COMPRESSIVE STRENTH OF RE-VIBRATED CONCRETE CONTAINING LOCUST BEAN EPICARP EXTRACT AND BIDA NATURAL STONES

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ABSTRACT

The compressive strength of re-vibrated concrete containing locust bean epicarp extract and Bida natural stone (BNS) as be presented. One hundred and sixty-eight concrete cubes were produced in six batches, in which twenty-eight cubes was produced in each of these batches. However, two of these batches were at 0% LBEE + 100% OPC and 100% LBEE + 100%OPC, the rest are at cement reduction content of 5, 10, 15 and 20% respectively but all the other concrete mix ingredients remained constant. The epicarp used was at a constant concentration of 0.1kg/l. The concrete mix adopted was 1 :2 :4 using ordinary Portland cement with water-cement ratio of 0.5. The preliminary result shows that the aggregate fall within the BS requirement. Concrete cubes were cast with re-vibration time lag intervals of 10minutes for the period of a 60minute re-vibration process and cured for 7 and 28days. When tested for their respective compressive strengths, the result obtained shows that there is an increase in compressive strength of the concrete with an increase in re-vibration time lag. The result also shows that the introduction of LBEE increase the compressive strength of concrete produced despite cement reduction up to 20%. The maximum compressive strength for all batches at 28days curing is obtained at 60 minutes' re-vibration time interval for the concrete. The maximum attained compressive strength for 28days curing is 38.65N/mm^2 for C_2 (100% LBEE + 100% OPC) is higher than 34.42N/mm^2 for C_1 (0% LBEE+ 100% OPC). This indicates that the uses of LBEE have increased compressive strength of concrete when re-vibrated.

TABLE OF CONTENTS

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

GLOSSARY AND ABBREVIATION

LBEE	Locust Bean Epicarp Extract
BNS	Bida Natural Stone
OPC	Ordinary Portland Cement
G	Weight in Gram
Gs	Specific Gravity
ASTM	American Standard for Testing Materials
SGs	Specific Gravity of Sand
SGb	Specific Gravity of Bida Natural Stone
SGc	Specific Gravity of Cement
C_1	0% LBEE + 100% OPC
C_2	100% LBEE + 100% OPC
C_3	100% LBEE + 95% OPC
C_4	100%LBEE + 90% OPC
C_5	100% LBEE + 85% OPC
C_6	100% LBEE + 80% OPC

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Innovators throughout the construction industry are making great strides towards increased environmental sustainability by updating processes, improving designs, and selecting greener materials. These aspects of modernization are both a response to demand from building owners and operators and a necessary means to remain competitive by achieving higher-performing buildings and infrastructure. Concrete producers have systematically improved the performance of their products by finding and exploiting benefits that are unique to concrete production. The significant advances have included durable finishes, superior quality in wall components, the economy of industry includes addressing the greenhouse-gas emissions associated with Portland cement and further integrating the benefits of concrete materials into building functions and operations (Brett *et al.,* 2015).

However, the Nigeria government has launched a mortgage refinance scheme for the reconstruction of some parts of the country affected by insecurity. The ways out is to replace a proportion of cement in concrete production with cheap and available pozzolanic materials from agro-waste. The analysis of locust bean epicarp extract (LBEE) showed that the combination of its chemical constituents qualifies it as pozzolanic material. The degradation of the environment has paused a serious challenge for an expert to embark on researches toward the possible ways of recycling these wastes products in order to keep the environment safe and ecologically habitable. The transportation, construction and environmental industries have a great potential to recycle these large quantities of agro-waste. The locust bean epicarp extract which is also pozzolanic materials contain siliceous oxide, aluminous oxide and iron oxide as the constituent materials. The locust bean epicarp extract is a bye product of African locust bean fruit and considerable quantities can be found across Northern Nigeria during the harvest season. The locust bean epicarp which is an agro-waste obtained from the fruit of African locust bean tree (*parkin Biglobsa*) is the material required for the -production of locust bean epicarp extract (LBEE). The fruits are ripped opened while the yellowish pulp and seeds are removed from the pods, the empty cover are the needed raw materials.

Plate I: Locust Bean Fruit (Adama and Jimoh, 2011)

The epicarp make 39% of the weight of the fruit while the mealy yellowish pulp and seeds make up of 61% (Adama and Jimoh, 2011). In the northern part of Nigerian, the seeds of locust bean are used for food and it is popularly known as *Dawadawa.* The fruit is also sweet and can be consumed directly by people while the epicarp is used in making gums in the industries. (Aguwa and okafor 2012) reported that the seeds contain 54% fat and 30% protein in addition to vitamins and minerals such as Calcium, Potassium and Phosphorus. The epicarp and roots are used as sponges and as strings for musical instruments. The trees serve as windbreak and provide shade. The African locust bean tree; "*Parkia biglobosa*" is a perennial tree legume, belonging to the sub family Mimosodeae and family Leguminosae. (Auta *et al.*, 2015a) reported that the *Parkia biglobosa* is an important multipurpose tree from the savannah zone of West Africa. The plant increases soil fertility, grows to about 16m in height and has dark, evergreen, pinnate leaves. Its fruit is a brown, leathery pod of about 10 to 30cm long and contains gummy pulp of an agreeable sweet taste, in which it bears number of seeds. The epicarp is often used in livestock feed. It has brought to notice that the bark of the plant can be used in the treatment of toothache; leprosy; fever and hypertension as well as wounds, ulcer and snake bites. The seeds are used extensively as a seasoning and also nutritious additives to soups and stews as well as good source of essential amino acids. The locust bean epicarp extract have a moisture-free basis, the fermented locust bean contains about 40 % protein, 32 % fat and 24 % carbohydrate (Okunola *et al.,* 2019). The locust bean seed produced by the *parkia* tree is embedded in a yellowish, sweet -tasting edible pulp. The epicarp, containing locust bean seeds, resembles that of a soya bean epicarp that starts out as a bright green and turns dry and deep brown as it matures on the tree. In the middle belt and the northern states of Nigeria, the epicarp is used in the rural areas in compaction of floor (Aguwa *et al.,* 2012).

The epicarp are collected and soaked in water for at least four days. The extract is the needed item that is used to cast the mud blocks for building purposes. At other hand, the epicarp is spread over mud fence and as soon as rain begins to fall on the epicarp, the leach percolates down into the mud fence. On further investigation, the natives or rural dwellers have simple evidence to show that buildings made of locust bean epicarp extracts are not attacked by termites in termites infested areas in comparison to those built without the epicarp extracts. These buildings and fence walls have been found to withstand different types of weather conditions such as rains, wind and heat over a long period. Hence this work sets out to study cementation nature of LBEE. The African locust bean (Parkia-biglobosa) has a wide distribution ranging across the Sudan and Guinea Savannas and the ecological zones. The range extends from the western coast of Africa in Senegal across to Sudan. It is found in nineteen African countries: Senegal, Gambia, Guinea Bissau, Guinea, Sierra Leone, Mali, Cote De Voir, Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria, Cameroon, Chad, Central Africa, Republic, Zaire, Sudan and Uganda. In Nigeria, it is predominantly found in the northern part of the country. Locust bean epicarp apart from being food is medicinal in relief of diarrhoea. The bark is boiled to make tea for the treatment of wounds and fever. Several authors have reported on its medicinal uses and treatments. Concentrated locust bean epicarp extract is used to impart water resiliency to floors, walls and ceramics pots. The tannins present in the husk act to bind the soil by their polymeric nature and render the surface impervious to water sealant to pot and create a dark, mottled surface. (Gernmah *et al., 2007*)

The waste agricultural biomass (WAB) which include rice husk, sawdust and locust bean epicarp usually pollute the environment where it is found in large quantities because it affects the environment in diverse ways, as such efforts should be made to find alternative ways and method for recycling this agro-waste and achieve environmental friendliness so that it can be economical to mankind (Adama and Jimoh, 2011).

For year running, a liquid extract had been obtained by soaking the epicarp husks of the locust tree fruits in water and usually reddish- brown. The local technology of extracting this liquid admixture from the locust bean epicarp husks has been commonly practice among the Nupe speaking tribe found in Niger, Kwara and Kogi state respectively. The extract was mainly used as a binding agent between locally manufactured clay tiles and the soil beneath in the construction of durable floor finishes for their room and the frontage of the rooms. The construction process involved the filling of the floor area with lateritic soil and compacted, the locust bean epicarp extract is then poured over the compacted surface at ordinary temperatures after which the clay tiles are spread over the wet floor and is further compacted to a firm finish using specially fabricated wooden rammers Some floors usually strengthened through this process (Adama and Jimoh, 2011).

Plate II: Locust bean epicarp husks on mud fence wall (Adama and Jimoh, 2011)

Bida natural stones are of different sizes and shape like the crushed granite, BNS contains impurities that will definitely affect the strength of resulting concrete therefore, locally source gravels need to be sieve and wash. (Shehu *et al.* 2016) reported that Granite materials have been found to be more suitable coarse aggregate as in the conventional concrete. Although, Bida natural stones have shown a tremendous performance in concrete works, there is information's on this material in the technology of self-compaction concrete. This research therefore is set to explore the strength of concrete using Bida natural stones (BNS) and locust bean epicarp extract (LBEE) instead processing granite and water.

Plate III: Bida natural stones (Shehu *et al.*, 2016)

1.2 Statement of the Research Problem

Shelter is one of most important needs of human being, as such, deficit of shelter in several or part of the world especially African countries including Nigerian which is under developed infrastructurally. The cost of construction materials (cement, crushed granite and sand) is high, however the attention should be shifted to the utilization of agricultural waste as a supplement for construction materials, and this will go a long way in reducing the cost of construction which at the same time will reduce environmental pollution as a result of these waste (Aguwa *et al.*, 2016). Research has shown that epicarp is an agricultural waste material which is proved to be pozzolanic in nature and can assist in the promotion of the concrete strength. The economy affects the type of coarse aggregate being used, generally crushed granite is usually more expensive than local gravel, because it has to undergo a more processes like blasting/crushing of the rocks before it can be used by consumer unlike local gravel which can be used without serious form of processing. The cost of processing granite is higher than that of locally sourced gravel (Gideon *et al.,* 2015). Bida natural stones are far cheaper than crushed granite, but provide lower strength as compared to the crushed granite. This Bida natural stones can be effectively improved by the method of re-vibration and addition of locust bean epicarp extract. The initial compaction of concrete may not totally eliminate defects, such as honey comb and voids leading to reduction in concrete strength and performance. But re-vibration eliminates defects (honey comb and voids) and thereby increasing the compressive strength of the concrete; improved concrete quality; increased bond; better permeability; reduction in shrinkage; creep reduction in the surface and other voids as well as cracks in hardened concrete (Auta *et al.,* 2015b).

It is on this note that this research is aimed at employing re-vibration and application of locust bean epicarp extract on concrete made using Bida natural stones as coarse aggregate.

1.3 Aim and objectives of the Study

The aim of this study is to determine the compressive strength of re-vibrated concrete containing Locust Bean Epicarp Extract (LBEE) and Bida natural stones (BNS).

The set objectives are to determine;

i. The chemical properties of LBEE, the physical and mechanical properties of aggregates.
ii. The workability of the fresh concrete made from locust bean epicarp extract and Bida natural stones
iii. The compressive strength of all categories of the concrete cube specimens.

1.4 Justification for the Study

The high rate of environmental pollution, resulting from the realised of an agricultural waste product has posed a serious problem to our environment and as such management of the waste needed to be employed. Waste management is an expensive venture and very serious issue as wastes (whether hazardous or non-hazardous, liquid or solid waste) if not properly managed, it exposes human health to danger. Wastes management is optimized when we can convert waste to treasure. Crushed granite stone is very expensive and it is not readily availability (especially in several desert region of the world) yet form a significant ingredient of the concrete. In fact, transportation help to push up the price considerable as the ingredient is not readily available in some part of the country. The cost of process granite is higher than that of locally sourced gravel (Gideon *et al.,* 2015). The overall granite require should be replace with locally sourced gravel and uses of locust bean epicarp extract with a substantial percentage reduction of cement and still achieve reasonable (compressive strength) of the concrete. The reduction of cement content lead to reduction of cost of production of this important construction material, thereby making it more affordable without compromised quality.

1.5 Scope of the Study

The scope of this study involves the collection of samples, characterizations of aggregate through sieve analysis, moisture content, bulk density, specific gravity, aggregate crushing value, (ACV) and aggregate impact value (AIV), determination of workability of the fresh concrete, production of 168 re-vibrated concrete cube specimen 150mmx150mmx150mm. And finally, determination of compressive strength of the re-vibrated concrete cube at 7 and 28days curing ages

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Background to the Study

The cost of manufacturing or producing the cement for construction is very high considering the factors of production that are involved such as raw materials, manpower, technological facilities and transportation. There arises the engineering consideration of the uses of cheaper and locally available materials to achieve the desired needs, which can help in self-efficiency and leading to an overall reduction in the cost of construction. Agricultural and industrial wastes may constitute the environmental pollutants if not properly controlled and converted into construction materials. These wastes include locust bean pods, saw dust, rice husk, slag, fly ash. In buttressing this (Oyekan *et al.,* 2011) stated that the profitable use of these agro-waste materials in an environmentally friendly manner will be a great solution to what is known as pollution.

Over the past decades the additions of mineral admixture to concrete mixture have been observed to significantly improve the strength, durability, workability of fresh concrete. The mineral admixtures can be extracted from agricultural and industrial wastes. They include locust bean epicarp extract (LBEE), saw-dust, rice husk ash and other types of agricultural waste ash. (Aguwa and Okafor, 2012) investigated the use of LBEE in determining the compressive strength of lateritic and sandcrete blocks and observed that it improves the strength of the block by 78.5%. The uses of agricultural waste material as an alternative to cement in construction industry and a desire to both short- and long-term stimulant for the socio-economic development and also to impart significant improvement on the strength, durability and workability of fresh concrete.

The need for locally produced, cost effective building materials in the developing countries such as Nigeria cannot be overemphasized due to the imbalance between the demand for housing and the expensive conventional building materials. Shelter is one of the basic needs of man and the means of possessing it is farfetched in this country especially among the teaming low-income earners. The over dependence on the utilization of Sandcrete blocks for buildings have kept the cost of these blocks as walling units in buildings financially high. This hitherto, has continued to deter the underdeveloped and the poor nations of the world from providing houses for their rural dwellers who constitute the higher percentage of their populations and are mostly agriculturally dependent (Aguwa *et al.,* 2016). The cost of procuring concrete materials for construction works have over the years constrained the users to compromise the require standard. Hence, it is exigent to carry out research on the available local waste materials that will partially or fully substitute costly conventional materials (Aminulai *et al*., 2013). Numerous results have been achieved in this regards, and the subject is attracting attention due to functional benefits of recycling and suitability in concrete work. Reduction in construction costs and the ability to produce lightweight structures are added advantages.

2.2 Concrete

Concrete is the most important building material playing part in all building structures. It is useful, durable and can resist fire when the specification and construction procedures are correctly followed. The concrete has been described as one of the engineering materials mostly used in a building component such as slabs, beams columns, staircase, foundation, dams and retaining wall. However, concrete is the most versatile composite construction materials and impetus of infrastructural development of any nation of the world. Civil engineering expert and the construction work around the world depend to a very large extent on concrete production. Further research show that concrete is a synthetic construction material made by mixing cement, fine aggregate, coarse aggregate and water in the right and specified proportion (Shetty, 1982). Each of these components contributes to the strength development of the concrete. Therefore, the overall cost of concrete production depends largely on the cost and the availability of the constituent materials.

Concrete consist mainly of three materials which are cement, aggregates (coarse and fine) and with addition mineral known as admixtures. Admixture is sometimes added to modify some of the concrete properties. The cement is brought into effective reaction when mixed with water after mixing. It improves the durability of the concrete and concrete can either be fresh green or hardened concrete (Shetty, 1982).

At the earlier stage of concrete development, it was believed that aggregates were chemically inert and held together by cement. But modern technology proves that aggregates exhibits chemicals bond at the interface of aggregate and paste (Nwokoye *et al*., 2016). Aggregate is such important matter in concrete that maximum properties and workability of concrete are directly changed with the properties of aggregate. Density of concrete is determined by the aggregate density, the aggregate with poor properties produce weak concrete with low wear resistance. That is why the overall or mechanical properties of concrete depends on the certain properties of aggregate like source of aggregates, normal, types aggregate, size of aggregate and shape of aggregate (Nwokoye *et al*., 2016)

Basically, there is a remarkable difference between the strength of mortar and that of concrete of the same mix proportion (about three times the strength of mortar). This is mainly because of the presence of coarse aggregate in concrete. The fine and coarse aggregates generally occupy larger percentage of the volume of the concrete (70% to 85% by mass) and strongly influence the concrete's freshly mixed with other concrete material and has a major role to play in the hardened strength of the concrete (Gideon *et al.*, 2015).

Concrete is a man-made composite, a major constituent of which is natural aggregate such as gravel and sand or crushed rock. Alternatively, artificial aggregate such as blast furnace slag, expanded clay, broken bricks and steel shots may be used where appropriate (Alhaji *et al.*,2019). There has been an alarming increase in resources depletion and global pollution which posed a major challenge in the country. A comprehensive and rational design of concrete mixes is influenced by numerous factors which depend upon the sources of materials and their properties, method of preparation, placement, compaction, curing of concrete and the requirements of a construction job. For an aggregate from a particular source having a specific gravity, the optimum design of a concrete mix involves selection of proportions of ingredients that yield concrete of the desired workability, strength and durability at minimum cost (Aminulai *et al.*,2013).

Concrete is essential material in structural and used for wide variety of purpose including

(a) Foundation and structural element,

(b) Walling and cladding element,

(c) Light weight material for insulation.

(d) Construction of walk ways, road. Piers and bridges, airfield, water retaining Structures, building, toxic and shielding structures.

Special concrete properties will therefore be required to meet some special purposes. It follows therefore that various properties of concrete will be of interest to the engineer. These properties include strength at various ages and ultimate strength, density, permeability, durability, ability to resist various salts and other chemical attacks. Their relative importance depends on the condition to which the concrete will be subjected to.

2.2.1 **Properties of fresh concrete**

The knowledge about the property of fresh concrete enable us to study the behaviour of the concrete in its hardened state and adjust them accordingly in order to obtain the desired results. The different properties of fresh concrete are explained below.

a) Workability of fresh concrete is the property of concrete, which determines the ease and the homogeneity with which it can be mixed, placed, compacted and finished

b) Segregation of fresh concrete; is the process of separation of the constituent particles. A good concrete is one in which all the ingredients of the concrete are properly distributed in order to make a homogeneous mixture.

c) Bleeding of fresh concrete; its p rocess in which some of the water from the concrete comes out of the surface of the concrete

d) Compatibility of fresh concrete; is the ease with which the concrete can be compacted.

e) Mobility; the property of fresh concrete to flow in to formwork around the steel reinforcement without occurrence of segregation or bleeding.

f) Consistency; refers to the fineness of the concrete or the ease with which it flows.

2.2.2 **Properties of hard concrete**

The properties of hard concrete are stated below

a) Strength

b) Deformation

c) Durability

d) Permeability

e) Shrinking

2.3 **Aggregates**

The water and cement paste hardens and develop strength over time, in order to ensure an economical practical solution for both fine and coarse aggregate, the production of concrete with sand, natural gravel or crushed stones are used for manufacture of the concrete. For the civil engineering work, aggregates are selected for its ability to meet the specific project requirements, rather than their geological history. The physical and chemical properties of the aggregate determine the acceptability of aggregate source for the construction project. These characteristics vary within the quarries or gravel pits, making it necessary to sample and test the materials continually as the aggregates are being produced. Due to the quantity of aggregate require for the typical civil engineering application, the cost and the availability of the aggregate are important when selecting an aggregate source.

One of the primary challenges facing the materials engineer on a project is how to use locally available material in most cost-effective manner. Economy also affect the types of coarse aggregate used. Generally, granite is usually more expensive than Bida natural stones because it has to undergo a more processes like blasting or crushing of the rocks before it can put to use by the consumer unlike the Bida natural stones which can be used at source without any form of processing. The cost of processing granite is higher that of locally sourced gravel (Shehu *et al.* 2016). The extensive research findings have advocated the use of locally-available materials to reduce the cost of infrastructure systems and thereby making building affordable to the middle and low–class residents. Hence any advocacy for the complete new or blended materials should be tested both structurally and mechanically to ascertain the short and long-time behaviours of the structure-. This will certainly help to establish a well-define boundary or clearly spelt out limitation especially when the local code of practice for the design, construction and workmanship is yet to be published for Engineers and builders (Gideon *et al.,* 2015). The ever-increasing population calls for the need to source for alternative coarse aggregates suitable for use in concrete as the quarry locations are not always close to the construction sites. Since the coarse aggregate accounts for the largest proportion of concrete, a research on locally available gravel with the satisfactory engineering properties is important (Yusuf *et al.,* 2020). Previous research reported that the poor choice of aggregate reactive, unsound and unsuitable aggregates is part of the causes of building failure.

Aggregates either locally or process one makes up or occupy 60% to 70% of concrete volume making its selection highly important. Aggregate should consist of particles with adequate strength and resistance to exposure condition and should not contain materials that will cause deterioration of concrete. (Abdullahi, 2012). The major coarse aggregate used in the production of concrete in Nigeria is crushed granite. Although other natural aggregates such as river gravel and naturally occurring stone deposits have been utilised in the production of concrete in different regions of the world and particularly in Nigeria (Yusuf *et al.,* 2020).

2.3.1 **Properties of aggregate**

The properties of aggregate determine selection of aggregate for concrete, the aggregate whose properties are satisfactory were mostly used for concrete production. The properties of the aggregate are classified into physical, mechanical and thermal properties (Neville, 2011)

(i) Particle shape and surface texture, the shape and surface texture of aggregate particle determine how the material will pack into a dense form and also determine the mobility of the stones within the mix. The roughness of the aggregate surface plays an important role in the way aggregate compacts and bonds with the binder material. Aggregate with a rough texture is more difficult to compact into a dense configuration than smooth aggregate. Rough texture generally improves bonding and increase interparticle friction. In general, natural gravel and sand have a smooth texture, whereas crushed aggregate has a rough texture.

(ii) Soundness and Durability; the ability of aggregates to withstand weathering is known as soundness or durability. Aggregates used in various civil engineering applications must be sound and durable, particularly if the structure is subjected to several climatic conditions.

(iii) Toughness of aggregate is the ability to resist the damaging effect of the loads, it is also related to the hardness of the aggregate. The aggregate must resist crushing, degradation and disintegration when stockpiled, mixed either Portland cement or asphalt concrete, placed and compacted and exposed to the loads.

2.4 **Cement**

Portland cement is the most common type of cement use general. it is a basic ingredient of concrete or mortar. It consists of a mixture of oxide such as calcium, silicon and aluminium. Portland cement is manufactured by heating limestone (source of calcium) with the clay and the grinded product is called clinker with a source of sulphide (commonly Gypsum). When mix with water the resulting powder will become a hydrated solid over time. Other types of

Portland cement are low heat Portland cement, extra-repaid harden Portland cement, high early strength cement.

The chemical compositions of cement are

Tricalcium Silicate. ($3Cao.SiO_2$)

Dicalcium Silicate. ($2Cao.SiO_2$)

Tricalcium Aluminate. ($3Cao.Al_2O_3$)

Tetra calcium Aluminate. ($4Cao.Al_2O_3.Fe_2O_3$)

2.4.1 **Types of Cement**

a) Ordinary Portland Cement

b) Portland Blast Furnace Cement

c) High Alumina Cement

d) Repaid Hardening Portland Cement

e) Low Heat Portland Cement

f) Coloured Cement

g) Sulphate Resisting Portland Cement

h) Air Entraining Portland Cement

a) Ordinary Portland Cement: Ordinary Portland cement is the most common type of cement having medium rate of strength development and heat dissipation in the course of hydration. It is suitable for normal concrete work.

b) Portland Blast Furnace Cement: Portland blast furnace cement has very similar property to ordinary Portland cement but evolves less heat and it is highly more resistant to chemical attack. It is made by grinding the mixture of cement clinker, gypsum and blast furnace slag in proper proportions and grinding it finely. This cement can be of benefit in marine works. Manufacture of Portland slag cement is aimed primarily at profitable utilizing blast furnace slag a waste product from the production of iron in blast furnace.

c) High Alumina Cement: it is manufactured by fusing together, a mixture of bauxite and limestone in the correct proportion and at high temperature. The resulting product is finely grounded. It develops strength rapidly; it is black and can resists chemical attack especially that of sulphate and sea-water. The ultimate strength is much higher than that of Portland cement. Its initial setting time is more than two hours. It is the most expensive of all cement. It is used extensively for refractory purposes.

d) Repaid Hardening Portland Cement: This cement gain strength faster than ordinary Portland cement. Its initial and final setting times are the same with that of ordinary Portland cement. It contains more tri-calcium silicate and more finely grounded. It gives out more heat while setting. It is used for a structure that will subjected to early loads like in the bridges and repair of roads.

e) Low Heat Portland Cement: Heat generation by the cement while setting may cause cracks in structures. In the case of concrete, heat generation is controlled by keeping the percentage of tri-calcium silicate low. Its initial and final setting times are nearly the same with that of ordinary Portland cement but the rate of strength development is very slow. It is commonly used in the construction of dams and other structure of mass concrete construction where there is danger of high temperature building up in the course of setting and hardening.

f) Coloured Cement: For architecture and visual presentation purposes particularly in tropical areas white concrete is sometimes used. For this purposes white or colour cement is used. It also used because of its low content of soluble alkalis so that straining is avoided. Colour cement is made from chain clay which contains little iron oxide and manganese oxide together with limestone free from specified impurities.

g) Sulphate Resisting Portland Cement: Sulphate resisting Portland cement is also similar to ordinary Portland cement but as the name implies, has a much higher resistance to sulphate attacks. In certain soils, there exist concentration of sulphate which cause the concrete made from ordinary Portland cement to crumble. Where such condition exists. The concrete in contact with the soil should be made with high alumina cement or sulphate resisting Portland cement.

h) Air Entraining Portland Cement: This is ordinary Portland cement mixed with small quantities of air entraining materials at the time of grinding. These materials have the property of air entraining in the form or air bubbles in concrete. These bubbles render the concrete more plastic, more workable and more resistance to freezing. However, because air is entrained and occupies some space meant for aggregate, the strength of such concrete and as such the quantity of air so entrained should not exceed five percent.

2.5 **Hydration of Cement**

Portland cement is the mixture of several compounds, all of which can hydrate with water, hydration being key for the strength development of the concrete. But all the compounds do not hydrate at the same rate, the rate of strength development being a function of time and temperature. The aluminates are the most reactive compound in cement and hydrate much faster rate than silicates (Mehta *et al., 2005*).

2.5.1 **Properties of hydration**

i) Setting refers to the stiffening of the cement paste or the change from plastic state to a solid state. Setting comes with strength. Setting is usually described by two levels which are initial setting and final setting time.

ii) Soundness of the cement paste refers to the ability to retain its volume after setting.

2.6 Water

Water is the most abundant chemical substance in the world and it covers 71% of the surface of the earth, it occurs inform of water vapour in the atmosphere which may be collect as a cloud and later come down to the earth inform of rain. It is also present below the earth. Water use in mixing the concrete must be proved to be fit for consumption. Water is used all over the world in vast quantities for drinking purpose, it is use in vast quantities for cooking, mixed concrete materials and raising steam to drive engines or turbine to generate electricity.

2.7 Compressive Strength of Concrete

Concrete mixture can be designed to provide a wide range of mechanical and durability properties to meet the design requirement of a structure. The compressive strength of the concrete is the most common performance measure used by the engineer in designing of structural components. The compressive strength is measured by crushing concrete cube specimen. The compressive strength is than calculated by dividing the failure loading by the cross-section area resisting the load and reported and recorded in a choosing unit that is newton or kilo newton.

2.8 Pozzolanic Admixtures

(Kourd *et al.*,2014) defined pozzolanic as an inert siliceous material which, in the addition of water, will combine with lime to produce a cementations matter with excellent structural properties.

Ancient Greeks and Romans used certain finely divided Siliceous material which when mixed with a lime produces strong cementation material with hydraulic properties. Such cement material was employed in the construction of Architectural work and Bridges.

Pozzolanic materials are siliceous and aluminous oxide that possess little or no cementations' value, but when in finely divided form and in the presence of moisture chemically reacts with calcium oxide liberated on hydration, at ordinary temperature to form compounds, possessing cementitious properties (Shetty, 1982).

Generally, amorphous silicate reacts much faster than the crystalline form. It is noted that calcium hydroxide, otherwise known as water-soluble material is converted into insoluble cementations material by the reaction of pozzolanic materials (Shetty, 1982). the reaction can be shown as follows;

a) Pozzolanic cementations reaction

Pozzolanic + calcium hydroxide + water C-SH this reaction involves the consumption of Ca $(OH)_2$. The reduction of Ca $(OH)_2$ improves the durability of cement paste by making the paste dense and impervious (Shetty 1982). Activity of pozzolanic is the capacity of pozzolanic to form alumina-silicates with a lime to form cementations products. Factors that affect the activity of Pozzolanic is;

1. SiO_2 + Al_2O_2 + $Fe_2O_:$ Equation show the sumination of composition of oxide of pozzolanic specified in ASTM C618.

2. Degree of amorphousness of its structure

3. Particles Fineness

Table 2.1 Chemical and Physical Requirement of Pozzolanic Source

Chemical Requirements	Mineral Requirements		
Silicon dioxide, Aluminum dioxide **and Iron oxide**	**N**	**F**	**C**
($SiO_2 + Al_2O_3 + Fe_2O_3$) Minimum %	70	70	50
Sulphur Trioxide (SO_3) Maximum %	4.0	5.0	5.0
Moisture content Maximum %	3.0	3.0	3.0
Loss on Ignition, Maximum %	10.0	6.0	6.0
Available Alkalis as Na_2O, Maximum %	1.5	1.5	1.5
Physical Requirements	34	34	34
Fineness, maximum % retained on 325-Mesh (44µm) sieves.			

(Source: ASTM Specification C618)

Table 2.1 give the typical oxide composition of different classes of pozzolanic as specified in ASTM C618

2.9 Use of Other Agricultural Biomass as Partial Replacement in the Construction Industry

2.9.1 Rice husk: Rice husk ash has been commonly used as a partial replacement of cement in concrete production. It is of the advantage that concrete should be prepared using agricultural waste as substitute, and the manufacture does not require special skills or machinery. It is suitable for rural and low-cost housing programmed and is highly pozzolanic and suitable for use in lime, pozzolanic mixes and for Portland cement replacement.

(Auta *et al.,* 2016) further stated that rice husk ash is produce by burning the rice husk under a controlled temperature and the atmosphere. The highly reactive rice husk ash is formed. Researchers have made these assertions of the possibility of replace cement in full or partial without compromising the standards guiding usage of such indigenous Cementous materials as rice husk ash which has been recently in use as partial replacement for cement (Auta et al., 2016).

2.9.2 Sugarcane bagasse: Bagasse ash is the product of sugarcane bark this is also use as a replacement of cement in concrete production. It is highly recommended for use in the production of lightweight concrete as its weight decreases with increasing quantity of the ash replacement. It can be recommended when low stress is required at reduced cost.

2.10 History and General Structure of Locust Bean Epicarp Tree

The African locust bean tree *(Parkiabiglobosa)* is a perennial tree legume, belonging to the sub-family Mimosodeae and family Leguminosae, (Auta *et al.,* 2015a), *Parkiabiglobosa* is an important tree from the savannah zone of West Africa. The plant increases the soil fertility, grows to about 16m in height and has dark, evergreen, pinnate leaves. Its fruit is brown, leathery epicarp of about 10 to 30cm long and contains gummy pulp of an agreeable sweet taste, in which lies a number of seeds. The epicarp is often used to feed livestock. It has brought to notice that the bark of the plant can be used in the treatment of toothache, leprosy, eye sores, fever, hypertension as well as wounds, and snake bites. The seeds are used extensively as a seasoning and also good source of essential amino acids (Auta *et al.,* 2015a).

The fruit analysed showed that the epicarp have moisture content of 8.43%, protein 6.58%, fat 1.82%, crude fibre 11.77%, ash 4.19% and carbohydrate of 67.32%. The locust bean seed produced by the parkia tree is embedded in a yellowish, sweet tasting edible pulp. The epicarps, containing locust bean seeds, look like that of a soya bean epicarp that starts out as a bright-green and turns dry and deep brown as it matures on the tree. The African locust bean has a wide distribution ranging across the Sudan, Guinea Savanna and the ecological zones. The range extends from the western coast of Africa in Senegal across to Sudan. It is found in nineteen African countries: Senegal, Gambia, Guinea Bissau, Guinea, Sierra Leone, Mali, Cote Devoir, Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria, Cameroon, Chad, Central Africa, Republic, Zaire, Sudan and Uganda. In Nigeria, it is predominantly found in the northern part of the country. Locust bean epicarps has a pH value of 6.10 indicating weak organic acid with a density of l0.98kg/m with a dark-brown in coloure. It has the following chemical composition the bark contains 12 – 14.2% of tannin while the husk contains 27- 44.4% of tannin.

(Campbell,1980) reported that Locust bean has a vitamin C per 100g of Locust bean epicarp. The pulp is a beneficial food source in the middle of the dry season with initial white colour turning to bright yellow as the epicarp matures.

Table 2.2 Chemical composition of locust bean epicarp extract (LBEE)

Chemical compositions of LBEE	Percentage (%)
Na_2O	1.21
K_2O	5.62
MgO	2.01
Pb_2O_5	5.82
Fe_2O_3	11.51
Al_2O_3	13.05
CaO	15.71
SiO_2	39.01
Losses on ignition (Lo1)	6.00

(Source: Adama, 2010)

Table 2.2 give the typical chemical composition of locust bean epicarp extract as pozzolanic material (Adama, 2010).

2.11 Locust Beans Epicarp Extract as a Replacement for Water in Concrete Production

The epicarp are usually measured in kilogram and soaked with a solvent (water) which have been identified as the best extractor. (Auta *et al.,* 2015a) state that the number of soaking days that give maximum strength in the production of concrete cubes is 4 days. The epicarp solution obtained after the required soaking days is used to mix the concrete in place of the ordinary distilled water. This is carried out at constant concentration of the epicarp extract which usually expressed in kilogram per litre. A lot of works has been done using the locust bean epicarp extract as a binder. (Aguwa and Okafor, 2012) report on uses of locust bean epicarp extract as a binder in the production of sandcrete block and found that locust bean epicarp extract can significantly increase the compressive strength of lateritic block by 78.56% and that the higher the concentration of the epicarp extract, the greater the compressive strength of lateritic blocks. All works carried out on the replacement of water with the locust bean epicarp extract have focused on the production of clay mud, sandcrete blocks and concrete cub using granite. But in this study locust bean epicarp extract (LBEE) and Bida a natural stone (BNS) was used in the production of concrete cubes at constant concentrations of 0.1kg/l to see possibilities of improving concrete strength. (Aguwa *et al*., 2016). investigate on high cost of Sandcrete blocks coupled with the low strength properties of commercially available Sandcrete blocks necessitates the need for alternative low-cost walling material. Sandcrete blocks are produced by mixing cement, sharp sand and water in a designed workable mix proportion, moulding into the desired sizes, finally watering and sun drying for some days to get the required strength.

2.11.1 Processing of locust bean epicarp extract

In the middle belt and Northern states of Nigeria, the epicarp are collected and soaked in water for at least 4 to 7days. The extract can also be obtained from leaching process of the epicarp through boiling that is extraction of soluble constituents from a solid by means of solvent, for example extraction of sugarcane or beets, so also binding materials can be leached out from locust beans epicarp through boiling. The leach process was at constant concentration of 0.1kg/litre (Aguwa *et al*., 2016).

2.12 Re- vibration of Concrete

(Abbas, 2017) report on the repeated operation of vibration of the fresh concrete after a period, which is called re-vibration, which may be beneficial to improve the properties of concrete especially when successive layer of fresh concrete was placed and the upper layer of fresh concrete was partially hardened. Re-vibration after time re-arranged the aggregate particles and eliminates entrapped water, which may improve the tensile strength, compressive strength and bond strength between the reinforcing bar and the concrete. Plastic shrinkage cracks for the exposed concrete can also be eliminated by the operation of re-vibration. Re-vibration affects significantly by the time duration of re-vibration. (Auta *et al.,* 2015b) investigate on Effect of Re-vibration on the compressive strength of 56-aged RHA - cement concrete. They reported that vibration of concrete has play a major role on the strength and quality of the concrete. It is also established that re-vibration can provide improved concrete-steel bond when compared with hand tapping with rod. (Auta *et al.,* 2015b) Re-vibration can be done usually at any time as long as the running internal vibrator can sink by its own weight into the concrete but not after the final setting time of the concrete. Re-vibration time lag is one of the major factors that can affect the compressive strength of concrete.

(Auta *et al*., 2016) investigate on the flexural strength of re-vibrated reinforced concrete beam with saw dust ash as partial replacement for cement. They tested seven beams of size 150 x

150 x 600 mm reinforced with 12 mm diameter steel bar. The beams were re-vibrated for 20 seconds at an interval of 10 minutes' successions up to one hour after initial vibration. They concluded that re-vibrated had improved the flexural strength of reinforced beams. (Auta *et al., 2015c)* investigate on the effect of water cement ratio on the compressive strength of re-vibrated concrete using mix ratio of 1:2:4 with 0.65, 0.70 and 0.75. Water cement ratio is a major factor that affect the compressive strength of concrete, whether with or without admixtures or with partial replacement for cement as case may be. However fresh concrete must be protected from further vibrations due to blasting, piling or very close or rail traffic once initial set has taken place from approximately 4hours to approximately one day. And further asserts that information is sparse on the level at which vibration become damaging, but indication is given by the peak particle velocity.

(Auta, 2011) investigated on the dynamic effect of re-vibration on the compressive strength of concrete using a mix ratio of 1:2:4. He observed that at successive time lag intervals of 5 minutes each for 60 minutes, there was an appreciable rise in the compressive strength of the concrete.

However, less is reported about the importance of re-vibration, the process in which a vibrator is reapplied to monolithic concrete at some time after initial vibration. Initial vibration of concrete may not totally eliminate defects, such as honey comb and voids leading to reduction in strength and performance of the concrete. But re-vibration eliminates defects (honey comb and voids) and thereby increasing the compressive strength of the concrete, improved concrete quality, increased bond, better impermeability, reduction in shrinkage and creep, reduction in surface and other voids as well as cracks in fresh concrete. The time of re-vibration and water cement ratio plays an important role in achieving a good re-vibration. But in this study the re-vibration time interval of 0, 10, 20, 30, 40, 50 and 60 minutes and mix ratio of 1:2:4 is considered.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Materials

The materials used for this concrete production are cement, water, fine aggregate, Bida natural stones and locust been epicarp.

3.1.1 Cement

Dangote cement is therefore employed. It was purchased and taken to the laboratory in 50kg sealed bags. The cement was properly store to avoid lumps. It is accordance to BS 12 of 1996

3.1.2 Fine aggregate

Fine aggregate was extracted from the abundant deposits which was collected around Gidan Kwano Minna. It was air-dried in the Civil Engineering laboratory before use to reduce excess moisture. It is in accordance BS 882.

3.1.3 Locust bean epicarp extract (LBEE)

The epicarp used was obtained from Kangi village and was pounded and soak in water for 4days and dissolved solution was then sieved to obtained the extract.

3.1.4 Water

Portable tap water supplied by the works department of the federal university of technology Minna, Gidan Kwano campus which is suitable for domestic use was used throughout the experiment especially for mixing and curing. Water is important in starting the reaction with cement in accordance to BS 3148 (BSI, 1980).

3.2 Methods

3.2.1 Moisture content (mc) test for fine aggregate

The test was carried out to ascertain the average natural moisture content for fine aggregate to be used

Apparatus: Electronic weighing balance, cans and oven.

The cans were weighed and recorded, W_1 is the weight of wet sample and container, W_2 is the weight of oven dry sample and container, W_3 is the weight of container. Therefore, weight of moisture is ($W_1 - W_2$) and weight of oven dry sample ($W_2 - W_3$), the moisture content of the aggregate will be calculated using the equation

$$MC = \frac{W1-W2}{W2-W3} \times 100\% \qquad (3.1)$$

3.2.2 Water absorption test for Bida natural stones

Test were carried out to ascertain the average water absorption for Bida natural stones using the following procedure

Apparatus: Electronic weighing balance, cans and oven.

The cans were weighed and recorded, W_1 is the weight of container, W_2 is the weight of wet sample and container, W_3 is the weight of container. And oven dry sample. Therefore, weight of dry sample is ($W_3 - W_1$) and increase in wet sample ($W_2 - W_3$), therefore water absorption of the aggregate was calculated using the equation

$$\text{Water absorption} = \frac{W2 - W3}{W3 - W1} \text{ X } 100\% \qquad (3.2)$$

3.2.3 Specific gravity test

The test was carried out to ascertain the specific gravity of both fine and Bida natural stones and average of value taken in each case.

Apparatus: electronic weighing balance, thermostatically controlled oven, rubber vessel, air-tight container and fine sand.

The plastic vessel was weighed empty as W_1. The vessel was then filled with appreciable sample of fine sand and weighed to obtain the weight of vessel plus sample as W_2. The vessel plus sample was partly filled with water and kept for 24 hours. After the 24 hours, the assembly was completely filled with water and weighed to obtain the weight of vessel plus sample plus water recorded as W_3. the vessel was then emptied and the saturated sample was surfaced dried. The vessel was then filled with water only and weighed to obtain the weight of vessel plus water recorded as W_4. The specific gravity

$$\text{Specific gravity} = \frac{W2 - W1}{(W4 - W2) - (W3 - W1)} \qquad (3.3)$$

3.2.4 Bulk density

Bulk density can be defined as the weight of aggregate required to fill a container of a giving volume. It can also be considered to be the measure of how dense or closely packed a sample is.

a) Bulk Density of Sharp Sand (fine aggregate)

The cylindrical moulds were cleaned, weighed empty and recorded as w_1. It was later filled with the fine aggregate sample, levelled off with a straight edge and weighed and recorded as w_2 for the uncompacted test.

The cylindrical mould was then filled in three layers each subjected to 25 blows of a standard tamping rod (16mm) the last layer was allowed to overflow the cylindrical measure and the surplus being struck off using a straight edge. The cylindrical measure plus the weight of the compacted aggregate was weighed and recorded as w_2 for the compacted test. The bulk density of the compacted and uncompacted test was calculated using equation (3.4).

b) Bulk Density of Bida natural stones (Coarse Aggregate)

The $1.69 \times 10^{-3} m^3$ cylindrical mould were weighed (w_1) and filled in three layers with each layer given 25 blows of the standard tamping rod (16mm). The last layer was allowed to overflow the cylindrical mould and the surplus being struck off using a straight edge. The weight of the cylindrical mould plus the compacted aggregate was weighed and recorded as w_2. The compacted bulk density was determined using the equation

$$\text{Bulk density} = \frac{\text{weight of sample}}{\text{volume of sample}} = \frac{W2 - W1}{V} \qquad (3.4)$$

Where: $V = l \times b \times d$

l = length of sample divider

b = breadth

d = depth

3.2.5 Aggregate Impact Value (AIV)

Test were carried out to ascertain the average aggregate impact value of Bida natural stones using the following procedure

W_1 is the weight of mould + aggregate, W_2 is the weight of mould and W_3 is the weight passing sieve 2.36mm. Therefore, the weight of aggregate (W_1-W_2) The aggregate impact value **(AIV)** was calculated. This is done in accordance BS 812 of 1990.

$$AIV = \frac{W3}{W1-W2} X\ 100\% \qquad (3.5)$$

3.2.6 Aggregate Crushing Values (ACV)

Test were carried out to ascertain the aggregate crushing values of Bida natural stones using the following procedure

W_1 is the weight of mould + aggregate, W_2 is the weight of mould and W_3 is the weight retained by sieve 2.36mm. Therefore, the weight of aggregate(W_1-W_2) The aggregate impact value **(AIV)** will be calculated using the equation

$$ACV = \frac{W3}{W1-W2} X\ 100\% \qquad (3.6)$$

3.3 Measurement for batching

The previous studies have confirmed that a water to cement ratio of 0.5 produces the optimum quality or compressive strength at mix of 1:2:4 (by weight batching) of concrete hence this water content of 0.5 was use throughout the batching. By using the scale balance for weighing, the batching was carried out by keeping all ingredients constant but at cement reduction content of 5, 10, 15 and 20%. A total of six (6) batches were casted with mix proportion by weight 1:2:4 and twenty-eight (28) cubes sample were cast from each batch. Twenty-eight cubes sample of each mix was test for compressive strength at 7 and 28days old of curing for the total of 168 cubes sample produced. The table 3.1 gives the weight in kg of each ingredient, in each batch C_1 to C_6 where batch C_1 is at (100% cement and 0%LBEE), C_2 is also at (100% cement and 100% LBEE), C_3 is at (95% cement and 100%LBEE), C_4 is at (90% cement and 100%LBEE), C_5 is at (85% cement and 100%LBEE) and C_6 is at (80% cement and 100%LBEE).

Table 3.1 Batching content of the mix

	Cement (kg)	Extract (Litre)	Water (kg)	Sand (kg)	Bida natural stones (kg)
C_1	32.3764	0.000	16.1883	64.7528	129.5056
C_2	32.3784	16.1883	0.0000	64.7528	129.5056
C_3	30.7576	16.1883	0.0000	64.7528	129.5056
C_4	29.1388	16.1883	0.0000	64.7528	129.5056
C_5	27.5199	16.1883	0.0000	64.7528	129.5056
C_6	25.9011	16.1883	0.0000	64.7528	129.5056
Total	178.0702	80.9409	16.1883	388.5168	777.0336

3.4 Method of mixing and preparation

Manual hand mix was used; it was done by spread the weighed fine aggregate on the mixing plate. The weighed cement was also then spread on it and thoroughly mix until the mixture is uniform grey in colour. The weighed Bida natural stones was evenly spread on the cement sand mixture. The weighed quantity of water was gradually pourer evenly on the cement aggregate mixture. The entire mixture was turn evenly with the hand-held shovel until a flowing concrete is achieve ready for placement. It is limited to six batches of concrete cubes specimen.

3.5 Workability test

The following tests were used as a measure of workability of concrete: compaction factor test and slump test

a) Compaction factor

The best method of measuring workability is inverse approach of the degree of compaction achieve by a standard amount of work done in achieving full compaction.

The degree of compaction, called the compaction factor, is measure by density ratio that, is the ratio of density actually achieve in the test to density of the same concrete fully compacted. The apparatus and associated equipment are clean before using it, for the test and keep off from hardened concrete. The sample of concrete to be tested should be placed in the upper hopper up to the brim. The trap-door is opened so that the concrete falls into the lower hopper. Then the trap-door of the lower hopper is opened and the concrete is allowed to fall into the cylinder. The excess concrete remaining above the top level of the cylinder is then trim off using a plane blade. The concrete is then filled exactly up to the top of the cylinder. It is weighed and recorded as the “weight of partially compacted concrete”.

The cylinder should be emptied and refilled with the concrete from the same sample in layers approximately 5cm deep. The layers will be heavily rammed so as to obtain full compaction.

The top of the fully compacted concrete is trimmed off and levelled with the top of the cylinder, weighed and recorded as “weight of fully compacted concrete.

$$\text{Compacting factor} = \frac{\text{weight of partially compacted concrete}}{\text{weight of fully compacted concrete}} \qquad (3.7)$$

b) Slump test

The slump test is a measure of workability of fresh concrete. Workability is the ease with which concrete can be compacted hundred percent having regard to mode of compaction and place of deposition. Slump test depends on the ingredients, amount of mixing water and addition of admixtures. The value of slump also changes with temperature and time after mixing.

Apparatus: slump metal cone, tamping rod, hand trowel, metal base plate and a steel ruler for slump measurement

The internal surface of the cone is thoroughly cleaned and freed from impurities before commencing the test. The cone was placed on a smooth, horizontal rigid and non-absorbent surface. The cone is then filled in three layers, in which each of the layers is tapped 25 times of a standard size of 16mm rod, with the tapped well distributed over the cross section. After the top layer has been rodded, the concrete is trimmed up with trowel. The cone is then removed from the concrete immediately by raising it slowly and carefully in a vertical direction. The difference in level between the height of the cone and that of highest point of subsided concrete is measured and recorded as the slump of the concrete.

3.6 Production of Concrete Cube Specimens

The batching was done in accordance with BS 1881of 1983. The following equipment was used in the concrete cube production: steel mould, metal base, steel rod, shovel and trowel. The mould was placed on a hard surface and filled with concrete in such a way that entrapped air can be easily removed and to produce full compaction concrete cube of size (150 x 150 x 150) mm to avoid excessive segregation. The concrete is placed in the mould in three (3) layers and compacted using tapping rod of 16mm diameter. Each layer is tapped 25 blows of the standard

16mm rod. The final layer of cube was smooth at the tip with use of hand trowel. They were allowed to set and harden for 24 hours before demould. They were transfer to curing tank fill with water where they will be cure for 7 and 28days. At end of 7and 28days curing, the cube was removed and compressive strength test were determined accordance to BS 1881 of 1983.

3.7 Curing of Concrete Cubes

The purpose of curing under wet conditions at a normal temperature is to keep the concrete saturated until the originally water filled space in the fresh cement paste has been occupied to the desired extent by the production of hydration of cement. This curing period will last for 7 and 28dayswhich is the curing ages to be considered for the purpose of this study; the curing of cubes is in accordance to BS 1881 of 1983.

3.8 Compressive Strength Test

The test was carried out in accordance to BS 1881 1983. The failure strength test of the cube was carried out using the electrically power testing machine in the concrete laboratory. Civil engineering department, federal university of technology Minna,168 cubes were caste and tested at7 and 28days and was taking for further analysis.

3.9 Mix Proportion of Concrete using Absolute Volume Method

The test is performed to obtain value of specific gravity of Bida natural stones s and fine aggregate which was used to obtain value of various ingredients require. (Yusuf et al., 2020).

$$\frac{W}{1000} + \frac{\mathrm{C}}{1000\mathrm{SGc}} + \frac{\mathrm{Fa}}{1000\mathrm{SGs}} + \frac{\mathrm{Ca}}{1000\mathrm{SGg}} - 0.05 = 1\mathrm{m}^3 \qquad (3.8)$$

Where; W= required quantity of water

C= Cement

Fa= required quantity of fine aggregate

Ca= required quantity of coarse aggregate

SGc= specific gravity of cement = 3.15

SGs= specific gravity of sand = 2.6

SGg= specific gravity of coarse = 2.68

Void space = 5%

Fine aggregate cement ratio is 2; F/C = 2

F = 2c (3.9)

Coarse aggregate cement ratio is 4; Coarse/c = 4

Ca = 4C (3.10)

Using a mix ratio of 1:2:4

$$\frac{0.5\mathrm{C}}{1000}+\frac{\mathrm{C}}{1000*3.15}+\frac{2\mathrm{C}}{1000*2.65}+\frac{4\mathrm{C}}{1000*2.68}-0.05=1\mathrm{m}^3$$

$$\frac{0.5\mathrm{C}}{1000}+\frac{\mathrm{C}}{3150}+\frac{2\mathrm{C}}{2650}+\frac{4\mathrm{C}}{2680}-0.05=1\mathrm{m}^3$$

$5.0 \times 10^{-4}C + 3.175 \times 10^{-4}C + 7.547\times 10^{-4} + 14.925\times 10^{-4}C = 1 + 0.05$

$3.0647\times 10^{-3}C = 1.05$

$$C = \frac{1.05}{3.0647\times 10-3}$$

C =342.611kg

Volume of mould; $0.15\times 0.15\times 0.15 = 3.375\times 10^{-3}\mathrm{m}^3$

$1m^3$ for342.611kg and 3.375×10^{-3} m^3 for Xkg

Xkg = 1.1563 of cement for a cube

Since 168 cubes is to be casted, the total quantity of cement requires before reduction of various percentage is 1.1563 x168 =194.2584kg.

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

For 100% cement and 100% portable water, 28 cubes will be casted; 28 × 1.1563kg = 32.3764kg

For 100% cement and 100% Epicarp/extract, 28 cubes will be casted; 28 × 1.1563kg = 32.3764kg

For 95% cement and 100% Epicarp/extract, 28 cubes will be casted at 5% cement reduction; $\frac{5}{100}\times 32.3764 = 1.6188$kg

The quantity of cement needed is 32.3764 – 1.6188 = 30.7576kg

For 90% cement and 100% epicarp/extract, 28 cubes will be casted at 10% cement reduction; $\frac{10}{100}\times 32.3764= 3.2376$kg.

The quantity of cement needed is 32.3764 -3.2376 = 29.1388kg

For 85% cement and 100% epicarp/extract, 28 cubes will be castedat15% cement reduction;

$\frac{15}{100}\times 32.3764 = 4.8565$kg

The quantity of cement needed is 32.3764 – 4.8565 = 27.5199kg

For 80% cement and 100% epicarp/extract, 28 cubes will be casted at 20% cement reduction;

$\frac{20}{100}$ × 32.3764 = 6.4753kg

The quantity of cement needed is 32.3764 – 6.4753 = 25.9011kg

Therefore, the total quantities of cement required is 32.3764 + 32.3764 + 30.7576 + 29.1388 + 27.5199 + 25.9011= 178.0702kg

The total quantity of cement requires before reduction is 194.2584kg since other materials remain constant.

The total quantity of fine aggregate required; 2 x 194.2584 = 388.5168kg

The total quantity of coarse aggregate required; 4 x194.2584= 777.0336k

The total quantity of water required; 0.5 x 194.2584 =97.1292kg

Since first control is at 100% cement and 100% potable water, therefore quantity of water require is 0.5 x 32.3764 = 16.1882kg.

Therefore, the quantity of water to be use to soak the epicarp is 97.1297 - 16.1882 = 80.9415kg

Then convert this quantity of water needed to soak epicarp from kilogram to litre, since we know mass and density of water require, Then the volume of water can be calculated

Using the formular below

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}} \qquad (3.11)$$

$$\text{Volume} = \frac{80.9415}{1000}$$

Volume = 0.0809415m^3

But

$1m^3$ = 1000Litre

$0.12691m^3$ = XLitre

Therefore

Xlitre = 0.0809415 x 1000

X = 80.9415Litre of water to be use to soak the epicarp

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

The result of the tests carried out on the chemical analysis of locust bean epicarp extract, physical and mechanical properties of aggregate and other ingredient for the production of the concrete were recorded. The result of the sieve analysis, moisture content, water absorption, aggregate impact value (AIV), aggregate crushing value (ACV) and bulk density of aggregate. Slump and compacting factor of the fresh concrete and finally the compressive strength test were also determining, discussed and compare. Thus comprehensive results are presented in Appendix.

4.2 Discussion of Result

4.2.1 Chemical properties locust bean epicarp extract

The result of chemical properties of locust bean epicarp extract qualify it as a pozzolanic material. Thus result presented in Table 4.1 show that summation of the Al_2O_3 + Fe_2O_3 + SiO_3

to be 66.908%, these value is above the minimum requirement of class C pozzolanic and have 50% has minimum percentage composition according to ASTM specifications C618 chemical and physical specifications (1991).

Table 4.1 Chemical Composition of LBEE

Element	Concentration
Na_2O	1.268Wt %
MgO	1.220Wt %
Al_2O_3	40.453 Wt %
SiO_2	15.845Wt %
P_2O_5	1.025 Wt %
K_2O	0.464Wt %
CaO	0.212 Wt %
TiO_2	0.597Wt %
Fe_2O_3	10.610 Wt %

4.2.2 Sieve Analysis of fine aggregate

The result in Fig 4.1 shows that the river sand contains particle sizes majority of which are smaller than 5mm and can be classified as fine aggregate based on BS 812 of 1985 classification. The sample used for experiment was properly air dried.

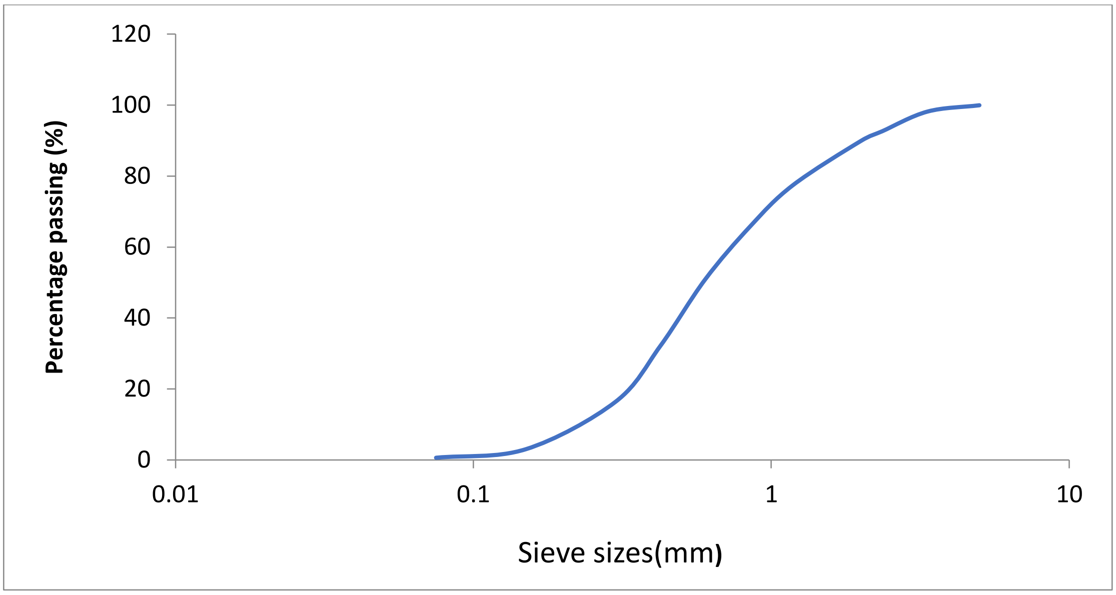

Figure 4.1: Sieve analysis of fine aggregate

4.2.3 Sieve analysis of Bida natural stones

The grading of Bida gravel is similar to that of crushed granite and the particle sizes falls under BS 812 of 1985 classification of coarse aggregate. It contains particles greater than 5mm based on the result in Fig 4.2 and 19mm sizes were selected for further experiment. Figure 4.2 shows that aggregates are well graded materials. These similar to that of (Yusuf *et al.,* 2020).

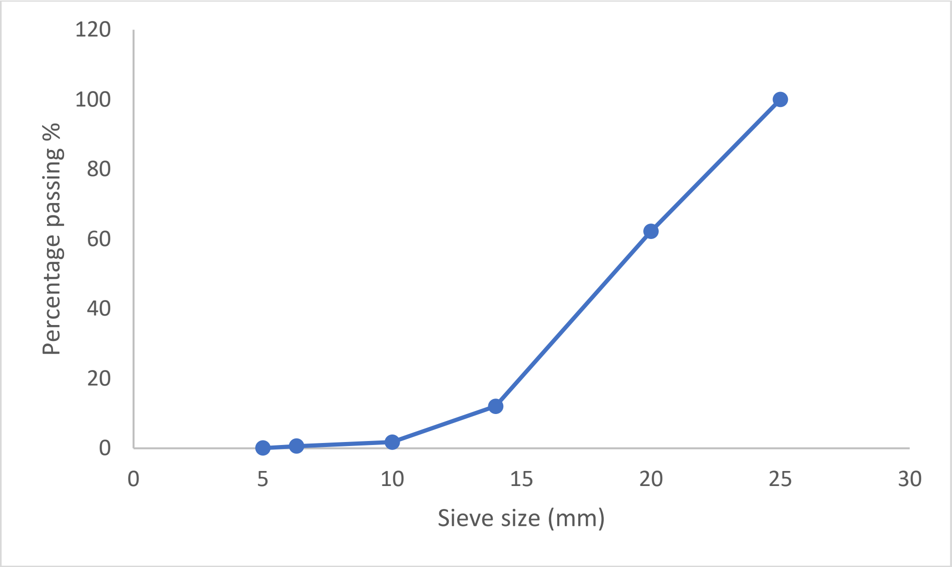

Figure 4.2: Sieve analysis of Bida natural stones

Table 4.2: 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)	16352	1568.13
Moisture Content (%)	6.54	5.51
Water absorption (%)	1.0	0.885

4.2.4 Physical properties materials

The result of other physical properties of aggregate are presented in table 4.2,

a) The average moisture content obtained for Bida natural stones is 5.51 % and that of fine aggregate is 6.54% respectively which are found to be within the BS 812: Part 109 (1990), 1 – 5% and 5 – 15% respectively.

b) The average specific gravity obtained for Bida natural stones is 2.68 and that of fine aggregate is also found to be 2.65. These values are in agreement with (BS 812 of 1995). requirement of 2.4 – 2.8 for coarse aggregate and 2.6 – 3.0 for fine aggregate respectively. Average water absorption capacity obtained for fine aggregate is 1.0% and Bida natural stones is 0.885% which are found to be within the standard range of 0.5 – 5% (BS 812 of 1995).

c) The average bulk density obtained for Bida natural stones was 1563.125kg/m^3 while that of fine aggregate is 1635kg/m^3 which fall within the standard range of 1300 – 1800kg/m^3 for Bida natural stones and 1500 – 1700kg/m^3 for fine aggregate respectively (BS 812 of 1995). d) The aggregate impact value was determined in accordance with standards BS 812: part 112 (1990). The slump test of fresh concrete was also determined in accordance with standards (BS EN 12350-2, 2000). Compacting factor of fresh concrete were determined in accordance with standards (BS 1881: Part 103, 1983).

4.2.5 Properties of fresh concrete mixes

a) Workability test:

All the mixes were prepared with a W/C ratio of 0.5 but the control mix of (0%LBEE + 100%OPC) has the slump of 9.0mm described as low slump according to BS (EN 12350 – 2, (2000). These mixes were partially stiff but workable to some extent. This is because the amount of water required to sufficiently lubricate aggregate surface to achieve high slump is in low range because Bida natural stone absorption move water and on introduction of LBEE shows that the pozzolanic nature of LBEE resulting continuous reduction in slump and concrete workability**.** The Compacting factor of fresh concrete were also determined in accordance with standards (BS 1881: Part 103, 1983).

4.2.5 Properties of hardened concrete

a) Compressive strength

The compressive strength of concrete at various re-vibration time intervals of 10minutes for 7 and 28 days of curing as be presented. While the graphical representation of the compressive strength of their respective ages are on Figures 4.3 and 4.4. It can be generally observed that compressive strength increases for all categories and control in accordance with standard BS 1881: part 116 (1983). The minimum compressive strength is obtained at 0minute re-vibration time for the 7days for all categories, the result show that despite cement reduction up to 20% and introduction of LBEE the compressive strength obtained matches and even surpasses that of control specimens of the same age. the result obtained is similar to that of (Auta, 2011) on dynamic effect of re-vibration. However, the maximum compressive strength is obtained at 60minute re-vibration time intervals for all categories of concrete produce. The compressive strength of concrete is generally increased as re-vibration time interval increase for all categories. The time of re-vibration process is observed for 60minute which is below the initial setting time of the concrete following that the compressive strength of re-vibrated concrete will be on the increase provided the re-vibration process is done within the initial setting time of the concrete thus enhancing the compressive strength of the concrete. The result also shows that the variation in compressive strength with non-re-vibrated concrete for 7 and 28days is up to 13.77% and 16.71% respectively.

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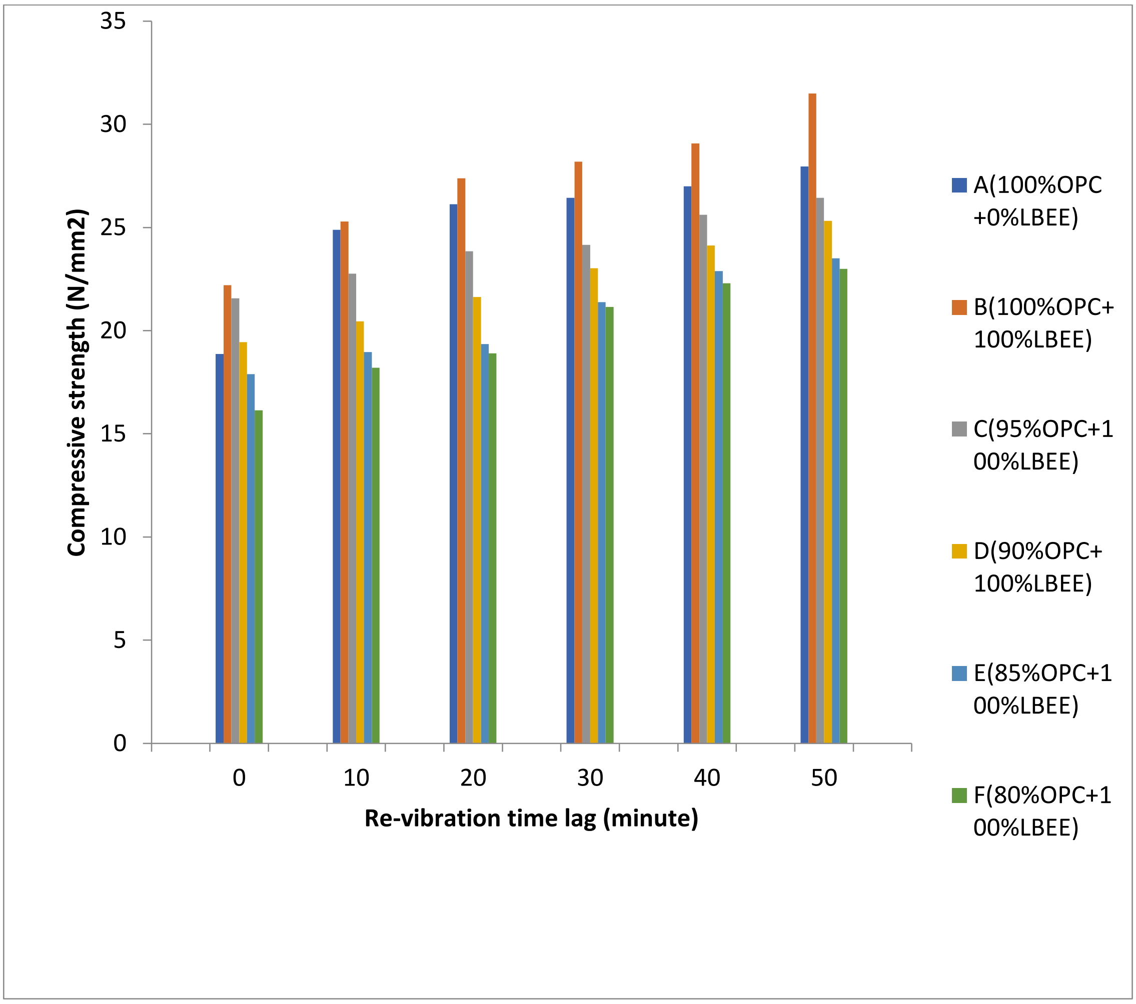

Figure 4.3: Compressive strength and re-vibration time lag for 7days curing

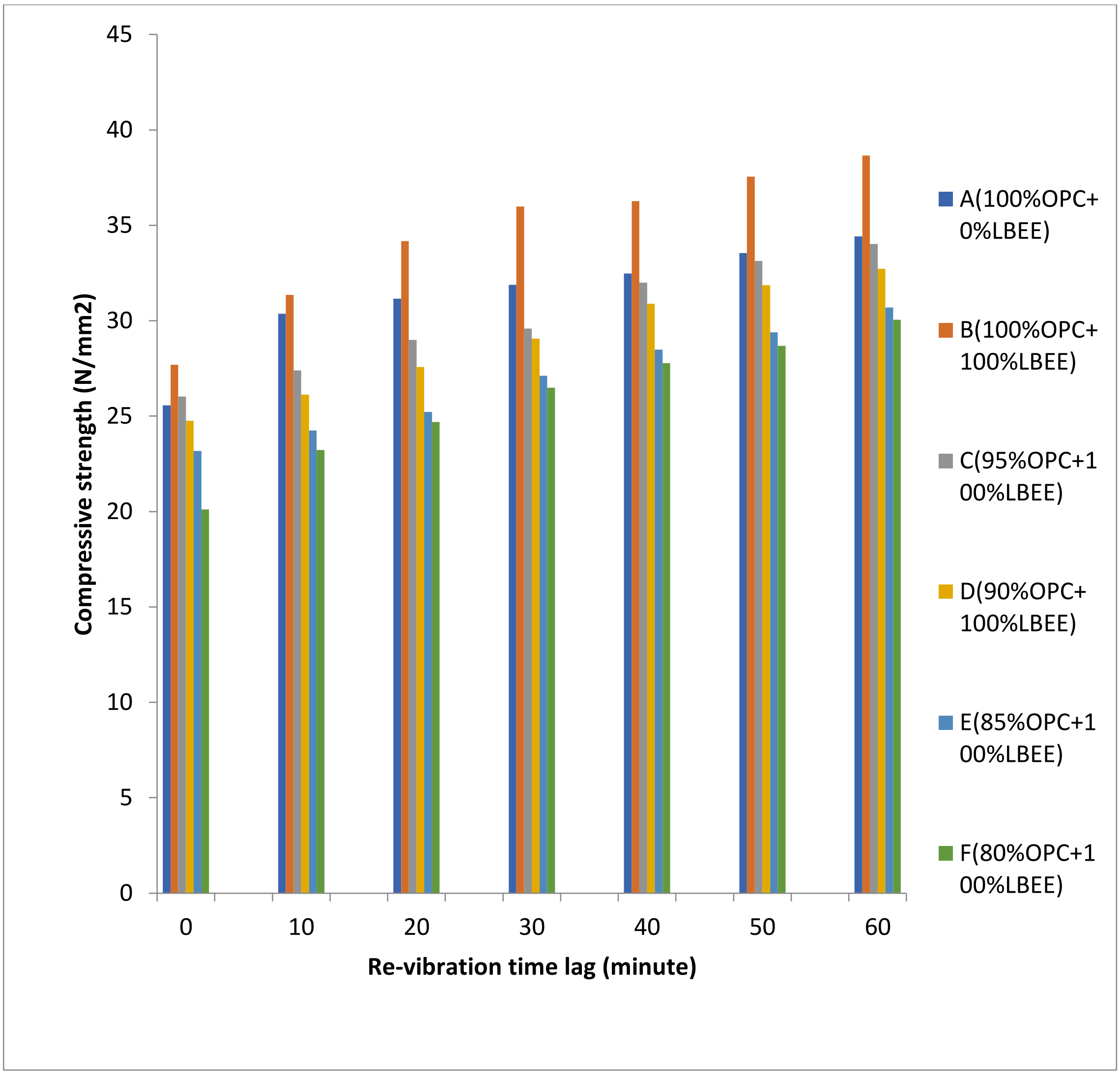

Figure 4.4: Compressive strength and re-vibration time lag for 28days curing

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMEDATION

5.1 Conclusion

The research work has considered compressive strength of re-vibrated concrete containing locust bean epicarp extract and Bida natural stones as coarse aggregate has been presented and the following conclusion can be deduced:

The physical properties of Bida natural stones and that of fine aggregate were determined and found to be suitable in concrete production. Workability of fresh concrete in term slump were determined and found to have low slump upon the introduction of LBEE slump kept decreasing. The compressive strength of the concrete for all batches were determined at 7 and 28days curing respectively. The gradual increase in compressive strength is believe to be attributed to the increase in curing age, application of re-vibration and addition of locust bean epicarp extract.

Bida natural stones can be used as a viable alternative when a concrete of normal strength is required.

5.2 Recommendations

From the result obtained and conclusions arrived at, the following recommendation could serve as an effective guide for LBEE, BNS and re-vibration in production of concrete:

1 Reduction of cement can be up to 20% if LBEE is used as a binder.

2 Re-vibrations increase compressive strength of the concrete.

3 For future work LBEE can be recommended in concrete production.

4 For future work concentration of LBEE should be varied to ascertain strength variation at different concentration also compressive strength of such produced concrete can be determined at 56 and 90days curing age respectively.

5 For future work cement reduction content should go beyond 20% to ascertain the effect on the strength of the concrete.

5.3 Contribution to Knowledge

Previous research work focus on the re-vibration of concrete using LBEE and granite to achieve concrete strength. But this research is set to open up the uses of LBEE, re-vibration with locally available gravel and gradual reduction in quantity of cement in the mix is up to 20% and the reasonable compressive strength are obtained. If this waste, re-vibration and locally source gravel are properly harness it will go a long way in reducing cost of construction material without compromised concrete strength.

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APPENDICES

Appendix A: Physical Properties of Concrete Constituents

Appendix A1: Sieve analysis of fine aggregate

Sieve Sizes (mm)	Weight Retained (g)	Cumulative Weight retained (g)	Cumulative Percentage Retained %	Cumulative Percentage Passing %
4.750	1.650	1.650	0.330	99.670
2.360	23.850	25.500	5.100	94.900
1.180	94.400	119.900	23.980	76.02
0.600	229.630	349.530	69.906	30.094
0.300	99.010	448.540	89.708	10.292
0.150	44.800	493.340	98.668	1.332
0.075	4.200	497.540	99.508	0.492
Pan	2.460	500.000	100.000	0.000

Total Weight: 500g

Appendix A2: Sieve analysis of Bida natural stones (As coarse aggregate)

Sieve	Weight s	Cumulative	Cumulative	Cumulative

Sizes (mm)	Retained (g)	Weight retained (g)	Percentage Retained %	Percentage Passing %
25. 0	0.00	0.00	0.00	100
20.0	378.20	378.20	37.82	62.18
14.0	501.50	879.70	87.97	12.03
10.0	103.20	982.90	98.29	1.73
6.3	11.40	994.30	99.43	0.57
5.0	5.20	999.50	99.95	0.05
Pan	0.50	1000	100	0.00
		Total Weigth:1000g		

Appendix A3: Computation of Moisture Content for Fine Aggregate

Trials	Test A	Test B
Can number	Z_{25}	Z_{20}
Weight of wet sample + container(W_1)	43.5	44.5
Weight of oven dry sample + container (W_2)	43.0	44.0
Weight of container (W_3)	24.5	23.0
Weight of moisture (W_1-W_2)	0.5	0.5
Weight of dry sample (W_2 – W_3)	18.5	21.0
MC $=\frac{W1-W2}{W2 - W3}$ X 100%	2.7	2.38
Average MC	2.54%	

Appendix A4: Computation of Moisture Content for Bida Natural Stones

Trials	Test A	Test B
Can number	K_{52}	K_{45}
Weight of wet sample + container(W_1)	52.5	55.0
Weight of oven dry sample + container (W_2)	50.5	53.5
Weight of container	20.5	19.0
Weight of moisture (W_1-W_2)	2.0	1.50
Weight of dry sample ($W_2 - W_3$)	30.0	34.50
MC $=\frac{W1-W2}{W2 - W3}$ X 100%	6.667	4.35
Average MC	5.51%	

Appendix A5: Computation of Water Absorption Test for Bida Natural Stones

Details	Test A	Test B
Container is weighed and recorded as(W_1)	23.7	23.4
Weight of container + wet sample as(W_2)	95.3	73.8
Weight of container + dry sample as (W_3)	94.9	73.2
Weight of dry sample (W_3 - W_1)	71.2	49.8
Increase in moisture ($W_2 – W_3$)	0.4	0.6
Water absorption$_s\frac{W2 - W3}{W3 - W1}$ X 100%	0.56	1.21
Average water absorption	0.885	

Appendix A6: Computation of Specific Gravity of Fine Aggregate

Details	Test A	Test B
Weight of cylinder(W_1)	268.5	262.0
Weight of cylinder + sample	486.0	461.5
Weight of cylinder + water + sample (W_3)	808.0	776.0

Weight of cylinder + water (W_4) g	684.0	651.5
Specific gravity= $\frac{W2 - W1}{(W4 - W2) - (W3 - W1)}$	2.64	2.66
Average specific gravity G_s	2.65	

Appendix A7: Computation of Specific Gravity of Coarse Aggregate.

Details	Test A	Test B
Weight of cylinder(W_1)	268.5	262.0
Weight of cylinder + sample (W_2)	486.5	462.5
Weight of cylinder + water + sample (W_3)	809.5	776.5
Weight of cylinder + water (W_4) g	684.0	651.5

Specific gravity = $\frac{W2 - W1}{(W4-W2)-(W3-W1)}$	2.69	2.66
Average specific gravity G_s	2.68	

Appendix A8: Computation of Bulk Density of Fine Aggregate

Trails	Uncompacted		Compacted	
	Test A	Test B	Test A	Test B
Weight of mould (W_1)	0.0475	0.0465	0.0475	0.0465
Weight of mould + sample (W_2)	0.641	0.666	0.6920	0.7100
Net weight of sample (W_2-W_1) =W_3	0.5935	0.6195	0.6445	0.6635
Volume of mould	0.0004	0.0004	0.0004	0.0004
Bulk density= $\frac{W3}{Volume}$	1483.75	1548.75	1611.25	1658.75
Average Bulk density	1516.25		1635.00	

Appendix A9: Computation of Bulk Density of Coarse Aggregate

Trials	Uncompacted		Compacted	
	Test A	Test B	Test A	Test B
Weight of mould (W_1)	0.0475	0.0465	0.0475	0.0465
Weight of mould + sample (W_2)	0.6185	0.6170	0.6595	0.6770
Net weight of sample (W_2-W_1) =W_3)	0.5710	0.5705	0.6120	0.6305
Volume of mould	0.0004	0.0004	0.0004	0.0004
Bulk density =$\frac{\mathrm{W3}}{\mathrm{Volume}}$	1425.75	1426.25	1530.00	1576.25
Average Bulk density	1426.00		1563.125	

Appendix A10: Computation of Aggregate Impact Value (AIV)

Details	Test A	Test B
Weight of mould + aggregate(W_1)	1010	1015
Weight of mould (W_2)	686	686

Weight of aggregate(W_1-W_2)	324	329
Weight passing sieve 2.36mm (W_3)	136.5	142
AIV = $\frac{W3}{W1-W2}$ X 100%	42.13	43.16
Average AIV	42.65%	

Appendix A11: Computation of Aggregate Crushing Values (ACV)

Trails	Test A	Test B
Weight of mould + aggregate(W_1)	3603.5	3694
Weight of mould (W_2)	2691	2691
Weight of aggregate(W_1-W_2)	913.5	913
Weight retained on sieve 2.36mm (W_3)	379.77	438.5
ACV =$\frac{W3}{W1-W2}$ X 100%	41.57	48.03

Average ACV	44.80%

Appendix B: Computation of Compaction Factor and Slump

Appendix B1: Compacting Factor

Details	Self Compacted	Fully compacted	Compaction factor
(0%LBEE + 100% OPC)	10.385	11.685	0.8888
(100%LBEE + 100% OPC)	8.685	10.785	0.8053
(100%LBEE + 95% OPC)	8.285	10.685	0.7754
(100%LBEE + 90%OPC)	8.585	11.385	0.7541
(100%LBEE + 85% OPC)	9.035	11.385	0.7936
(100% LBEE + 80% OPC)	9.185	11.385	0.8068

Appendix B2: Slump Test

Details	Slump (mm)
(0%LBEE + 100% OPC)	9.0
(100%LBEE + 100% OPC)	7.0
(100%LBEE + 95% OPC)	5.0
(100%LBEE + 90%OPC)	2.0
(100%LBEE + 85% OPC)	0.0
(100% LBEE + 80% OPC)	0,0

Appendix C: Compressive Strength of C_1 for 7 Days Curing

Interval period of re-vibration(min)	Mode of re-vibration	Area of cube (mm^2)	Weight of specime	Density (kg/m^3)	Crushing load (kN)	Compressive strength	Average compressive strength

			n (kg)			(N/mm^2)	(N/mm^2)
0	Non re-vibrated	22500	8.10	2400.00	414	18.400	
0	Non re-vibrated	22500	8.20	2429.63	435	19.33	18.87
10	Re-vibrated	22 500	8.11	2402.96	566	25.16	
10	Re-vibrated	22500	8.20	2429.63	554	24.62	24.89
20	Re-vibrated	22500	8.09	2397.04	608	27.02	
20	Re-vibrated	22500	8.00	2370.37	568	25.24	26.13
30	Re-vibrated	22500	8.44	2500.74	587	26.09	
30	Re-vibrated	22500	8.13	2408.89	602	26.76	26.43
40	Re-vibrated	22500	8.24	2441.48	634	28.18	
40	Re-vibrated	22500	8.18	2423.70	576	25.60	27.00
50	Re-vibrated	22500	8.19	2426.67	584	25.96	
50	Re-vibrated	22500	8.21	2432.59	646	28.71	27.95
60	Re-vibrated	22500	8.02	2376.30	596	26.49	
60	Re-vibrated	22500	8.18	2423.70	684	30.40	29.45

Appendix D: Compressive Strength of C_2 for7 Days Curing

Interval period of re-vibration(min)	Mode of re-vibration	Area of cube (mm^2)	Weight of specimen (kg)	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
0	Non re-vibrated	22500	8.28	2400.00	511	22.71	
0	Non re-vibrated	22500	8.29	2429.63	488	21.69	22.20
10	Re-vibrated	22500	7.98	2402.96	628	27.91	
10	Re-vibrated	22500	7.98	2429.63	510	22.67	25.29
20	Re-vibrated	22500	7.98	2397.04	608	27.02	
20	Re-vibrated	22500	8.00	2370.37	624	27.73	27.38

30	Re-vibrated	22500	8.01	2500.74	688	30.58	
30	Re-vibrated	22500	7.98	2408.89	580	25.78	28.18
40	Re-vibrated	22500	8.20	2441.48	620	27.56	
40	Re-vibrated	22500	7.85	2423.70	688	30.58	29.07
50	Re-vibrated	22500	8.61	2426.67	604	26.84	
50	Re-vibrated	22500	7.89	2432.59	678	30.13	31.49
60	Re-vibrated	22500	8.02	2376.30	696	30.93	
60	Re-vibrated	22500	8.07	2423.70	588	26.13	33.53

Appendix E: Compressive Strength of C_3 for7 Days Curing

Interval period of re-vibration(min)	Mode of re-vibration	Area of cube (mm^2)	Weight of specimen (kg)	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
0	Non re-vibrated	22500	8.10	2400.00	506	22.49	21.56
0	Non re-vibrated	22500	8.21	2429.63	464	20.62	
10	Re-vibrated	22500	8.60	2402.96	528	23.47	22.76
10	Re-vibrated	22500	8.01	2429.63	496	22.04	
20	Re-vibrated	22500	8.56	2397.04	564	25.07	
20	Re-vibrated	22500	7.90	2370.37	464	20.62	23.85
30	Re-vibrated	22500	8.44	2500.74	504	22.40	
30	Re-vibrated	22500	8.10	2408.89	538	23.91	24.16
40	Re-vibrated	22500	8.30	2441.48	608	27.02	
40	Re-vibrated	22500	8.10	2423.70	500	22.22	25.62
50	Re-vibrated	22500	8.60	2426.67	626	27.82	
50	Re-vibrated	22500	8.09	2432.59	496	22.04	26.43
60	Re-vibrated	22500	8.03	2376.30	628	27.91	

60	Re-vibrated	22500	8.07	2423.70	516	22.93	27.82

Appendix F: Compressive Strength of C_4 for 7 Days Curing

Interval period of re-	Mode of re-vibration	Area of cube	Weight of specime	Density (kg/m^3)	Crushing load	Compressive strength	Average compressive strength

vibration(min)		(mm^2)	n (kg)		(kN)	(N/mm^2)	(N/mm^2)
0	Non re-vibrated	22500	8.20	2400.00	460	20.44	
0	Non re-vibrated	22500	8.21	2429.63	505	22.44	19.44
10	Re-vibrated	22500	8.05	2402.96	374	16.62	
10	Re-vibrated	22500	8.01	2429.63	636	28.27	20.45
20	Re-vibrated	22500	8.05	2397.04	602	26.76	
20	Re-vibrated	22500	8.10	2370.37	416	18.49	21.63
30	Re-vibrated	22500	8.00	2500.74	504	22.40	
30	Re-vibrated	22500	8.10	2408.89	532	23.64	23.02
40	Re-vibrated	22500	7.90	2441.48	532	23.64	
40	Re-vibrated	22500	8.10	2423.70	554	24.62	24.13
50	Re-vibrated	22500	8.05	2426.67	530	23.56	
50	Re-vibrated	22500	8.10	2432.59	564	25.07	25.32
60	Re-vibrated	22500	8.30	2376.30	574	25.51	
60	Re-vibrated	22500	8.00	2423.70	544	24.18	26.85

Appendix G: Compressive Strength of C_5 for 7 Days Curing

Interval period of re-vibration(min)	Mode of re-vibration	Area of cube (mm^2)	Weight of specimen (kg)	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
0	Non re-vibrated	22500	8.25	2400.00	456	20.27	
0	Non re-vibrated	22500	8.00	2429.63	484	21.51	17.89
10	Re-vibrated	22500	8.40	2402.96	364	16.18	
10	Re-vibrated	22500	8.10	2429.63	624	27.73	18.96
20	Re-vibrated	22500	8.60	2397.04	488	21.69	

20	Re-vibrated	22500	7.98	2370.37	512	22.76	19.35
30	Re-vibrated	22500	7.80	2500.74	611	27.16	
30	Re-vibrated	22500	8.10	2408.89	396	17.60	21.38
40	Re-vibrated	22500	8.00	2441.48	534	23.73	
40	Re-vibrated	22500	8.20	2423.70	496	22.04	22.89
50	Re-vibrated	22500	8.10	2426.67	524	23.29	
50	Re-vibrated	22500	8.03	2432.59	534	23.73	23.51
60	Re-vibrated	22500	8.30	2376.30	556	24.71	
60	Re-vibrated	22500	8.00	2423.70	542	24.09	24.40

Appendix H: Compressive Strength of C_6 for 7 Days Curing

Interval period of re-vibration(min)	Mode of re-vibration	Area of cube (mm^2)	Weight of specimen (kg)	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
0	Non re-vibrated	22500	8.40	2400.00	498	22.13	
0	Non re-vibrated	22500	8.00	2429.63	408	18.13	16.13
10	Re-vibrated	22500	8.01	2402.96	540	24.00	
10	Re-vibrated	22500	8.10	2429.63	414	18.40	18.20
20	Re-vibrated	22500	8.21	2397.04	340	15.11	
20	Re-vibrated	22500	8.10	2370.37	649	28.84	18.90
30	Re-vibrated	22500	8.50	2500.74	576	25.60	
30	Re-vibrated	22500	8.10	2408.89	420	18.67	21.14
40	Re-vibrated	22500	8.00	2441.48	612	27.20	
40	Re-vibrated	22500	8.20	2423.70	414	18.40	22.30
50	Re-vibrated	22500	8.10	2426.67	428	19.02	

50	Re-vibrated	22500	8.30	2432.59	607	26.98	22.99
60	Re-vibrated	22500	8.20	2376.30	528	23.47	
60	Re-vibrated	22500	8.00	2423.70	530	23.56	23.52

Appendix I: Compressive Strength of C_1 for 28 Days Curing

Interval period of re-vibration(min)	Mode of re-vibration	Area of cube (mm^2)	Weight of specimen (kg)	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
0	Non re-vibrated	22500	8.05	2400.00	538	23.91	
0	Non re-vibrated	22500	8.10	2429.63	522	23.20	25.56
10	Re-vibrated	22500	8.06	2402.96	704	31.29	
10	Re-vibrated	22500	8.30	2429.63	662	29.42	30.36
20	Re-vibrated	22500	8.00	2397.04	682	30.31	
20	Re-vibrated	22500	8.09	2370.37	720	32.00	31.16
30	Re-vibrated	22500	8.20	2500.74	704	31.29	
30	Re-vibrated	22500	8.15	2408.89	722	32.09	31.89
40	Re-vibrated	22500	8.20	2441.48	748	33.24	
40	Re-vibrated	22500	8.10	2423.70	722	32.09	32.47
50	Re-vibrated	22500	8.14	2426.67	758	33.69	
50	Re-vibrated	22500	8.20	2432.59	774	34.40	33.55
60	Re-vibrated	22500	8.04	2376.30	820	36.44	
60	Re-vibrated	22500	8.16	2423.70	774	34.40	34.42

Appendix J: Compressive Strength of C_2 for 28 Days Curing

Interval period of re-vibration(min)	Mode of re-vibration	Area of cube (mm^2)	Weight of specimen (kg)	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
0	Non re-vibrated	22500	8.28	2400.00	612	27.20	
0	Non re-vibrated	22500	8.29	2429.63	634	28.18	27.69
10	Re-vibrated	22500	7.98	2402.96	754	33.51	
10	Re-vibrated	22500	7.98	2429.63	612	27.20	31.36
20	Re-vibrated	22500	7.98	2397.04	790	35.11	

20	Re-vibrated	22500	8.00	2370.37	748	33.24	34.18
30	Re-vibrated	22500	8.01	2500.74	820	36.44	
30	Re-vibrated	22500	7.98	2408.89	754	33.51	35.98
40	Re-vibrated	22500	8.20	2441.48	806	35.82	
40	Re-vibrated	22500	7.85	2423.70	826	36.71	36.27
50	Re-vibrated	22500	8.61	2426.67	786	34.93	
50	Re-vibrated	22500	7.89	2432.59	814	36.18	37.56
60	Re-vibrated	22500	8.02	2376.30	810	36.00	
60	Re-vibrated	22500	8.07	2423.70	794	35.29	38.65

Appendix K: Compressive Strength of C_3 for 28 Days Curing

Interval period of re-vibration(min)	Mode of re-vibration	Area of cube (mm^2)	Weight of specimen (kg)	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
0	Non re-vibrated	22500	7.89	2400.00	604	26.84	
0	Non re-vibrated	22500	8.21	2429.63	608	27.02	26.03
10	Re-vibrated	22500	8.60	2402.96	634	28.18	
10	Re-vibrated	22500	8.01	2429.63	644	28.62	27.40
20	Re-vibrated	22500	8.56	2397.04	678	30.13	
20	Re-vibrated	22500	7.90	2370.37	626	27.82	28.99
30	Re-vibrated	22500	8.44	2500.74	656	29.16	
30	Re-vibrated	22500	8.10	2408.89	698	31.02	29.59
40	Re-vibrated	22500	8.30	2441.48	650	28.89	
40	Re-vibrated	22500	8.10	2423.70	790	35.11	32.00
50	Re-vibrated	22500	8.60	2426.67	694	30.84	

50	Re-vibrated	22500	7.88	2432.59	752	33.42	33.13
60	Re-vibrated	22500	8.03	2376.30	670	29.78	
60	Re-vibrated	22500	8.07	2423.70	816	36.27	34.03

Appendix L: Compressive Strength of C_4 for 28 Days Curing

Interval period of re-vibration(min)	Mode of re-vibration	Area of cube (mm^2)	Weight of specimen (kg)	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
0	Non re-vibrated	22500	8.20	2400.00	598	26.58	
0	Non re-vibrated	22500	8.21	2429.63	606	26.93	24.76
10	Re-vibrated	22500	8.05	2402.96	624	27.73	
10	Re-vibrated	22500	8.01	2429.63	642	28.53	26.13
20	Re-vibrated	22500	8.05	2397.04	624	27.73	
20	Re-vibrated	22500	8.10	2370.37	662	29.42	27.58
30	Re-vibrated	22500	8.00	2500.74	656	29.16	
30	Re-vibrated	22500	8.10	2408.89	692	30.76	29.06
40	Re-vibrated	22500	7.90	2441.48	714	31.73	
40	Re-vibrated	22500	8.10	2423.70	694	30.84	30.89
50	Re-vibrated	22500	8.05	2426.67	722	32.09	
50	Re-vibrated	22500	8.10	2432.59	712	31.64	31.87
60	Re-vibrated	22500	8.30	2376.30	748	33.24	
60	Re-vibrated	22500	8.00	2423.70	698	31.02	32.73

Appendix M: Compressive Strength of C_5 for 28 Days Curing

Interval period of re-vibration(min)	Mode of re-vibration	Area of cube (mm^2)	Weight of specimen (kg)	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
0	Non re-vibrated	22500	8.25	2400.00	630	28.00	
0	Non re-vibrated	22500	8.00	2429.63	548	24.46	23.18
10	Re-vibrated	22500	8.40	2402.96	588	26.13	
10	Re-vibrated	22500	8.10	2429.63	638	28.36	24.25
20	Re-vibrated	22500	8.60	2397.04	624	27.73	

20	Re-vibrated	22500	7.98	2370.37	646	28.71	25.22
30	Re-vibrated	22500	7.80	2500.74	672	29.87	
30	Re-vibrated	22500	8.10	2408.89	638	28.36	27.12
40	Re-vibrated	22500	8.00	2441.48	640	28.44	
40	Re-vibrated	22500	8.20	2423.70	732	32.53	28.49
50	Re-vibrated	22500	8.10	2426.67	696	30.93	
50	Re-vibrated	22500	8.03	2432.59	698	31.02	29.39
60	Re-vibrated	22500	8.30	2376.30	722	32.09	
60	Re-vibrated	22500	8.00	2423.70	704	31.29	30.69

Appendix N: Compressive Strength of C_6 for 28 Days Curing

Interval period of re-vibration(min)	Mode of re-vibration	Area of cube (mm^2)	Weight of specimen (kg)	Density (kg/m^3)	Crushing load (kN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
0	Non re-vibrated	22500	8.40	2400.00	598	26.58	
0	Non re-vibrated	22500	8.00	2429.63	532	23.64	20.11
10	Re-vibrated	22500	8.01	2402.96	648	28.8	
10	Re-vibrated	22500	8.10	2429.63	532	23.64	
							23.22
20	Re-vibrated	22500	8.21	2397.04	638	28.36	24.69
20	Re-vibrated	22500	8.10	2370.37	608	27.02	
30	Re-vibrated	22500	8.50	2500.74	630	28.00	26.49
30	Re-vibrated	22500	8.10	2408.89	652	28.98	
40	Re-vibrated	22500	8.00	2441.48	674	29.96	27.78
40	Re-vibrated	22500	8.20	2423.70	684	30.40	
50	Re-vibrated	22500	8.10	2426.67	658	29.24	28.69
50	Re-vibrated	22500	8.30	2432.59	704	31.29	

60	Re-vibrated	22500	8.20	2376.30	718	31.91	30.06
60	Re-vibrated	22500	8.00	2423.70	698	31.02	