarse agg. To cement ratio 4: C = 4C

Water cement ratio: W = 0.5C

$$\frac{0.5C}{1000} + \frac{C}{1000\ x\ 3.15} + \frac{2C}{1000\ x\ 2.65} + \frac{4C}{1000\ x\ 2.68} + 0.05 = 1.0m^3$$

$$5.0\ x\ 10^{-4}C + 3.175\ x\ 10^{-4}C +\ 7.547\ x\ 10^{-4}C +\ 1.487\ x\ 10^{-4}C = 0.95$$

$$3.0592\ x\ 10^{-3}C = 0.95$$

C = 310.54kg

Mould Size = 150 x 150 x 150mm

Volume of mould = (0.15 x 0.15 x 0,15) m^3 = 3.375 x 10^{-3} m^3

1 m^3 for 310.54kg and 3.375 x 10^{-3} m^3 for X kg

X kg = 1.046 of cement for a cube

Since 132 cubes is to be casted, the total quantity of cement required before reduction of various percentage is 1.046 x 132 = 138.072 kg.

But we are only interested in the cement reduction not on the other ingredients, therefore other ingredient remains constant such as coarse aggregate, fine aggregate and water.

For 100% cement and 100% portable water, 12 cubes is needed:

12 x 1.046kg = 12.552kg

For 95% cement, fine aggregate, coarse aggregate and water 100%, 24 cubes is needed at 5% cement reduction;

$$12.552\ x\ \frac{5}{100} = 1.2552kg$$

The quantity of cement needed is (12.552 x 2) – 1.2552 = 23.849 kg

For 90% cement, fine aggregate, coarse aggregate and water 100%, 24 cubes are needed at 10% cement reduction;

$$25.102\ x\ \frac{10}{100} = 2.5104kg$$

The quantity of cement needed is (12.552 x 2) – 2.5104 = 22.594 kg

For 85% cement, fine aggregate, coarse aggregate and water 100%, 24 cubes are needed at 15% cement reduction;

$$25.104\, x\, \frac{15}{100} = 3.766kg$$

The quantity of cement needed is 25.104 – 3.766 = 21.338kg

For 80% cement, fine aggregate, coarse aggregate and water 100%, 24 cubes is needed at 20% cement reduction;

$$25.104\, x\, \frac{20}{100} = 5.021\ kg$$

The quantity of cement needed is 25.104 – 5.021 = 20.083 kg

For 75% cement, fine aggregate, coarse aggregate and water 100%, 24 cubes are needed at 25% cement reduction;

$$25.104\, x\, \frac{25}{100} = 6.276kg$$

Therefore, total quantity of cement required is

12.552 + 23.849 + 22.594 + 21.338 + 20.083 + 18.828 = 119.244kg

The total quantity of cement required before reduction is 138.072kg

Since other materials remain constant

The total quantity of fine aggregate required; 2 x 138.072 = 276.144kg

The total quantity of coarse aggregate required; 4 x 138.072 = 552.288kg

The total quantity of coarse aggregate required; 0.5 x 138.072 = 69.036kg

3.2.14 Fineness test: The test was carried out to check proper grinding of cement.

Fineness of cement samples (specific surface area) was determined in accordance with BS 4550: Part 3: Section 3.3:1978 using the sieve method. This method serves only to demonstrate the presence of coarse cement particles. The fineness of cement was measured by sieving it on standard sieves 75μm. The proportion of cement of which the grain sizes are larger than the specified mesh size was thus determined. Table 3.5 shows the sieve analysis of cement.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Materials

The constituent materials used for the concrete mix as stated in chapter three are: cement, fine and coarse aggregates, rice husk ash, bone powder ash, and water. The properties test results of these materials and their effect on concrete are thus tabulated, compared and discussed detailed results are presented in Appendix.

4.1.1 Properties of constituent materials

4.1.2 Physical properties of concrete constituent, concrete containing RHA and BPA

Appendix A shows the results for the physical properties of concrete constituent concrete containing ashes. The results highlight the sieve analysis, moisture content, specific gravity, bulk density, aggregate impact value and aggregate crushing value of the materials which indicates an increase in the consistency with increase in the percentage of the ashes i.e. RHA and BPA. This implies that the quantity of water required to keep the mix in a uniform paste has increased and this can be attributed to the increase in percentage and carbon content from the ashes. This is similar to the work of Al-Khalaf and Yousif (1984).

4.1.3 Properties of aggregates (Bida natural stones and fine river sand)

Locally available natural aggregates 19mm maximum size having specific gravity, moisture content and unit weight as given in Table 4.1 was used as fine and coarse aggregate. Both fine aggregate and coarse aggregate conformed to BS 812: Part 2: 1995.

Table 4.1 Physical properties of fine and coarse aggregate

Physical properties	Fine Aggregate (River Sand)	Coarse Aggregate (Bida Natural Stone)
Specific Gravity (g/cm^3)	2.65	2.68
Bulk Density (kg/m^3)	1682.3	1598.04
Moisture Content (%)	2.54	5.51
Aggregate impact value	-	42.645
Aggregate crushing value	-	44.8

4.1.4 Specific gravity of the materials

The specific gravities of coarse aggregate and fine aggregate are 2.68 and 2.65 respectively. This is in accordant with BS 882: 1992. The specific gravities of the RHA and BPA are 1.87 and 2.49 respectively. This is in accordance with AASHTO T133 and ASTM C188.

4.1.5 Sieve analysis of a coarse aggregate

Coarse aggregate is Bida natural stones of nominal size of 5-14mm with a specific gravity of 2.68. The figure 4.2 below shows the distribution of coarse aggregate. It indicates that the particle size of the coarse aggregate contains aggregate particles of the same size.

4.1.6 Sieve analysis of fine aggregate

The fine aggregate used was cleaned sharp sand sourced from River Gidan Kwano in Minna, Niger State, with a specific gravity of 2.65. The fine aggregate used fall within zone three of BS 882 (1992).

4.1.7 Sieve Analysis of Rice Husk Ash

The sieve analysis was done according to BS 812(1995)

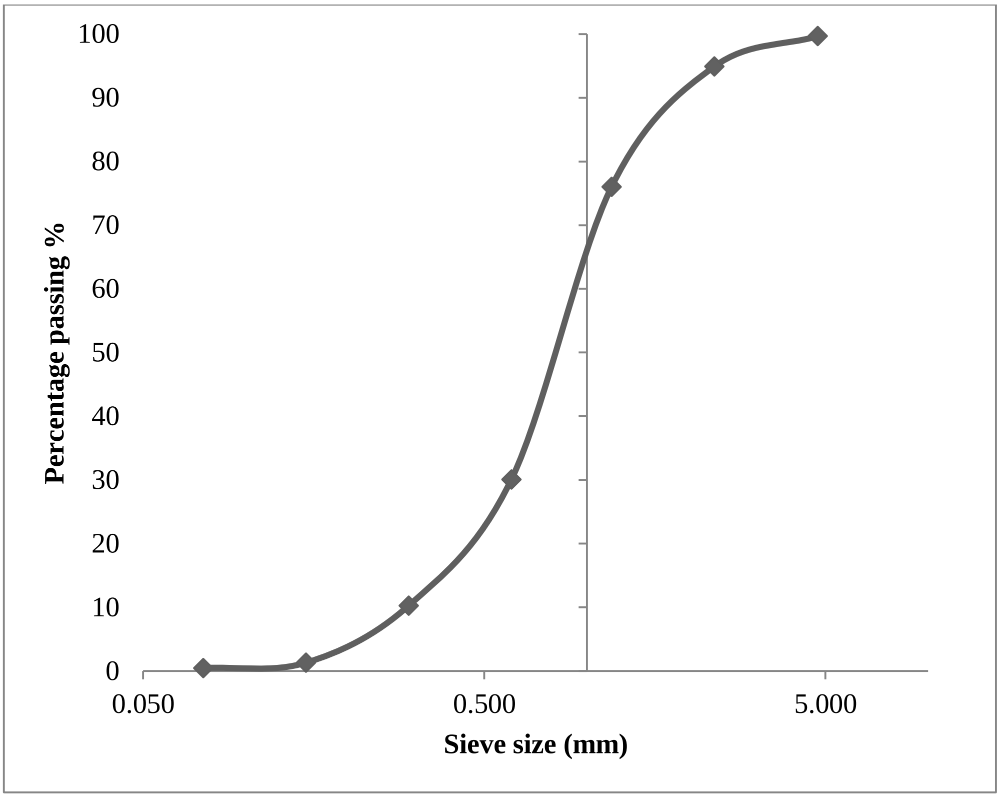

Figure 4.1: Particle size distribution curve for fine aggregate

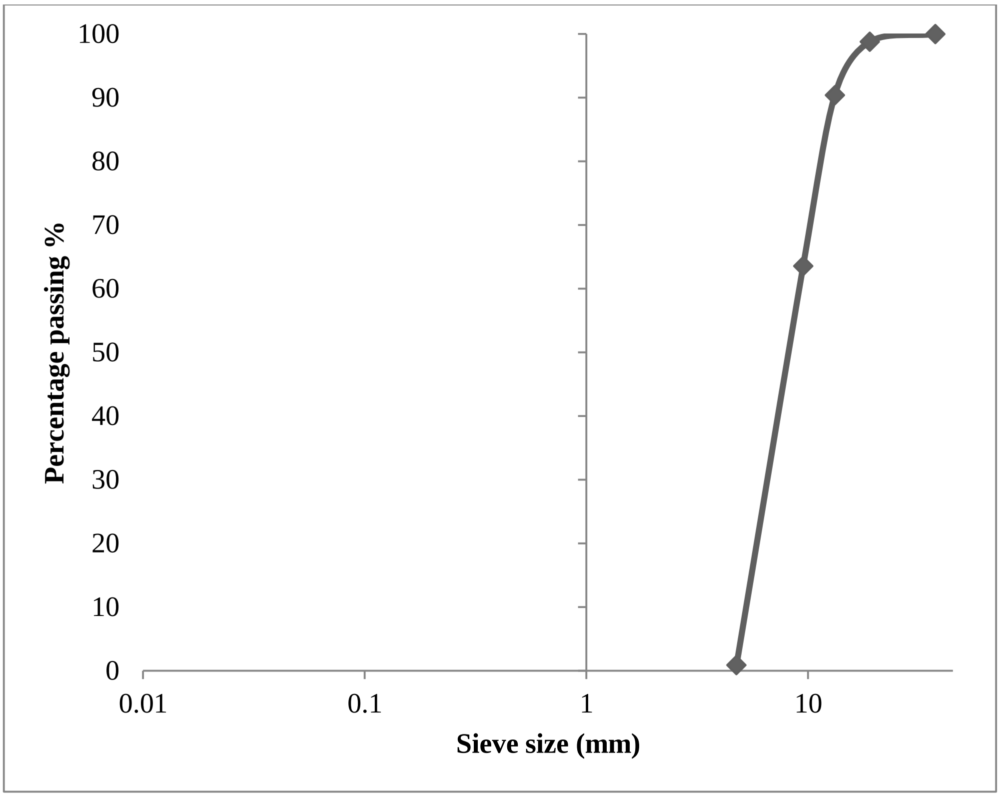

Figure 4.2: Particle size distribution curve for coarse aggregate

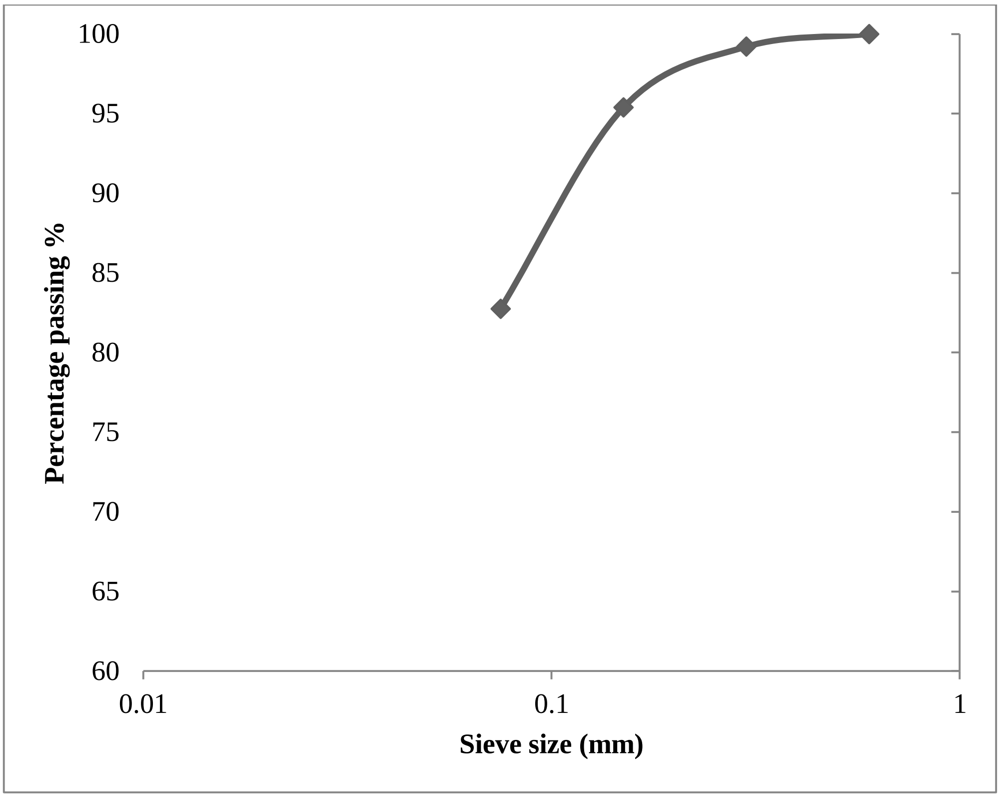

Figure 4.3: Particle size distribution curve for cement

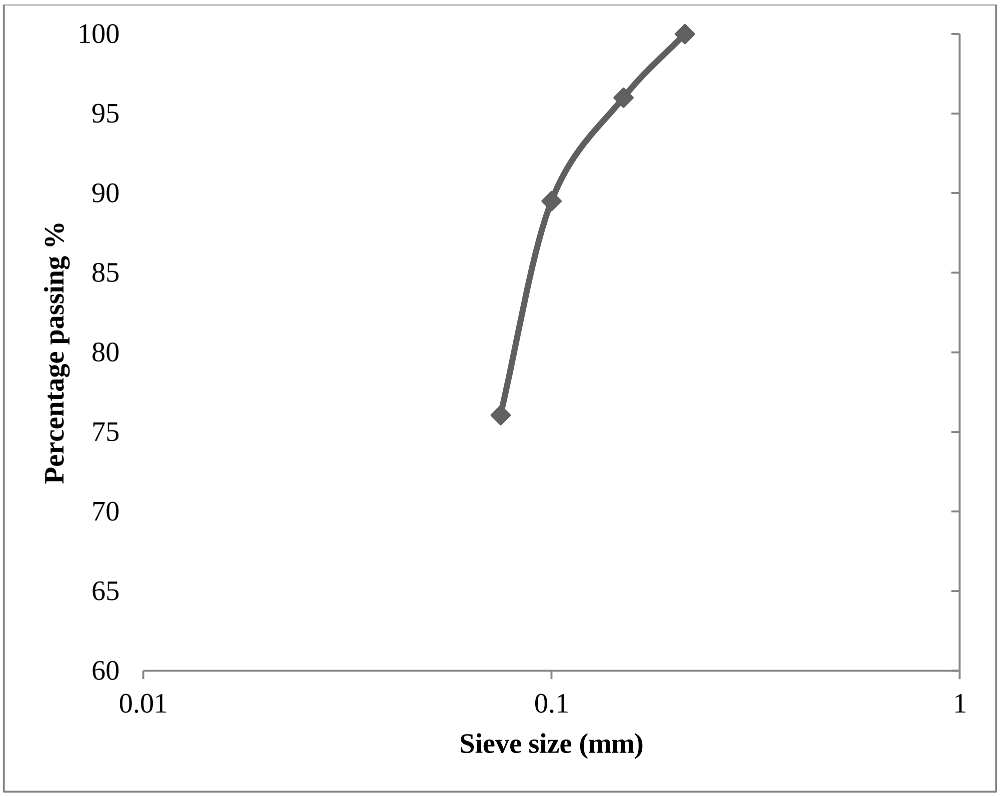

Figure 4.4: Particle size distribution curve for RHA

4.2 Properties of fresh concrete mixes

4.2.1 Workability test:

Appendix B shows the workability test result for the fresh concrete mixes. The workability of the fresh concrete mixes experiences a significant reduction with the partial replacement of cement with some percentage of ashes. The control mix had a slump of 10mm while 25% of the ashes have slump of 0.00 and 0.00mm for RHA and BPA respectively indicating about 100 and 100% reduction in slump. That is increase in ashes reduce the slump in all cases. The compacting factor indicate a reduction at 25% RHA mix (0.77) and 25% BPA mix (0.8152) as compared to the control mix with a compacting factor of 0.8674 while 5%BPA mix (0.8473) have compacting factor more than the RHA at 5% replacement and other subsequent percentage replacement. In general, the composite with cement partially replaced by various percentages of ashes have significantly reduced the workability and these can be attributed to the low specific gravity of the ashes as compared to that of the cement with which they are replacing in the mix of the ashes particles could contribute to the decrease in workability.

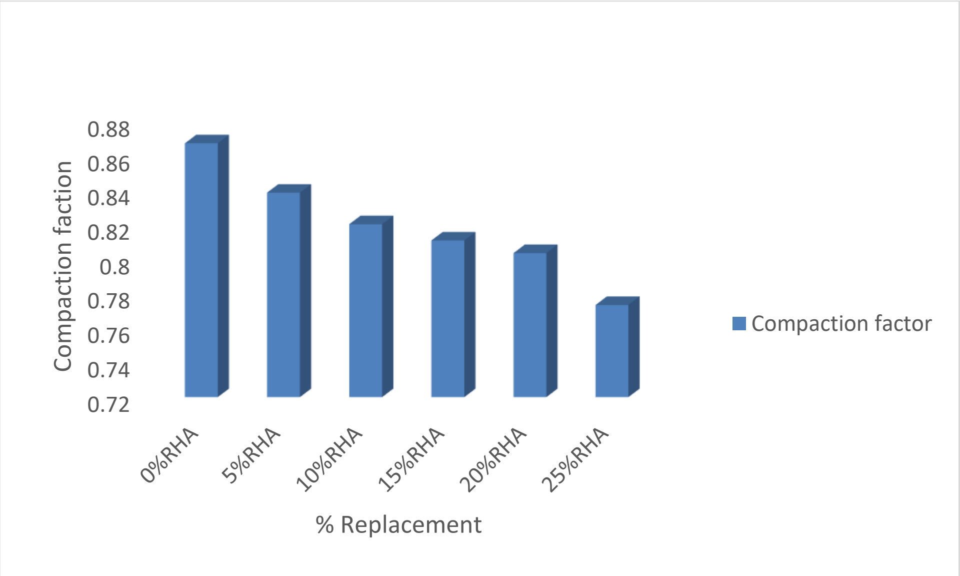

Figure 4.5: Compaction factor with various percentages of RHA

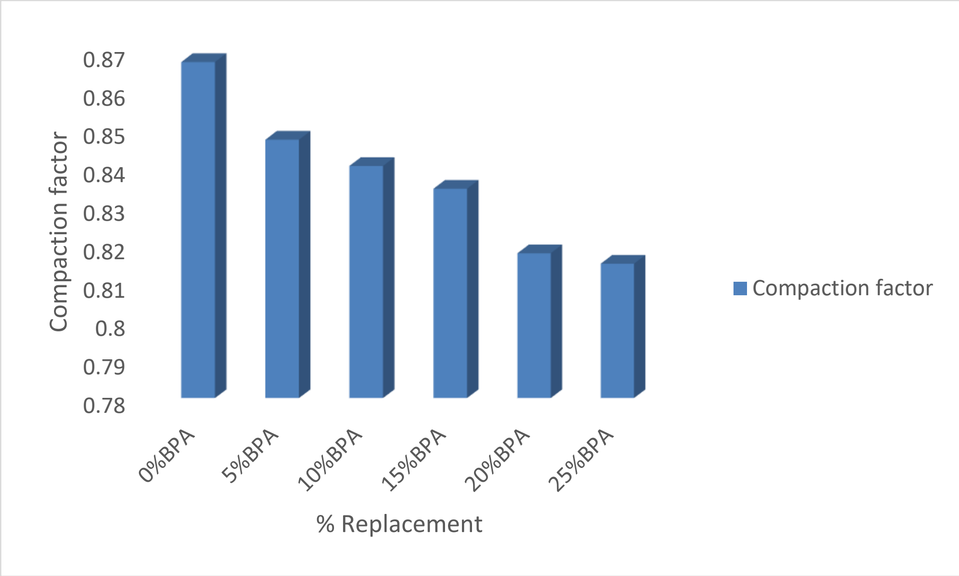

Figure 4.6: Compaction factor with various percentages of BPA

4.2.2 Slump test on fresh concrete

The values of the slump which is used measure the fluidity, softness or wetness of a batch of concrete ASTM C143 is represented in Figures 4.5 and 4.6.

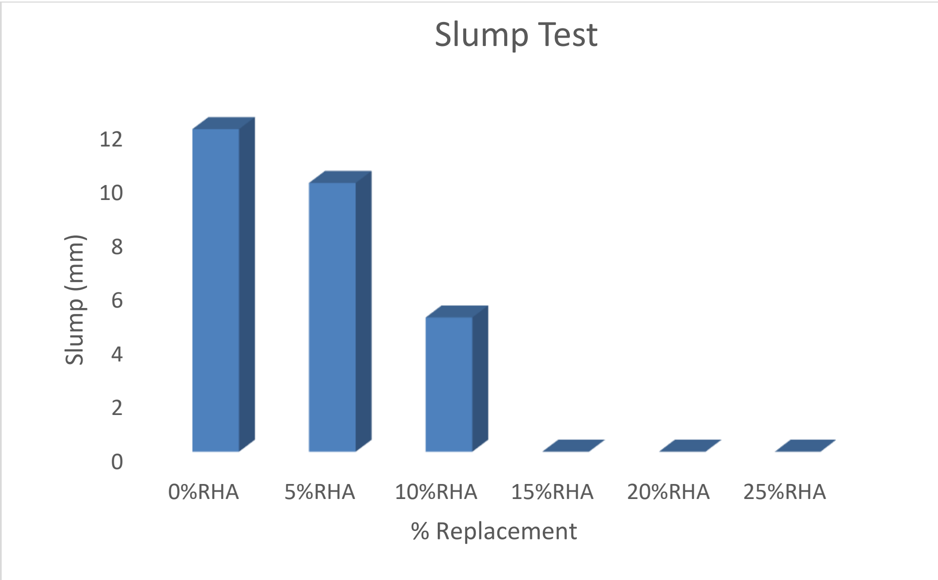

Figure 4.7: Slump test of fresh concrete for various types with percentages of RHA

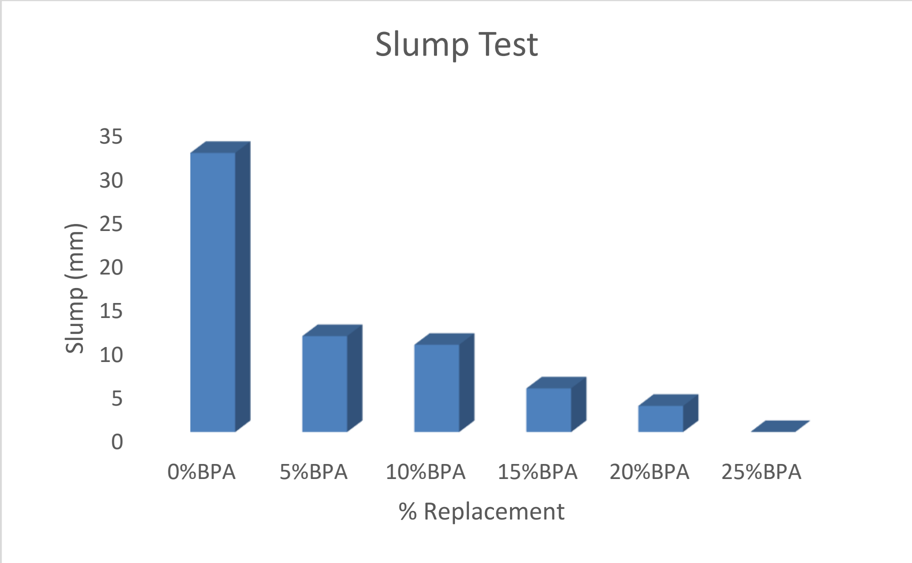

Figure 4.8: Slump test of fresh concrete for various types with percentages of BPA

4.3 Properties of Hardened Concrete

4.3.1 Compressive strength

The compressive strength of control concrete mix and concrete containing agro waste ashes (RHA and BPA) were investigated at 7, 14, 21 and 28 days curing age. The summary of the results are tabulated and presented graphically in Appendix C and Figure 4.9 and 5.0 for different replacement percentages of the ashes. Since concrete are mostly characterized by the 28 days compressive strength, a compressive strength of 26.28N/mm^2 was obtained for control concrete after 28 days of standard curing while concrete with 25% RHA and BPA in different mixes have a comprehensive strength of 7.05, and 8.77N/mm^2 respectively which indicates a percentage decrease in strength of 73.17% and 66.63%.

The reduction in compressive strength for the replacement is due to low percentage of Alumina, ferric oxide and Calcium Oxide in the ash (RHA, BPA). These two oxides compositions are one of the main constituent of cement and are mainly responsible for the strength development. So as the cement content is gradually replaced by the ash, the quantity of cement for hydration is reduced thereby the strength of the concrete is reduced. The 20% RHA and BPA replacement in concrete indicate a slight increase at 28 days. This behavior can be linked to the rate of pozzolanic reaction in the ashes which implies the early pozzolanic reaction rate is slow. Without super plasticizer, RHA concrete attained lower compressive strength than that of the control due to the higher amount of water for similar workability (Kartiniet *et al*., 2008).

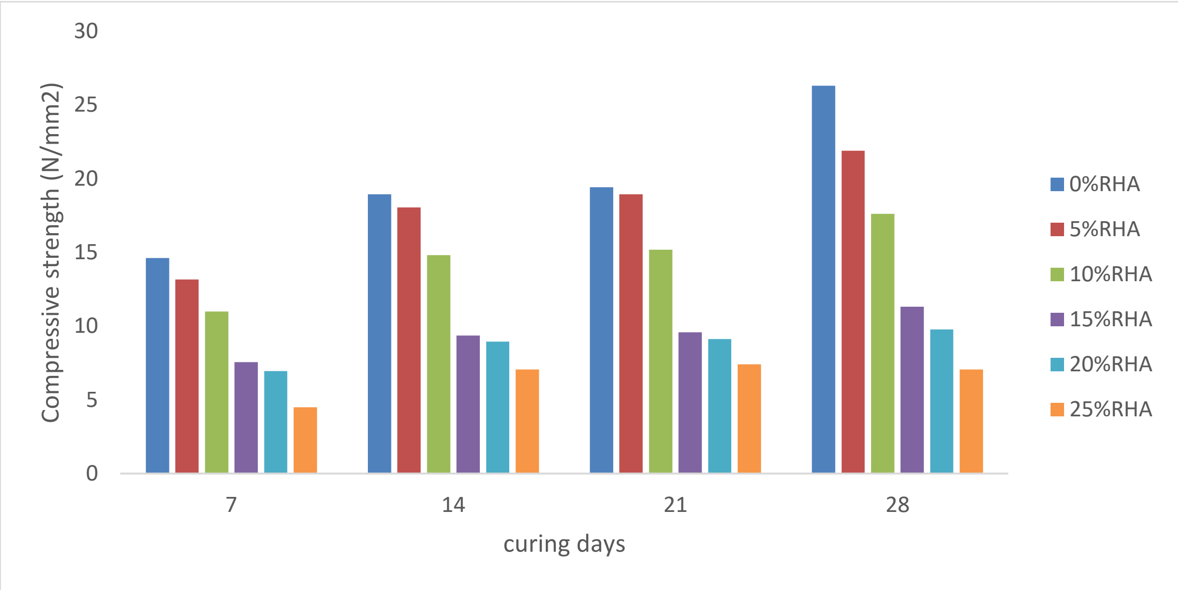

Figure 4.9: Compressive strength for various curing days with percentages of RHA concrete

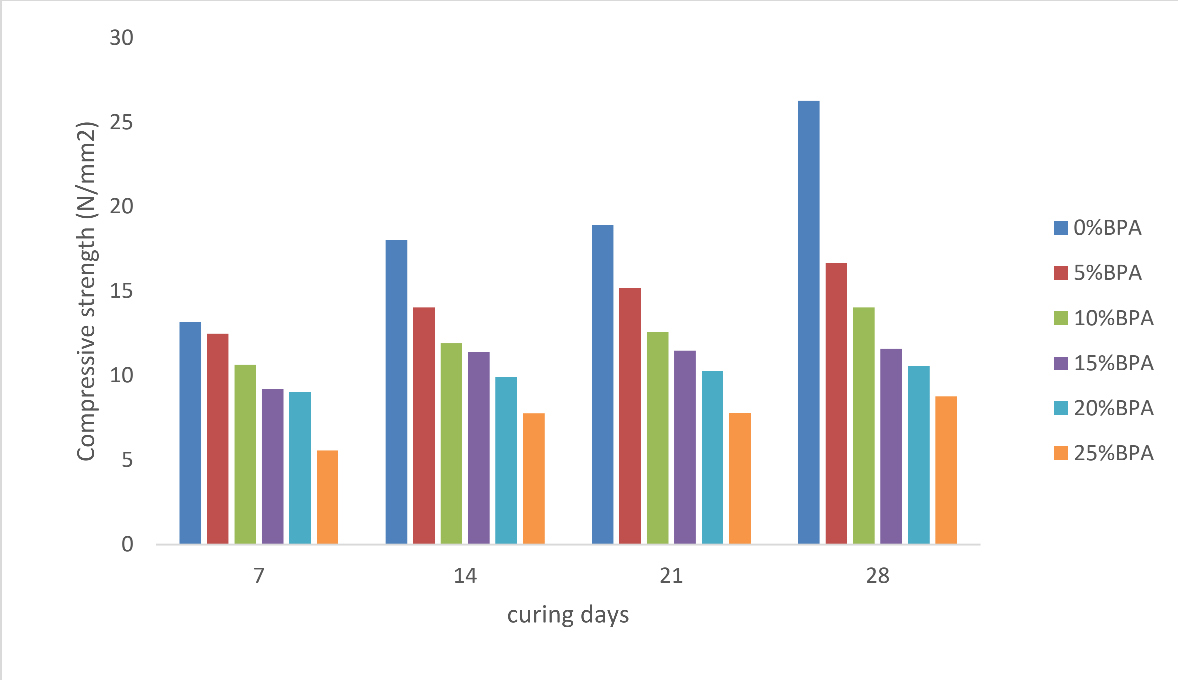

Figure 5.0: Compressive strength for various curing days with percentages of BPA concrete

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the experimental investigation, the following conclusions are drawn:

The result of physical and mechanical properties of aggregate shows that the aggregates are adequate for concrete production.

The workability of fresh concrete decreases as ash content increases.

The compressive strength of 26.28 N/mm^2 was obtained for control concrete after 28 days of standard curing while concrete with 25% RHA and BPA in different mixes have a comprehensive strength of 7.05, and 8.77 N/mm^2 respectively which indicates a percentage decrease in strength of 73.17% and 66.63%.

5.2 Recommendations

On the basis of the investigation carried out on RHA, and BPA as a pozzolana for partial replacement of cement in concrete production, the following recommendations were drawn:

1 It is also recommended that the RHA, BPA should be within the range of 20-25% replacement of the cement.

2 Further studies are required on thermal behavior of concrete using ash of waste materials as partial replacement to cement.

5.3 Contribution to Knowledge

This study will help enlighten the stallholders of bone powder ash and rice husk in the country on the possibility of monetizing the disposal of these ashes instead of the prevalent careless disposal in the environment.

The re-use and recycling of these ashes in concrete production will help safeguard our fast depredating environment and this will be in compliance with the global drive for a green and clean environment.

The use of the ashes in concrete production as partial replacement of cement will also help in reducing the cost of buildings and other infrastructural project in the country.

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APPENDICES

Appendix A: Physical Properties of Concrete Constituents

Appendix A1: Sieve Analysis Result for Fine Aggregates – Total Sample Weight 500g

Sieve size(mm)	Mass retained (g)	Cumulated weight retained (g)	Cumulated percentage retained (%)	Cumulative percentage passing (%)
4.75	1.65	1.65	0.33	99.67
2.36	23.85	25.5	5.1	94.9
1.18	94.4	119.9	23.98	76.02
0.60	229.63	349.53	69.906	30.094
0.30	99.01	448.54	89.708	10.292
0.15	44.80	493.34	98.668	1.332
0.075	4.20	497.54	99.508	0.492
Pan	2.46	500	100	0.00

Appendix A2: Sieve Analysis Result for Coarse Aggregates – Total Sample Weight 1000g

Sieve size(mm)	Wt. Retained (g)	Percentage Retained (%)	Cumulative percentage passing (%)
37.5	0.000	0.00	100
19.00	12.000	1.20	98.80
13.2	84.000	8.42	90.38
9.5	268.200	26.87	63.52
4.75	625.300	62.64	0.88
Pan	8.790	0.88	0.00
TOTAL		100.00	353.58

Appendix A3: Sieve Analysis Result for Cement – Total Sample Weight 500g

Sieve size (mm)	Wt. retained (g)	Percentage retained (%)	Percentage passing (%)
0.6	-	-	100
0.3	4.0	0.8	99.25
0.15	19.1	3.82	95.44
0.075	63.2	12.64	82.80
Pan	413.7	82.34	0.40 loss
Total	500		

Appendix A4: Sieve Analysis Result for Rice Husk Ash (RHA) – Total Sample Weight 500g

Sieve size (mm)	Wt. retained (g)	Percentage retained (%)	Percentage passing (%)
212	0	0	100
150	20	6.5	89.5
100	32.5	3.82	95.44
75	67.2	13.44	76.06
Pan	380.3	76.06	0
Total	500		

Appendix A5: Computation of Moisture Content for Fine Aggregate

Can number	**Z_{25}**	**Z_{20}**
Weight of wet sample + container (W_1)g	43.5	44.5
Weight of oven dry sample + container (W_2)g	43.0	44.0
Weight of container (W_3)g	24.5	23.0
Weight of moisture (W_1-W_2)g	0.5	0.5
Weight of dry sample(W_2-W_3)g	18.5	21.0
$MoistureContent = \frac{(W_1 - W_2)}{(W_2 - W_3)} X100$ (%)	2.7	2.38
Average M.C (%)	**2.54**	

Appendix A6: Computation of Moisture Content for Coarse Aggregate (Bida Natural Stone)

Can number	**Z_{25}**	**Z_{20}**
Weight of wet sample + container (W_1)g	52.5	55.0
Weight of oven dry sample + container (W_2)g	50.5	53.5
Weight of container (W_3)g	20.5	19.0
Weight of moisture (W_1-W_2)g	2.0	1.5
Weight of dry sample(W_2-W_3)g	30.0	34.5
$MoistureContent = \frac{(W_1 - W_2)}{(W_2 - W_3)} X100$ (%)	6.667	4.348
Average M.C (%)	**5.51**	

Appendix A7: Computation of Specific Gravity for Fine Aggregate

Details	**TEST A**	**TEST B**
Weight of cylinder (W_1)g	286.50	262.60
Weight of cylinder + sample (W_2)g	486.00	461.50
Weight of cylinder + sample + water (W_3)g	808.00	776.00
Weight of cylinder + water (W_4)g	684.00	651.50
$specificgravity = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$	2.64	2.66
Average specific gravity	**2.65**	

Appendix A8: Computation of Specific Gravity for Coarse Aggregate

Details	**TEST A**	**TEST B**
Weight of cylinder (W_1)g	286.5	262
Weight of cylinder + sample (W_2)g	486.5	462.5
Weight of cylinder + sample + water (W_3)g	809.5	776.5
Weight of cylinder + water (W_4)g	684	651.5
$specificgravity = \dfrac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$	2.69	2.66
Average specific gravity	**2.68**	

Appendix A9: Computation of Specific Gravity for Rice Husk Ash (RHA)

Details	**TEST A**	**TEST B**
Weight of cylinder (W_1)g	213.27	213.77
Weight of cylinder + sample (W_2)g	251.35	243.88
Weight of cylinder + sample + water (W_3)g	501.23	486.74
Weight of cylinder + water (W_4)g	489.26	473.95
$specific\ gravity = \dfrac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$	1.99	1.74
Average specific gravity	**1.87**	

Appendix A10: Computation of Specific Gravity for Bone Powder Ash (BPA)

Details	**TEST A**	**TEST B**
Weight of cylinder (W_1)g	215.27	213.77
Weight of cylinder + sample (W_2)g	309.66	313.87
Weight of cylinder + sample + water (W_3)g	534.73	531.37
Weight of cylinder + water (W_4)g	476.26	473.95
$specific\ gravity = \dfrac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$	2.63	2.35
Average specific gravity	**2.49**	

Appendix A11: Computation of Bulk Density for Fine aggregate

Details	1	2	1	2
	Uncompacted		Compacted	
Weight of mould (W_1)kg	0.0475	0.0465	0.0475	0.0465
Weight of mould + sample (W_2)kg	0.641	0.666	0.692	0.71
Net weight M_{net} = ($W_2 – W_1$)kg	0.5935	0.6195	0.6445	0.6635
Volume of mould M^3	0.000376	0.0004	0.00038	0.00064
$Bulk\ density = \frac{M_{net}}{V} kg/m^3$	1578.46	1541.05	1714.1	1650.5
Average bulk density Kg/m^3	**1559.75**		**1682.3**	

Appendix A12: Computation of Bulk Density for Coarse aggregate

Details	1	2	1	2
	Uncompacted		Compacted	
Weight of mould (W_1)kg	0.0474	0.0465	0.0475	0.0465
Weight of mould + sample (W_2)kg	0.6185	0.617	0.6595	0.677
Net weight M_{net} = ($W_2 – W_1$)kg	0.571	0.5705	0.612	0.6305
Volume of mould M^3	0.000376	0.0004	0.00038	0.0004
$Bulk\ density = \frac{M_{net}}{V} kg/m^3$	1518.62	1419.15	1627.66	1568.41
Average bulk density Kg/m^3	**1468.89**		**1598.04**	

Appendix A13: Computation of Aggregate Impact Value (AIV)

Detail	TEST A	TEST B
Weight of mould + aggregate (W_1)g	1010	1015
Weight of mould (W_2)g	686	686
Weight of aggregate (W_1-W_2)g	324	329
Weight of passing sieve 236mm (W_3)g	136.5	142
$AIV = \frac{W_3}{(W_1 - W_2)} X100$ (%)	42.13	43.16
Average aggregate impact value (%)	**42.645**	

Appendix A14: Computation of Aggregate Crushing Value (ACV)

Detail	TEST A	TEST B
Weight of mould + aggregate (W_1)g	3604.5	3604
Weight of mould (W_2)g	2691	2691
Weight of aggregate (W_1-W_2)g	913.5	913
Weight of passing sieve 236mm (W_3)g	379.77	438.5
$AIV = \frac{W_3}{(W_1 - W_2)} X100$ (%)	41.57	48.03
Average aggregate impact value (%)	**44.8**	

Appendix B: Computation of Compaction Factor for Rice Husk Ash and Bone Powder Ash

Appendix B1: Computation of Compaction Factor for Rice Husk Ash (RHA)

Detail	Control 100% Cement	95% 5%RHA	90% 10%RHA	85% 15%RHA	80% 20%RHA	75% 25% RHA
Partly Compacted	10.305	9.985	8.885	9.585	8.685	7.785
Fully Compacted	11.88	11.785	11.485	10.585	10.585	9.685
Compaction Factor	0.8674	0.8388	0.8205	0.8111	0.8038	0.7736

Appendix B2: Computation of Compaction Factor for Bone Powder Ash (BPA)

Detail	Control 100% Cement	95% 5%BPA	90% 10%BPA	85% 15%BPA	80% 20%BPA	75% 25%BPA
Partly Compacted	10.305	9.985	10.785	9.585	9.485	8.985
Fully Compacted	11.88	11.785	11.785	11.485	11.285	10.985
Compaction Factor	0.8674	0.8473	0.8405	0.8346	0.8179	0.8152

Appendix B3: Computation of Slump Test for Rice Husk Ash (RHA)

Detail	Control 100% Cement	95% 5%RHA	90% 10%RHA	85% 15%RHA	80% 20%RHA	75% 25% RHA
Slump Value (mm)	12	10	5	0.00	0.00	0.00

Appendix B4: Computation of Slump Test for Bone Powder Ash (BPA)

Detail	Control 100% Cement	95% 5%BPA	90% 10%BPA	85% 15%BPA	80% 20%BPA	75% 25%BPA
Slump Value (mm)	32	11	10	5	3	0.00

Appendix C-J: Results of Compressive Strength of Concrete Cubes

Appendix C: Results of Compressive Strength of Concrete Cubes (N/mm^2) with various dosages of Rice Husk Ash (RHA) at 7 days curing period

Percentage Replacement (%)	Wt (kg)	Av. Wt (kg)	Load (KN)	Av. load (KN)	Density (kg/m^3)	Failure stress (N/mm^2)
	8.365		354.25		2478.52	
0%	8.530	8.462	334.4	328.8	2527.41	14.61
	8.490		297.86		2515.56	
	8.095		275.59		2398.52	
5%	8.115	8.172	305.27	295.98	2404.44	13.16
	8.305		307.09		2460.74	
	7.570		246.46		2242.96	
10%	8.190	7.722	203.06	247.28	2426.67	10.99
	7.405		293.31		2194.07	
	8.335		210.88		2469.63	
15%	7.310	7.523	164.55	169.98	2165.93	7.56
	6.925		134.54		2051.85	
	7.665		99.5		2271.11	
20%	7.635	6.947	67	101.17	2262.22	6.94
	7.460		137		2210.37	
	7.170		99.5		2124.44	
25%	6.815	6.947	67	101.17	2019.26	4.50
	6.855		137		2031.11	

Appendix D: Results of Compressive Strength of Concrete Cubes (N/mm^2) with various dosages of Rice Husk Ash (RHA) at 14 days curing period

Percentage Replacement (%)	Wt (kg)	Av. Wt (kg)	Load (KN)	Av. load (KN)	Density (kg/m^3)	Failure stress (N/mm^2)
	8.1		332		2400.00	
0%	8.5	8.3	474	426.00	2518.52	18.93
	8.3		472		2459.26	
	8.2		443		2429.36	
5%	7.8	8.1	339	406.00	2311.11	18.04
	8.3		436		2459.26	
	7.9		360		2340.74	
10%	7.8	7.9	296	333.33	2311.11	14.81
	7.9		344		2340.74	
	7.6		196		2251.85	
15%	7.2	7.5	220	210.67	2133.33	9.36
	7.8		216		2311.11	
	8.1		340		2400.00	
20%	7.3	7.6	96	201.33	2162.96	8.95
	7.5		168		2222.22	
	7.2		174		2133.33	
25%	7.5	7.3	166	158.67	2222.22	7.05
	7.3		136		2311.11	

Appendix E: Results of Compressive Strength of Concrete Cubes (N/mm^2) with various dosages of Rice Husk Ash (RHA) at 21 days curing period

Percentage Replacement (%)	Wt (kg)	Av. Wt (kg)	Load (KN)	Av. load (KN)	Density (kg/m^3)	Failure stress (N/mm^2)
	8.5		386		2518.52	
0%	8.2	8.37	480	437.00	2429.63	19.42
	8.4		445		2488.89	
	8.2		426		2429.63	
5%	8.1	8.13	428	426.00	2400.00	18.93
	8.1		424		2400.00	
	8.4		394		2488.89	
10%	7.6	8.00	314	341.00	2251.85	15.17
	8.0		316		2370.37	
	7.3		256		2162.96	
15%	7.2	7.43	204	215.33	2133.33	9.57
	7.8		186		2311.11	
	7.6		344		2251.85	
20%	7.6	7.57	174	205.33	2251.85	9.13
	7.5		98		2222.22	
	7.9		182		2340.74	
25%	7.5	7.60	176	166.67	2222.22	7.41
	7.4		142		2192.59	

Appendix F: Results of Compressive Strength of Concrete Cubes (N/mm^2) with various dosages of Rice Husk Ash (RHA) at 28 days curing period

Percentage Replacement (%)	Wt (kg)	Av. Wt (kg)	Load (KN)	Av. load (KN)	Density (kg/m^3)	Failure stress (N/mm^2)
	8.4		594		2488.89	
0%	8.2	8.20	591	591.33	2429.63	26.28
	8.0		589		2370.37	
	8.0		487		2370.37	
5%	8.2	8.10	490	492.67	2429.63	21.89
	8.1		501		2400.00	
	8.3		403		2459.26	
10%	7.9	8.10	398	396.33	2340.74	17.61
	8.0		388		2370.37	
	7.8		289		2311.11	
15%	7.4	7.70	267	254.67	2192.59	11.32
	7.9		208		2340.74	
	7.7		299		2281.48	
20%	7.6	7.6	189	220.00	2251.85	9.78
	7.5		172		2222.22	
	7.6		181		2251.85	
25%	7.4	7.50	119	158.67	2192.59	7.05
	7.5		176		2222.22	

Appendix G: Results of Compressive Strength of Concrete Cubes (N/mm^2) with various dosages of Bone Powder Ash (BPA) at 7 days curing period

Percentage Replacement	Wt (kg)	Av. Wt (kg)	Load (KN)	Av. load (KN)	Density (kg/m^3)	Failure stress (N/mm^2)
	8.095		275.59		2398.52	
0%	8.115	8.172	305.27	295.98	2404.44	13.16
	8.305		307.09		2460.74	
	8.125		378.09		2407.41	
5%	8.870	8.593	240.67	278.8	2628.15	12.48
	8.985		217.64		2662.22	
	8.658		189.96		2565.33	
10%	8.420	8.502	245.64	239.36	2494.81	10.64
	8.430		282.49		2497.78	
	8.585		246.02		2543.7	
15%	8.345	8.403	196.31	207.11	2472.6	9.21
	8.280		176.01		2453.33	
	8.190		218.02		2426.67	
20%	7.540	8.043	189.41	205.94	2234.07	9.02
	8.400		209		2488.89	
	7.835		138.07		2321.48	
25%	7.785	7.71	111.78	125.36	2306.67	5.57
	7.510		126.24		2225.19	

Appendix H: Results of Compressive Strength of Concrete Cubes (N/mm^2) with various dosages of Bone Powder Ash (BPA) at 14 days curing period

Percentage Replacement	Wt (kg)	Av. Wt (kg)	Load (KN)	Av. load (KN)	Density (kg/m^3)	Failure stress (N/mm^2)
	8.2		443		2429.63	
0%	7.8	8.10	339	406.00	2311.11	18.04
	8.3		436		2459.26	
	7.9		315		2340.74	
5%	8.5	8.13	298	316.00	2518.52	14.04
	8		335		2370.37	
	8.6		254		2548.15	
10%	8.4	8.30	338	268.00	2488.89	11.91
	7.9		212		2340.74	
	8.1		288		2400.00	
15%	7.5	7.93	263	256.33	2222.22	11.39
	8.2		218		2429.63	
	8.1		240		2400.00	
20%	7.9	7.93	215	223.33	2340.74	9.93
	7.8		215		2311.11	
	7.4		186		2192.59	
25%	7.2	7.47	164	174.67	2133.33	7.76
	7.8		174		2311.11	

Appendix I: Results of Compressive Strength of Concrete Cubes (N/mm^2) with various dosages of Bone Powder Ash (BPA) at 21 days curing period

Percentage Replacement (%)	Wt (kg)	Av. Wt (kg)	Load (KN)	Av. load (KN)	Density (kg/m^3)	Failure stress (N/mm^2)
	8.2		426		2429.63	
0%	8.1	8.13	428	426.00	2400.00	18.93
	8.1		424		2400.00	
	8.5		316		2518.52	
5%	8.0	8.27	458	342.00	2370.37	15.20
	8.3		252		2459.26	
	8.5		294		2518.52	
10%	8.3	8.28	276	283.33	2459.26	12.59
	8.1		280		2400.00	
	8.2		260		2429.63	
15%	7.9	8.10	258	258.00	2340.74	11.47
	8.2		256		2429.63	
	7.6		258		2251.85	
20%	8.0	7.70	212	231.33	2370.37	10.28
	7.5		224		2222.22	
	7.4		114		2192.59	
25%	7.7	7.57	168	175.33	2281.48	7.79
	7.6		244		2251.85	

Appendix J: Results of Compressive Strength of Concrete Cubes (N/mm^2) with various dosages of Bone Powder Ash (BPA) at 28 days curing period

Percentage Replacement (%)	Wt (kg)	Av. Wt (kg)	Load (KN)	Av. load (KN)	Density (kg/m^3)	Failure stress (N/mm^2)
	8.4		594		2488.89	
0%	8.2	8.20	591	591.33	2429.63	26.28
	8.0		589		2370.37	
	8.4		376		2488.89	
5%	8.2	8.37	450	375.00	2429.63	16.67
	8.5		299		2518.52	
	8.5		340		2518.52	
10%	8.4	8.30	312	315.67	2488.89	14.03
	8.0		295		2370.37	
	8.4		234		2488.89	
15%	8.2	8.13	288	261.00	2429.63	11.60
	7.8		261		2311.11	
	7.9		290		2340.74	
20%	7.9	7.97	209	237.67	2340.74	10.56
	8.1		214		2400.00	
	7.9		178		2340.74	
25%	7.7	7.67	160	197.33	2281.48	8.77
	7.4		254		2192.59	