Effectıveness of Locust Bean Epıcarp Extract on Re-vıbrated Concrete Usıng Pebbles from Bıda Envırons as Coarse Aggregate.

Authors: **Abbas Bala Alhaji*[1], Mohammed Tahir Abdul[1], Yusuf Abdulazeez[1], Kolo Daniel Ndakuta[1], Abubakar Mahmud[1] and Abdullahi Aliyu[1].**

Institution: [1] Department of Civil Engineering, Federal University of Technology, PMB 65, Minna, Niger state, Nigeria

Email: *bala.alhaji@futminna.edu.ng

Abstract

Purpose: In this research, the effect of re-vibrated concrete using locust bean epicarp extract and Bida natural stone (Pebbles) as coarse aggregate was presented.

Design/ Methodology/ Approach: The concrete mix of 1:2:4 and water cement ratio of 0.5 was adopted respectively. One hundred and sixty-eight (168) concrete cubes were produced in six (6) batches, 28 cubes were produced for control (mix A= 0% LBEE + 100%OPC) and 28 for (0%, 5%, 10%, 15% and 20%) cement reduction respectively.

Findings: The results of preliminary test of the aggregates indicate that they are suitable for concrete production and the chemical analysis of LBEE showed that it is a very good pozzolana. Concrete cubes were cast with re-vibration time lag intervals of 10minute for the period of 60minute re-vibration process and cured for 7 and 28days. The result shows that introduction of LBEE improve the compressive strength of concrete. The result obtained also shows that there is increase in compressive strength with the increase in re-vibration time lag of LBEE concrete, hence the maximum compressive strength was obtained at 60minutes for all batches. The maximum compressive strength obtained at 28days curing was 35.70N/mm^2 for B (0% cement reduction) at 60% re-vibration which is higher than 34.0N/mm^2 for control mix A. The optimum cement reduction of concrete made incorporating LBEE without re-vibration and the one with re-vibration is 5% and 20% respectively.

Practical Implications

This types of concrete can be used for structural application such as in the construction of reinforced concrete slabs, beams, columns and foundations.

Social Implications: In order to provide adequate housing for over increasing population of people in Bida and Environs the use of Locust Bean Epıcarp Extract on Re-vıbrated Concrete Usıng Pebbles from Bıda as coarse aggregate should be encouraged by individuals and government at all levels. This will also lead to reduction in construction cost of houses in Nigeria and create employment to the rural dwellers where locust been trees are grown.

Originality and Value: This study contributed to the pool of knowledge on how Locust Bean Epıcarp Extract and concrete Re-vibration has improved the strength of concrete. Thus 20% and 5% is recommended as the optimum cement reduction of concrete made incorporating LBEE with re-vibration and the one without re-vibration respectively.

Keywords: *Concrete, Bida Natural stone, Locust Bean Epicarp Extract, Ordinary Portland Cement.*

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.

https://doi.org/10.1007/978-3-030-68836-3 1

1.0 INTRODUCTION

Concrete is a combination of cement, water, fine and coarse aggregates, which are mixed in a right proportion to obtain a particular strength. The cement and water react together chemically to form a paste, which binds the aggregate particles together. The mixture sets into a rock-like solid mass, which has considerable compressive strength but little resistance in tension. Concrete has tremendous versatility because of its initial fluid state. It may be poured into a mould, and it is compacted by vibration or ramming to remove any entrapped air. The mixture sets within a few hours for the mould or formwork to be removed. It is ideal for use in foundation where the load that is to be carried is wholly compressive. But in bending, tension could be developed at low loads. The lack of resistance to overcome tensile strength is overcome by providing steel bars at appropriate places. The resulting composite structure is called reinforced concrete. Agbede and Manseh (2009).

Aggregates 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). Coarse aggregates which occupy up to 55% of the concrete volume has been reported to have a direct relationship to the strength, durability, workability, volume stability (Yusuf *et al*., 2020). Research on the locally available gravel with satisfactory engineering properties is important. Previous research reported that poor choice of aggregate, reactive, unsound and unsuitable aggregates are part of the causes of building failure (Yusuf *et al*., 2020). The granite materials have been found to be more suitable coarse aggregate as in the conventional concrete. Although, Bida natural stone has shown a tremendous performance in concrete works, although there is very little information on this material in the technology of self-compaction concrete (Shehu *et al*., 2016). The extensive research findings have advocated the use of locally-available gravel to reduce the cost of infrastructure systems and thereby making building affordable to low-income earner (Gideon *et al*., 2015). The repeated vibration of the fresh concrete after a successive period, which is called re-vibration, may be useful to improve the properties of concrete especially when successive layer of fresh concrete has to be placed and the upper layer of fresh concrete is partially hardened. Re-vibration after

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

time re-arranged the aggregate particles and eliminates voids to improve 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. The research finding has shown that operation of re-vibration had improves the compressive strength, tensile and flexural strength of concrete (Abbas, 2017 and Auta, 2011). Locust bean epicarp are agricultural by-products of the African locust bean fruit, which can be found in larger quantities across northern Nigeria during the harvest period. Some globe system researchers in recent times were working towards possible ways of recycling the agricultural wastes to keep the environment clean and safe. The epicarps containing locust bean seeds resemble 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 Northern states of Nigeria, the epicarp is used in the rural areas in compaction of floor, the epicarps are collected and soaked in water for at least four days and extract is the needed item which is used to produce the mud blocks for building purposes. (Aguwa and Okafor, 2012; Auta *et al.*, 2015). Therefore, the aim of this work is to produce the revibrated concrete cubes using locust bean epicarp extract (LBEE) and Bida natural stone as coarse aggregate. Addition of LBEE as binder in the production of concrete has been established to have significant increase in the compressive strength of the concrete (Aguwa *et al*., 2016) The objectives of the study include: carrying out physical and mechanicals properties of aggregate, Production of 168 re-vibrated concrete cubes specimens containing LBEE and Bida natural stone as coarse aggregate, determination of workability of fresh concrete, determination of compressive strength of concrete produce.

2.0 Materials and Methods

2.1 Materials

The re-vibrated concrete Sample were made by selecting suitable materials, ensuring good quality control and proper proportioning. The following materials were used for this research: Sand (fine aggregate), Bida natural stone, Ordinary Portland cement, locust bean epicarp and portable water.

a) Water: Potable drinking water from Civil Engineering laboratory, Federal University of Technology Minna was used throughout this work. It was ensured that the water for concrete was clean, free from deleterious materials and fit for drinking as recommended

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

by BS EN 1008 (2002). The quantity of water in a concrete mix has a substantial effect on the strength of the resulting concrete. In addition, the quality of water is important because impurities in it may affect the setting time and the strength of the concrete or cause the surface of the concrete to be stained. The poor quality of water may cause corrosion of the reinforcement (Neville and Brooks, 2002). Conventionally, water used for concrete mixing is meant to be fit for drinking.

b) Ordinary Portland cement (OPC): The Ordinary Portland Cement used in this study was sourced within Minna metropolis and conforms to BS EN 197- 1 (2000). The specific gravity of the cement is 3.15. In addition, the cement sample was manufactured about two (2) months prior to purchase and use for the laboratory work.

c) Coarse aggregates: The Bida natural stone that was utilized in this study was sourced from Bida basin (Trough). The Bida natural stone is a by-product of the parent rock through decomposition, transportation, and the deposition of rocks in the Bida Basin. It is an extension of the Iullemmeden Basin which runs through Niger Republic and Mali in West Africa. The aggregates that were used in this study have a maximum size of 19mm in diameter, retained in sieve size 4.75mm and conform to the standard requirement of BS EN 12620 (2008). Plate I shows the coarse aggregates in its natural form after being washed and cleaned from all dirt and as prepared for the experiments.

Plate I: Cluster of Bida natural stones (Pebble)

d) Fine aggregates: The fine aggregates that were used in this study have all particles passing through sieve size 4.75 mm and retained on sieve size 150 μm. To produce good quality concrete, it is imperative that fine aggregates should possess certain characteristics. The sand that was clean sharp Sand free from loam, clay, and organic impurities conforming to (NIS 87: 2004) and BS EN 12620 (2008) was used as a basic requirement for fine the aggregate in this research. The sand was sourced from Gidan Mangoro, Minna, Niger state of Nigeria.

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

f) The epicarp: 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. (Aguwa *et al*., 2016).

Plate Il: Locust Bean Fruit

2.2 Methods

Aggregate characterization involves the determination of physical and mechanical properties of the aggregates. The physical properties tests include sieve analysis test, specific gravity, bulk density, aggregate impact value, aggregate crushing value. The mechanical test conducted on fresh and hardened concrete are slump test, dry density and compressive strength test respectively.

a) Specific Gravity Test

Specific gravity is defined as the ratio of the density (weight per unit volume of a substance) of substance to the density of water. This test was conducted in accordance with BS EN 12620 (2008).

b) Sieve Analysis Test

Sieve analysis test was carried out to determine the particle size distribution of aggregate used in concrete mix. Well graded aggregate contains aggregate sizes ranging from the smallest to the largest, while poorly graded aggregate contain particles of the same size. Well graded aggregate produce concrete of higher strength. Total weight of coarse and fine aggregate is 1000g and 500g respectively. The BS 822: part 1: (1973) and BS 812 Part 103:1: (1985) Method for determination of particle size distribution for fine and coarse aggregate were used respectively.

c) Bulk Density Test

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

Bulk density is defined as actual mass of sample that would fill a unit volume of container. It depends on particle size distribution and shape of the particles. It is used to converts quantities by mass to quantities by volume. This test was conducted in accordance with BS 812 part 2: 1975 uncompacted and compacted bulk density tests were carried out.

d) Aggregate Impact Value (AIV) Test

The aggregate impact value test is used to determine the impact of a sample of coarse aggregate, degradation may take place if the aggregate is weak and this will lead to a change in grading or production of excessive and undesired fines.

e) Aggregate Crushing Value (ACV) Test

The aim of this test is to determine the aggregate crushing values of a coarse aggregate, aggregate should be strong enough to resist crushing under loading. If the strength of aggregate is weak then failure is inevitable. Hence strength of aggregate is accessed by the means of aggregate crushing value test.

f) Curing of Cubes

This is the usual means of applying water to the cubes to ensure adequate hydration to reduce the porosity to a level such that the design strength and durability can be attained. The method of curing used for this research was total immersion method of the cubes in water for specific age of 7 and 28 days from the day of demoulding the cast concrete (BS EN 1008, 2002).

g) Crushing Test

Crushing is the practice of placing the concrete cubes in the crushing machine in other to determine the compressive strength of the cubes. The crushing load reading was taken after the cube has failed in accordance with (BS EN 12390, 2009).

2.3 Methodology:

a) Sample preparation for Compressive strength

The sample was thoroughly mixed manually until the required homogeneity was achieved; the standard iron moulds of 150×150×150 mm3 were used. The moulds was lubricated with engine oil in other to reduce friction and to enhance removal of cubes from the moulds, they were then filled with fresh concrete in three layers and each layer was tamped 25times.

b) Processing of locust bean epicarp extract

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

Epicarp extract was obtained from kangi village, Bida Niger state, pounded and soak in water for 4days, the dissolved solution was then sieved to obtain the extract.

c) Sample distribution according to mix batches:

This study encompasses the production of re-vibrated concrete using locust bean epicarp extract and Bida natural stone.

One hundred and sixty-eight concrete cubes specimen of size

150 x150 x 150mm^3 were produce in six batches and in each batch, twenty-eight concrete cubes was produced at cement reduction of 0 5, 10, 15 and 20%. The effort was geared up to compare compressive strength at different percentage cement reduction of a concrete at end 7 and 28days. Some of the parameters adopted are water cement ratio of 0.5, epicarp concentration of 0.1kg/l and mix design 1: 2: 4. The method used to calculate the quantities of each material required in kilogram was absolute volume method.

Absolute volume method was use;

$$Vw + Vc + Vfa + Vca + Vv = 1 \quad (1)$$

$$\frac{Ww}{1000} + \frac{Wc}{1000SGc} + \frac{Wfa}{1000SGf} + \frac{Wca}{1000SGca} + Vv = 1m^3 \quad (2)$$

$$Wfa = 2c \quad (3)$$

$$Wca = 4C \quad (4)$$

Table 1.0 Mix composition of batches

Concrete mix	Cement (kg)	Extract (Litre)	Water (kg)	Sand (kg)	Bida natural stones (kg)
A	32.38	0.00	16.19	64.75	129.57
B	32.38	16.19	0.00	64.75	129.51
C	30.76	16.19	0.00	64.75	129.56
D	29.14	16.19	0.00	64.75	129.56
E	27.52	16.19	0.00	64.75	129.56
F	25.90	16.19	0.00	64.75	129.56
Total	178.1	80.94	16.19	388.51	777.03

Where:

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

A= (0%LBEE + 100% OPC)

B= (100%LBEE + 100% OPC)

C= (100%LBEE + 95% OPC)

D= (100%LBEE + 90% OPC)

E= (100%LBEE + 85% OPC)

F= (100%LBEE + 80% OPC)

3.0 RESULTS AND DISCUSSION

3.1 Result

Table 2.0 Summary of preliminary Test

Test	Bida natural stones	Sand
Specific gravity	2.68	2.65
Bulk density (kg/m^3) (compacted)	1732.00	1539.05
Bulk density (kg/m^3) (uncompacted)	1563.13	1635.00
Moisture content	4.51	6.45
Water absorption	0.885	1.25
ACV	36.5%	-
AIV	40%	-
Porocity%	0.42	0.38

Table 3.0 Chemical Composition of LBEE

Element	Concentration Wt%
Na_2O	1.268
MgO	1.220
Al_2O_3	6.45
SiO_2	65.35
P_2O_5	1.03
K_2O	0.46

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

CaO	0.21
TiO_2	0.60
Fe_2O_3	3.11

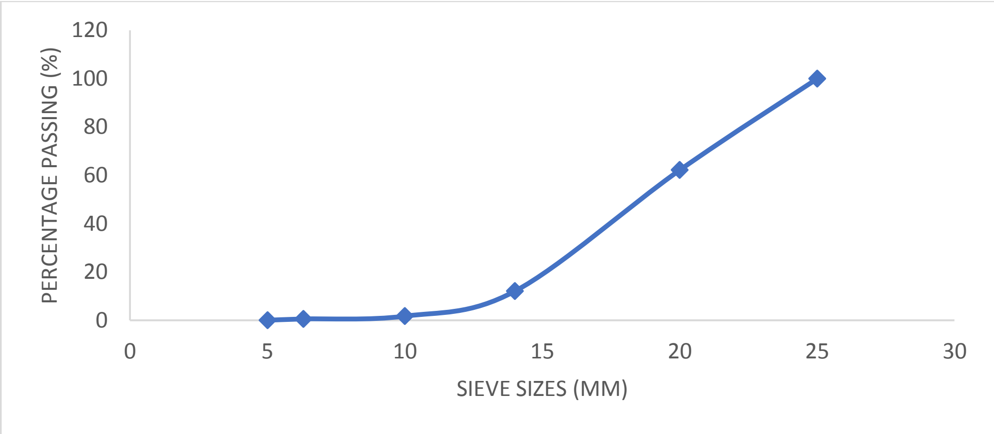

Figure 1.0 Sieve analysis of Bida natural stone (Pebbles)

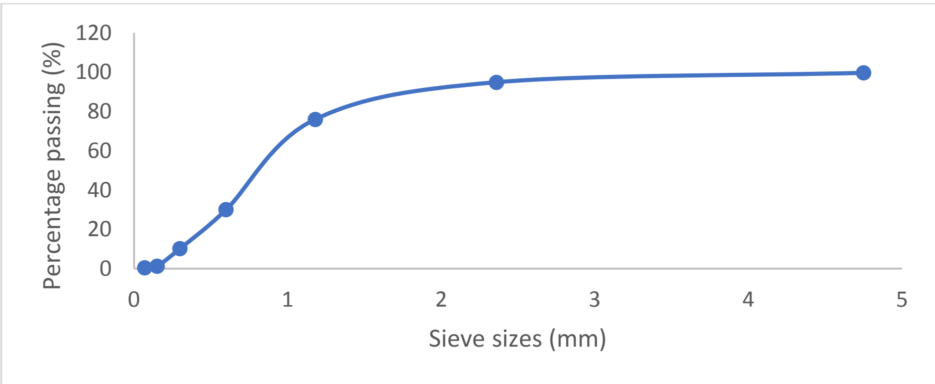

Figure 2.0 Sieve analysis of fine aggregate

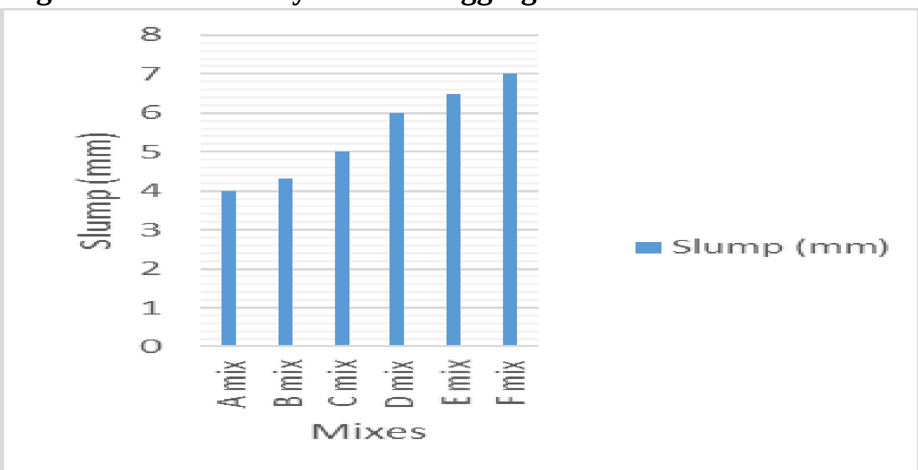

Figure 3.0 Slump of a fresh concrete

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

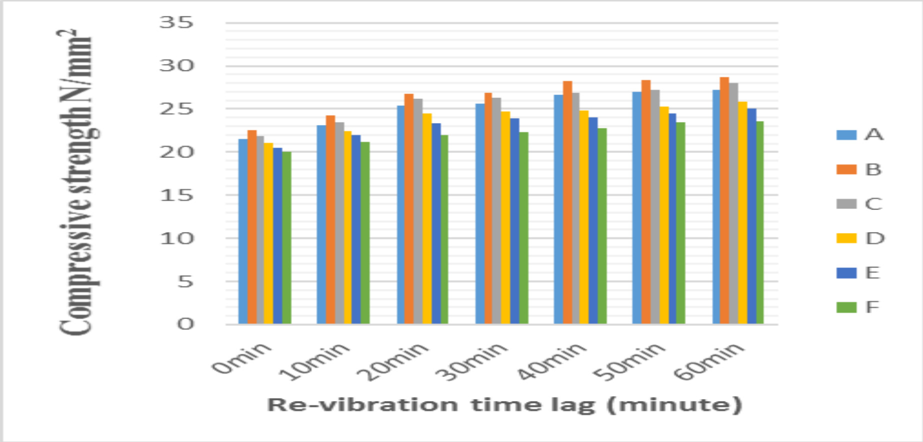

Figure 4.0: Compressive strength and re-vibration time lag for 7days curing

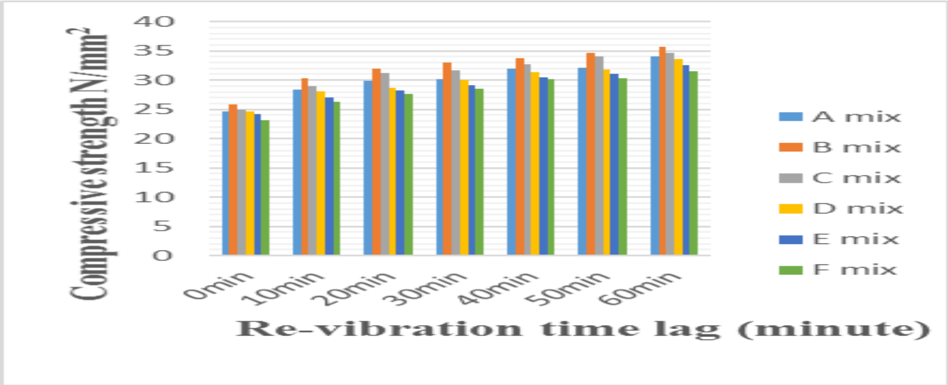

Figure 5.0: Compressive strength and re-vibration time lag for 28days curing

3.2 Discussion

a) Aggregate characterization

The result of specific gravity, bulk density (compacted and uncompact), moisture content, aggregate impact value (AIV), aggregate crushing value (ACV), sieve analysis are presented in Table 2.0 The specific gravity of Bida natural stone and fine aggregate are 2.68 and 2.65, respectively. These value obtained fall within the limit for natural aggregate between 1.3-3.0 and 2.6-2.7 respectively. It implies that the aggregate can be conveniently use for construction work (concrete) without much need for mix proportioning adjustment (Naville, 1995).

The bulk density results of Bida natural stone are 1625kg/m³ and 1732kg/m³ for uncompacted compacted respectively, which classified Bida natural stone as normal

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

weight aggregate, it also shows the bulk density of sand as 1539.05kg/m³ and 1620kg/m³ for uncompacted and compacted respectively. However, the compacted and uncompacted bulk density of Bida gravel agree with the value of 1729kg/m^3 and 1628kg/m^3 report by Alhaji (2020). In addition, the compacted and uncompacted bulk density of sand agree with the value of 1602kg/m^3 and 1468.46kg/m^3 report by Abdullahi *et al.* (2017).

The average moisture content for Bida natural stone is presented in Table 2.0 as 4.51% and that of fine aggregate is 6.54% which are within the specification of BS 812: Part 109 (1990), 1 – 5% and 5 – 15% respectively. Average water absorption capacity obtained for fine aggregate is 1.0% and that of Bida natural stone is 0.885% which are also within the standard range of 0.5 – 5%.

Figure 1.0 depict the particle size distribution of the sand used for this experiment. The sand was found to be in zone 2 in accordance with NIS 87 of 2004 and BS 882 of 1992 classifications. The porosity of Bida natural stone and sand are 0.42% and 0.38%. This values are very low compared with most natural aggregate, which have their porosities in the range of 6 – 10% as reported by Abdullahi (2017). Hence high strength is expected, because the higher the porosity of aggregate, the lower the strength and durability of concrete. The value of porosity also indicates that those aggregate may absorb less amount of water and cement paste during mixing compared to normal aggregates. The uncompacted bulk density was used to calculate porosity in this research work because in practice, the material is not likely to be compacted before use in mixing. Table 2.0 present the result of Aggregates Crushing Value (ACV) for the Bida natural stone as 36.5%. It is important to note that, a material which has undergone a complete process of physical weathering offers a less resistance to crushing value. BS EN: 13043 (2002) identified that, aggregates crushing value (ACV) below 10% is regarded as very strong aggregates while those above 35% are regarded as weak aggregates and should not be used as wearing surface concrete. Hence this aggregates is not suitable for wearing surface concrete, because the ACV is above 35%.

Table 2.0 also revealed that the result of average Aggregates Impact Value (AIV) for Bida natural stone as 40%. BS EN 13043 (2002) specified that, AIV of material for concrete

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

pavement must not exceed 30% and must be less than 45% for concrete wearing surface. Hence, this aggregates with AIV of 40% which is within the range is suitable for concrete wearing surface.

b) Chemical properties of locust bean epicarp extract

The result of chemical properties of locust bean epicarp extract revealed that it is a pozzolanic material. Thus result presented in Table 3.0 show that summation of the Al_2O_3 + Fe_2O_3 + SiO_3 is equal to 74.91%, The value is above the required limit of 70% minimum for Pozzolanas as specified by ASTM C618 (2012).

This result is in good agreement with that of Bala et al(2015) =76.7%, Marthong (2012)=77.58 and Auta and Kabiru (2020) =77.81% who work on corn cob ash, rice husk ash and locust bean pod ash respectively.

c) P**roperties of concrete**:

i) Fresh concrete

Figure 3.0 demonstrate the graph of slump, the slump increases as the cement content decreases this is as a result of reduction in the quantity of the cement which give rise to reduction of the surface area of the constituent material needed to be lubricated by the cement paste. Hence more fluid (cement paste) is available as the cement (powdery material) reduces, giving more room for high slump in the concrete mix.

(**c) Hardened concrete**

ii) The compressive strength of concrete

The compressive strength of concrete at different intervals of re-vibration of 10minutes up to 60minute for 7 and 28days curing ware obtained and displayed in Figure 4.0 and 5.0 respectively. It was observed that compressive strength has significantly increases for all categories and control. The strengths increase as the curing age increases for all specimens tested. This is primarily due to the fact that concrete hardening is caused by chemical reaction between cement and water which continues for a long period of time and consequently concrete get stronger with age (Gambhir, 2004).

It was observed from Figure 3.0 and 4.0 that the concrete without LBEE (mix A) shows a lower compressive strength as compared with the 100% LBEE (mix B). This is a clear

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

indication that LBEE is a pozzolana, hence the increasement in the compressive strength is a further proof of cementitious contribution by LBEE. Thus a further justification of the chemical analysis result in Table 3.0 obtained above. This finding is in line with the recommendation of Aguwa *et al.* (2016) who concluded in his study that Locust Bean Pod Solution (LBPS) can economically and effectively be used in the production of Sandcrete blocks for buildings with some percentage reduction in the quantity of cement. He concluded that the percentage reduction in quantity of cement can be up to 25% without reducing the compressive strength of the Sandcrete blocks to unsatisfactory level.

Figure 3.0 and 4.0 also shows that the strength reduces with the reduction in the quantity of cement, this behaviour is very logical, because the reduction in the strength is as a result of reduction in the binding effort of the cement removed from mix B(100%LBEE+ 100%OPC). It was observed that despite the reduction of cement by 5% (100%LBEE + 95% OPC), the strength was still greater than initial /control mix A(0%LBEE+100OPC). Considering the re-vibration of the LBEE concrete, the strength of concrete is directly proportional to the degree of re-vibration. In otherworld's the strength increase as the re-vibration effort increases. This trend is in good agreement with the findings of Auta and Kabiru (2020). The minimum compressive strength was obtained at 0minute re-vibration for control and the maximum strength was obtained at 60miute re-vibration time.

The results also proved that despite reduction of cement up to 20% upon the introduction of LBEE and re-vibration effort, the compressive strength is not reduced to unsatisfactory level of construction demand.

CONCLUSION

Effect of locust bean epicarp extract (LBEE) on the compressive strength of re-vibrated concrete using Bida natural stone as coarse aggregate in concrete production has been examined and the results have been analyzed, discussed and presented. From the study, the following conclusions were drawn:

1) LBPEE used is a good pozzolana with its $SiO_2 + Al_2O_3 + Fe_2O_3$ content equal to 74.91% (ASTM C618, 2012); The compressive strength of concrete mixed with LBEE but without re-vibration at 28 days curing gave compressive strength of mix C greater than that of mix A, this shows an advantage in compressive strength

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1

due to LBEE incorporation as the binder in the concrete mix. Thus, a 5% reduction in OPC with LBEE concrete can be adopted for concrete production.

2) Effect of locust bean epicarp extrat (LBEE) on the compressive strength of re-vibrated concrete has shown that compressive strength increases as the vibration effort increases. It was observed that with some percentage reduction in the quantity of cement between 5%-20%. the compressive strength of the concrete dose not attain unsatisfactory level. Hence, the cost of concrete can be reduced significantly by partially reducing the quantity of cement when mixed with locust bean epicarp extract and revibrated. This will lead to reduction in construction cost of houses in Nigeria. Hence will also create employment to the rural dwellers where locust been trees are grown.

Recommendation

1) A 5% reduction in cement content of concrete mixed with LBEE without re-vibration at 28 days curing can be adopted for construction of slab, beam, column and foundation of building
2) A 20% reduction in cement content of Concrete of all mixes A, B, C, D, E and F with LBEE and re-vibration at 28 days curing can be adopted for construction of slab, beam, column and foundation of building

REFERENCE

Abbas S. A. (2017). Effect of Re-vibration Process on Axial Capacity of Short Reinforced Concrete Circular Columns Engineering & Technology Journal,Vol. 35, Part A, No. 7, pp. 776- 787, 2017.

Abdullah, M. (2012). Effect of aggregate type on compressive strength of concrete. International Journal of Civil and Structural Engineering, 2, 791–800. Research. 1 (2) 5767

Agbede O. I. and Manasseh J. (2009). Suitability of Periwinkle Shell as Partial Replacement for river Gravel in Concrete, *Leonardo Electronics Journal of Practices and Technologies*.

ASTM C618 (2012) Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. ASTM International, West Conshohocken, 2012.

Aguwa J. I., Alhaji B. A., Jiya A. and Kareem D. H. (2016). Effectiveness of Locust Bean Pod Solution (LBPS) in the Production of Sandcrete Blocks for Buildings Department of Civil Engineering, Federal University of Technology Minna, Nigeria.

Aguwa J. I. and Okafor J. O. (2012). Preliminary Investigation in the Use of Locust Bean Epicarp Extract as Binder for Production of Laterite Blocks for Buildings.

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.

https://doi.org/10.1007/978-3-030-68836-3 1

International Journal of Environmental Science, Management and Engineering.
Alhaji, B**.** (2020) Suitability of periwinkle shell as partial replacement of Bida natural stone in concrete production. 2nd International Civil Engineering Conference (ICEC 2020) Federal Univeresity of Technology, Minna, Niger state Nigeria. Pp 463-470
Auta S. M., Solomon B. U. and Tsado T. Y. (2015). Effect of LBPE as a partial Replacement for Water on the Compressive Strength of Concrete, Proceeding of 1st International Conference on Green Engineering Sustainable Development (ICGESD), Faculty of Engineering Bayero University, Kano in Collaboration with Faculty of Engineering Tanta Egypt. PP 119 -123.
Auta S. M. (2011). Dynamic Effect of Re-vibration on Compressive strength of Concrete Nigeria Journal of Technological Research, 6(2), 13-17.
Bala, A**.,** Aminulai, H. O., Abubakar, M., Abdulrahman, H. S. and Musa, U. (2015). Partial Replacement of Cement with Corn Cob Ash in Concrete. *1st International Engineering Conference (IEC 2015), School of Engineering and Engineering Technology, Federal University of Technology, Minna, Nigeria*. Pp. 465-469.
BS 812 Part 109 (1990). *Method for determination of moisture content of aggregates,* British Standard Institute (BSI), 2 Parks Street, London.
BS 822: part 1: 1973 Method for determination of particle size distribution for fine aggregate
BS 812 Part 103:1: 1985 Method for determination of particle size distribution of coarse aggregate.
BS 812: part 2: 1975 Method for determination of loose and compacted bulk density
BS EN 1008 (2002). Mixing water for concrete: Specification for sampling, testing and assessing the suitability of water, including water recovered from concrete industry as mixing water for concrete. London, British Standard Institution
BS 882 (1992) Aggregates from Natural Sources for concrete, British Standards Institution, 2 Park Street, London
Gambhir, M. L. (2004). Concrete technology second edition, *Tata McGraw-Hill Publishing Company Limited*, New Delhi. London Madrid Mexico.
Marthong, C. (2012) Effect of Rice Husk Ash (RHA) as Partial Replacement of Cement on Concrete Properties, *International Journal of Engineering Research & Technology* (IJERT) ISSN: 2278- 0181Vol. 1 Issue 6, August - 2012
Neville, A. M., and Brooks, J. J. (2002). Concrete Technology, 3rd edition. Pearson Education Publisher. Limited New Delhi India, 623.
Neville, A. M. (1995). Properties of concrete. 4th edition: Longman Group UK Limited.
NIS 87 (2004). Standard for sandcrete blocks. Nigeria Industrial Standard: *Standard Organization of Nigeria*, Lagos, Nigeria.
Shehu I. A., Mohammed A. D., Sheshi A. U. and Alpha A. A. (2016). Assessment of Potentials of Bida Bush Gravel on Strength Properties of Self Compacting Concrete International Journal of *Structures;* Volume 90. No 9002
Yusuf A., Abdullahi M., Sadiku S. and Aguwa J. I. (2020). Mechanical Properties of Concrete using Bida Natural Aggregate as Coarse Aggregates. USEP: Journal of Research Inform ation in Civil Engineering, Vol.17, No.3

.

C. Aigbavboa et al. (Eds.): Sustainable Education and Development, pp. 818-832, 2024.
https://doi.org/10.1007/978-3-030-68836-3 1