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Assessment of the Suitability of Timber Products as Concrete Reinforcement Bars in Green Buildings

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ABSTRACT

This study considered the use of three locally available materials as a replacement for carbon steel reinforcement bar in reinforced concrete. Melina, Opepe and Bamboo specimens were obtained, prepared and subjected to six structural tests. Three specimens each were prepared for each test giving a total of 54 specimens. Hounsfield tensometer was used to carry out the structural tests. Tensile strength, Compressive strength, Shear strength, Charpy impact, Brinell's hardness and Flexural tests were carried out. Results showed that Melina had the highest Compressive strength of 16.250 N/mm^2, which is approximately 6.5% that of carbon steel. The highest Flexural strength was 77.097 N/mm^2 which is approximately 4.406% that of carbon steel while the highest Hardness strength was 78.733 HB 5/1000, which is approximately 65.611% that of carbon steel. Opepe had the highest shear strength of 70.721 N/mm^2 which is approximately 30.1% that of carbon steel and the highest impact strength of 8.874 J/cm which is approximately 13.09% that of carbon steel. Bamboo had the highest tensile strength of 138.158 N/ mm^2 which is approximately 33.66% that of carbon steel. It was concluded that Melina is the best alternative of the three materials, but would be an unsuitable, unsafe and weaker reinforcement alternative to carbon steel.

1. INTRODUCTION

Building construction projects in Nigeria have both direct and indirect impacts on the environment. The identification of likely impacts on the environment in order of severity is a task that needs to be accomplished for the realization of a minimum effect of construction project on the environment (Koleosho and Adeyinka, 2006). As the world population increases in conjunction with rapid development in economy and society, the need for buildings continues to increase thus leading to shortage of energy and deterioration of the environment (Shi and Liu, 2019). Buildings consume 30 – 40% of the worlds' energy consumption, generates 30 – 40% of wastes and accounts for 30 – 40% of greenhouse gases released annually (Umar and Khamidi, 2012; Nduka and Sotunbo, 2014). Green building practices aim to reduce the environmental impact of building. According to USEPA (2009), over 130 million housing units and buildings in the United States have been developed. The International Energy Agency, in 2008, released a publication that estimated that existing buildings are responsible for more than 40% of the world's total primary energy consumption and for 24% of global carbon dioxide emissions (Howe, 2010).

Green building (also known as green construction or sustainable building) refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from planning to design, construction, operation, maintenance, renovation, and demolition (USEPA, 2009). The common objective of green buildings is to reduce the overall impact of the built environment on human health and the natural environment. This is achieved by efficient usage of energy, water, and other resources, protection of occupant health and improvement in employee productivity and reducing waste, pollution and environmental degradation (USEPA, 2009). It is easier and more cost-effective to prevent waste than to clean it up afterward. Waste exist at every stage of a products transition from a raw material through manufacturing, transportation and use (Ross and Meadows, 2006). The concept of green buildings in Nigeria and Africa is an alien technology which has not been adequately addressed in previous works. Also, it is a general belief that a green building will cost much more than a conventional building (Cole, 2000) but some middle point is required to be found out by analyzing the real situations and conditions in the market. Furthermore, Nigeria as a nation is now spending her huge resources on importation of steel which is not necessary even in fabrication of long span trusses for sophisticated structures because timber can be used to achieve economy, strength, durability, aesthetic, and time saving (Ezeagu and Nwokoye, 2009).

Rebar (short for reinforcing bar), known when massed as reinforcing steel or reinforcement steel is a steel bar or mesh of steel wires used as a tension device in reinforced concrete and reinforced masonry structures to strengthen and aid the concrete under tension (Merritt, 1995). They are generally solid and circular in shape. The most common type of rebar is carbon steel, typically consisting of hot-rolled round bars with deformation patterns.

According to Mehta et al. (2014), integrating green building materials into building projects can help reduce the environmental impacts associated with the extraction, transportation, processing, fabrication, installation, reuse, recycling, and disposal of these building industry source materials. In the process, the construction cost both on the building and its maintenance is reduced using green materials.

There exists a knowledge gap in the areas of the strength properties of some of these green materials, affecting their integration into designs or construction and a proper understanding of the interactions of these materials to other materials and building components as a whole. This work addresses the lag in knowledge with a view of obtaining a paradigm shift towards the greater interest in use of green materials for building constructions in Nigeria.

According to a study carried out by Ezeagu et al. (2015), it was concluded that timber is an elastic material that depicted deflections that are within the safe limits. It has been judged to be good as structural members for structures with loads less than their maximum compressive forces. Bamboo has been shown to be a viable alternative to reinforcing steel in concrete construction. There are more than 90 genera of Bamboo divided into about 1,200 species (Mehra et al, 2007). Bamboo is commonly found in Africa, Asia and Central, South America, some parts of Europe and North America. Compared to steel, concrete and timber, less mass of Bamboo is able to withstand more loads. Bamboo is one of the strongest building materials. It is reported that 50 times less energy is required to generate $1m^3$ per unit stress for Bamboo as a construction material as compared to steel or concrete. This makes Bamboo a suitable alternative to steel in load bearing applications

(Liese, 1985; Ghavami, 2009). Bamboo plant is found to be an effective carbon sink and effective in mitigation of greenhouse effect (Choi and Ahn, 2014).

The aim of this work is to determine the strength properties of some green building materials i.e. Bamboo, Melina and Opepe. The qualities of these materials shall be put to structural test to determine their suitability as structural reinforcement replacement materials to reinforcement steel.

2. MATERIALS AND METHODS

2.1. Materials collection

The Opepe and Melina wood specimens were obtained from a carpenter's workshop at Ifite Awka while the Bamboo specimen was obtained from Bamboo log bought at Timber market, Umuokpu both in Awka-South LGA, Anambra state.

2.2. Apparatus

The tests were carried out with the following apparatus: A Hounsfield tensometer, a sensitive weighing balance and ventilated oven.

2.3. Specimen Preparation

Three specimen labelled specimen 1, specimen 2 and specimen 3 were used for each of the tests for each sample of Opepe, Melina and Bamboo. There was no difference in the dimensions of the specimen for each test. The specimen were cut to the standard dimensions of 160 mm × 19 mm × 3.2 mm for tensile strength test, 20 mm × 20 mm × 20 mm for compressive strength test, 100 mm × 20 mm × 3.2 mm for Charpy impact and moisture content test, 300 mm × 19 mm × 3.2 mm for flexural strength test and 20 mm × 20 mm × 3.2 mm for shear strength and Brinell's hardness test, through the following steps:

- Standard measurements were marked out for each specimen on the material using a metre rule and a pencil.
- These measurements were cut out using a saw giving some allowance around the measured boundary.
- Using an electric sandpaper machine, the edges were evened out to produce a uniform dimension throughout the specimen.
- Measurement was carried out regularly during the sandpapering process in order not to exceed the required dimensions.

The method of test, analysis and presentation of test results were in accordance with ASTM D638 (ASTM 2014).

2.4. Tensile Strength

Tensile tests are used to determine how materials will behave under tension load. The chucks of the tensile test were fixed on the nose pieces of the tensometer. The test pieces were inserted one at a time into the tensile chucks and locked up approximately. The tensometer graph was fixed to the graph drum of the machine firmly. The working fluid (mercury) of the machine was initialised and the load/extension scale zeroed. Gradual but continuous load was applied through the longer handle of the machine; causing the working fluid to begin its movement. At each interval, the recording pin attached to the cursor was pressed down with the left hand while the machine was gradually loaded with the right hand. The load/extension property of the test piece is drawn on the graph attached to the revolving recording drum. At failure, the true values of the load and extension were extracted and converted into stress/strain. The graph of the stress/strain of the test pieces was plotted to determine/measure the Tensile Strength and Modulus of elasticity (MOE) of the test pieces.

2.5. Compressive Strength

This is a mechanical test that measures the maximum amount of compressive load a material can bear before fracturing. For the compressive strength test, the chucks of the tensile test were replaced with the chucks of the compressive test on the nose pieces of the tensometer and the same process for the tensile strength test was carried out. The graph of the stress/strain of the test pieces was plotted to determine/measure the compressive strength of the test pieces.

2.6. Impact Strength

The standard test for measuring impact energy is the Charpy test. This gives an indication of the characteristics of the material during fracture. The specimen was clamped into the pendulum impact test fixture with the notched side facing the striking edge of the pendulum. The pendulum was released and allowed to strike through the specimen. The energy absorbed during the impact is recorded and measured in Ft-lb and then converted to S.I. unit of J.

2.7. Shear Strength

Shear test is designed to apply stress to a test sample so that it experiences a sliding failure along a plane that is parallel to the forces applied. The shear spindle was fixed on the compressive chamber of the testing machine (spindle diameter = 6.00mm) to create the sharing effect. The test piece was inserted horizontally on the compressive chamber to make contact with the spindle knob. A gradual but continuous load was applied through the handle of the machine which is recorded on the graph drum. This loading was continued until the spindle had perforated the sample. The load application was stopped and the amount of force required to shear the test piece was measured.

2.8. Flexural Bending Strength

The three-point flexural bending test provides values for the modulus of elasticity in bending (Ef), flexural stress (σf), flexural strain (□f), and the flexural stress-strain response of the material. The chucks of the flexural tester were fixed on the nose pieces of the tensometer. The sample was inserted into the 3-point flexural tester chamber firmly. The tensometer graph was fixed to the graph drum of the machine firmly. The working fluid (mercury) of the machine was initialized and the load/extension scale zeroed. Gradual but continuous load was applied through the longer handle of the machine causing the working fluid to begin its movement. At each interval, the recording pin attached to the cursor was pressed down with the left hand while the machine was gradually loaded with the right hand. The load/extension property of the test piece was then drawn on the graph attached to the revolving recording drum. Once the mercury level was constant, irrespective of the amount of load applied, the loading was stopped and the corresponding value on the graph noted.

2.9. Brinell's Hardness Test

Hardness test is used to determine the resistance of a material to indentation. The Brinell Bulb (indenter pin) was fixed on the Hounsfield testing machine. The test piece was inserted facing the direction of the indenter in a horizontal direction. The surface area of the test piece was well polished. A constant load applicable to the samples was chosen. The load was applied to reach the chosen value then stopped and the sample removed. The depth of penetration on the test piece was measured and recorded.

2.10. Moisture Content

Water content or moisture content is the quantity of water contained in a material. The specimen was dried in a ventilated oven at a temperature of 105 ^oC to 115 ^oC. The specimen was then cooled to room temperature and its mass obtained. The completely dried specimen was immersed in clean water at temperature of 27 ^oC – 29 ^oC for 24 hours. The specimen was then removed and traces of water were wiped out with a damp cloth. The specimen was then weighed and its new mass was obtained.

3. RESULTS AND DISCUSSION

3.1. Tensile Strength

All three (3) materials exhibited very low tensile strength and modulus of elasticity compared to carbon steel which is 410 N/mm^2 and 140000 N/mm^2 respectfully. From Figure 1, the three specimens for Opepe wood showed similar trend when subjected to an equal range of tensile stress. The same is seen from Figure 2 for Melina specimen and Figure 3 for Bamboo specimen. This indicates that an average value from results of the three specimen is suitable to draw conclusions. From Table 1, for Opepe wood, the average tensile strength and modulus of elasticity were 76.754 N/mm^2 and 2371.666 N/mm^2 respectively. For Melina wood, the average tensile strength and modulus of elasticity were 99.232 N/mm^2 and 2344.547 N/mm^2 respectively. For Bamboo log, the average tensile strength and modulus of elasticity were 132.401 N/mm^2 and 2638.528 N/mm^2 respectively. The low strength values obtained from the test on the various wood specimen, therefore, implies that Bamboo, Melina and Opepe have low strength under tensile loading. The low values could be attributed to the structure and composition of the wood materials (Winandy and Rowell, 1984).

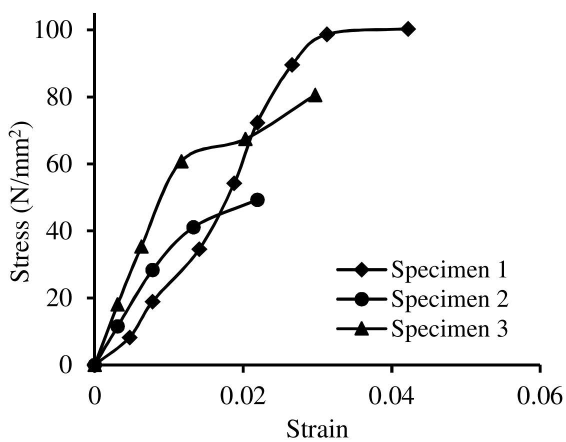

Figure 1: Tensile stress – strain curves for Opepe specimen

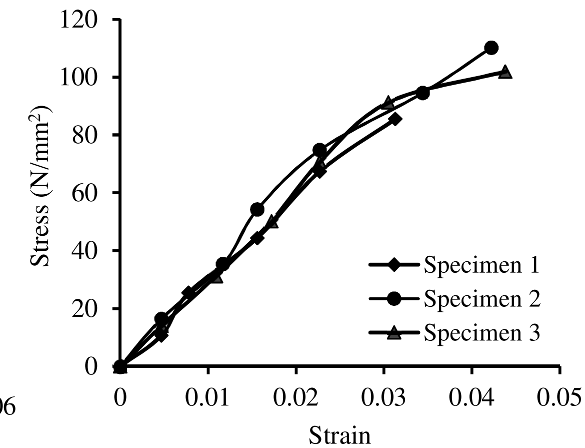

Figure 2: Tensile stress – strain curves for Melina specimen

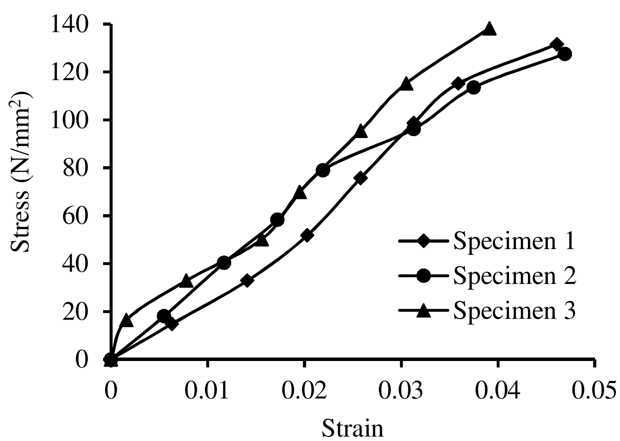

Figure 3: Tensile stress – strain curve for Bamboo

Table 1: Tensile strength and modulus of elasticity of the test materials

Material	Specimen	Maximum tensile strength (N/mm^2)	Modulus of elasticity (N/mm^2)
Opepe	Specimen 1	100.329	2638.421
	Specimen 2	49.342	2330.827
	Specimen 3	80.592	2145.749
	Average	76.754	2371.666
Melina	Specimen 1	85.526	2105.263
	Specimen 2	110.197	2033.64
	Specimen 3	101.974	2894.737
	Average	99.232	2344.547
Bamboo	Specimen 1	131.579	2687.815
	Specimen 2	127.467	2548.342
	Specimen 3	138.158	2679.426
	Average	132.401	2638.528

3.2. Compressive Strength

All three (3) materials exhibited very low compressive strength when compared to that of carbon steel which is 250 N/mm^2. From Figure 4, the three specimen for Opepe wood showed similar trend when subjected to the same range of compressive stress. The same is seen from Figure 5 for Melina specimen and Figure 6 for Bamboo specimen. This indicates that an average value from results of the three specimen is suitable to draw conclusions From Table 2, the average compressive strength of Opepe wood was 8.67 N/mm^2. The average compressive strength of Melina wood was 15.67 N/mm^2 while that of Bamboo log was 10.58 N/mm^2. The low strength values obtained from the test on the various wood specimen, therefore, implies that Bamboo, Melina and Opepe have low resistance to compressive forces when compared to carbon steel. The low values could be attributed to the structure and composition of the wood materials (Winandy and Rowell, 1984). However, this could be substantiated by further research.

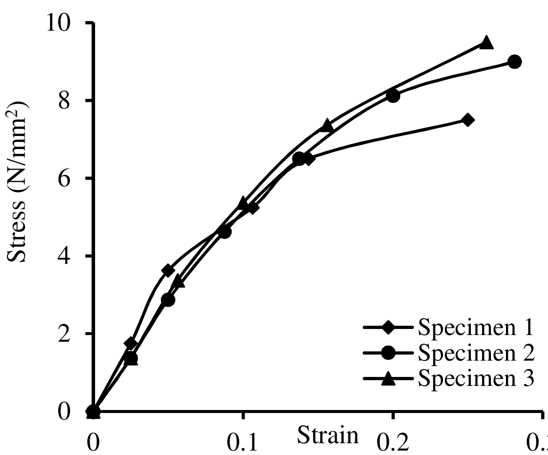

Figure 4: Compressive stress – strain curve for Opepe

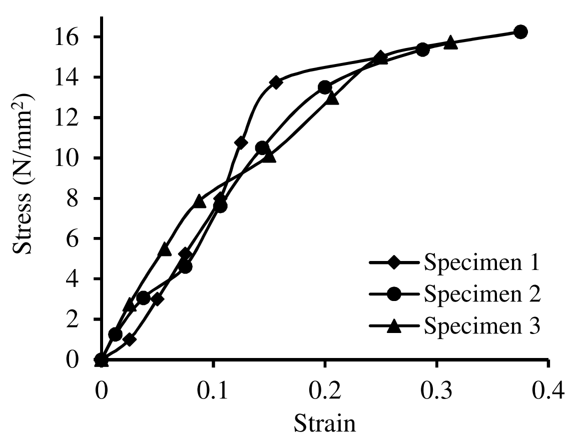

Figure 5: Compressive stress – strain curve for Melina

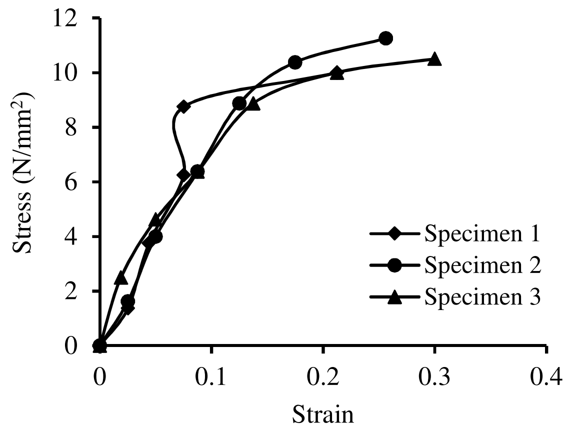

Figure 6: Compressive stress – strain curve for Bamboo

Table 2: Compressive strength of the test materials

Material	Specimen	Maximum compressive strength (N/mm^2)
Opepe	Specimen 1	7.500
	Specimen 2	9.000
	Specimen 3	9.500
	Average	8.67
Melina	Specimen 1	15.000
	Specimen 2	16.250
	Specimen 3	15.750
	Average	15.67
Bamboo	Specimen 1	10.000
	Specimen 2	11.250
	Specimen 3	10.500
	Average	10.58

3.3. Impact Strength

The three (3) materials exhibited low impact strength to impact loading compared to that of carbon steel which is 67.7909 J/cm. From Table 3, the average value of Opepe wood was 8.227 J/cm. The average value of Melina wood was 8.014 J/cm while that of Bamboo log was 7.829 J/cm. The low impact strength values obtained from the test on the various wood specimen implies that Bamboo, Melina and Opepe have very low absorption ability to mechanical energy under impact loading. The poor performance could also be attributed to the structure and composition of the wood material (Winandy and Rowell, 1984) which defines its response to applied load.

3.4. Shear Strength

The three (3) materials exhibited low shear strength compared to that of carbon steel which is 235 N/mm^2. From Table 4, the average value of Opepe wood is 67.185 N/mm^2. The average value of Melina wood is 57.756 N/mm^2 while that of Bamboo log is 61.881 N/mm^2. The low strength values obtained from the test on the various wood specimen, therefore, implies that Bamboo, Melina and Opepe would exhibit a weaker bond compared to that of carbon steel rebar. The reason for this could be attributed to the structure and composition of the wood materials (Winandy and Rowell, 1984). However, the values obtained from the tests could have also been affected by human errors in measurements and in conducting tests.

Table 3: Impact strength of the test materials

Material	Specimen	Impact strength (J/cm)
Opepe	Specimen 1	7.897
	Specimen 2	7.909
	Specimen 3	8.874
	Average	8.227
Melina	Specimen 1	7.909
	Specimen 2	7.999
	Specimen 3	8.135
	Average	8.014
Bamboo	Specimen 1	7.888
	Specimen 2	7.593
	Specimen 3	8.006
	Average	7.829

Table 4: Shear strength of the test materials

Material	Specimen	Shear strength (N/mm^2)
Opepe	Specimen 1	70.721
	Specimen 2	63.649
	Specimen 3	67.185
	Average	67.185
Melina	Specimen 1	53.041
	Specimen 2	63.649
	Specimen 3	56.577
	Average	57.756
Bamboo	Specimen 1	60.113
	Specimen 2	67.185
	Specimen 3	58.345
	Average	61.881

3.5. Flexural Strength

The three (3) materials exhibit very low flexural strength compared to that of carbon steel which is 1750 N/mm^2. From Table 5, the average value of Opepe wood was 57.92 N/mm^2. The average value of Melina wood was 61.164 N/mm^2 while that of Bamboo log was 48.99 N/mm^2. The low strength values obtained from the test on the various wood specimen could be attributed to the structure and composition of the wood materials with special emphasis on non-homogenuity and anisotropic properties of wood (Winandy and Rowell, 1984). The low values implies that the wood materials cannot effectively withstand any load that would subject it to excessive bending and it would easily snap under heavy load.

Table 5: Flexural strength of the test materials

Material	Specimen	Maximum load (N)	Flexural strength (N/mm^2)
Opepe	Specimen 1	87.50	67.460
	Specimen 2	63.00	48.571
	Specimen 3	74.88	57.730
	Average	75.13	57.92
Melina	Specimen 1	100.00	77.097
	Specimen 2	63.00	48.571
	Specimen 3	75.00	57.823
	Average	79.33	61.164
Bamboo	Specimen 1	50.00	38.549
	Specimen 2	62.50	48.186
	Specimen 3	78.13	60.236
	Average	63.54	48.99

3.6. Brinell's Hardness

From Table 6, the results show that all three materials exhibited close hardness range of values with Bamboo hardness number range of 77.4947 - 78.3285 HBS 5/1000 and average value of 77.8039 HBS 5/1000. Melina exhibited hardness range of values 77.5886 - 78.6614 HBS 5/1000 with average value of 78.2135 HBS 5/1000. Opepe exhibited hardness range of values 77.7160 - 78.7332 HBS 5/1000 with average value of 78.096 HBS 5/1000. These values are low when compared to the Hardness number of carbon steel which is 120 HBS 5/1000. These discrepancies could be attributed to the structure and composition of the wood materials in contrast to steel material which is a manufactured material (Winandy and Rowell, 1984).

Table 6: Brinell's hardness number of the test materials

Material	Specimen	Hardness number (HBS 5/1000)
Opepe	Specimen 1	78.7332
	Specimen 2	77.7160
	Specimen 3	77.8388
	Average	78.096
Melina	Specimen 1	78.6614
	Specimen 2	77.9404
	Specimen 3	78.0388
	Average	78.2135
Bamboo	Specimen 1	78.3285
	Specimen 2	77.4947
	Specimen 3	77.5886
	Average	77.8039

3.7. Moisture Content

From Table 7, the moisture content of all wood specimen was within the range of 0.3% to 3.5%, having the lowest value with Opepe at 0.3925% and the highest value with Melina at 3.2283% which is below the recommended 9% to 14% for construction (Loffer, 2018). The range indicates that the specimen used were properly seasoned wood specimen. Gerhards (1982) reported that mechanical properties of wood increase as the moisture content decreases below fibre saturation point, at about 5% MC. Thus, the mechanical strength values obtained from these wood materials should be among the highest possible values that can be obtained for such wood materials.

Table 7: Moisture content of the test materials

Material	Specimen	Moisture content (%)
Opepe	Specimen 1	0.3925
	Specimen 2	0.5916
	Specimen 3	0.8868
	Average	0.6236
Melina	Specimen 1	2.4592
	Specimen 2	3.2283
	Specimen 3	2.7786
	Average	2.822
Bamboo	Specimen 1	0.95
	Specimen 2	0.6145
	Specimen 3	1.7857
	Average	1.1167

4. CONCLUSION

From the results and analysis on the results obtained we arrive at the following specific conclusions:

1. Both tensile strength and elastic modulus of all three materials of Opepe, Melina and Bamboo are low compared to that of steel rebar.
2. Compressive strength of all three materials of Opepe, Melina and Bamboo are very low compared to that of steel rebar.
3. Shear strength of all three materials of Opepe, Melina and Bamboo are very low compared to that of steel rebar.
4. Impact strength of all three materials of Opepe, Melina and Bamboo are very low compared to that of steel rebar.
5. Flexural strength of all three materials of Opepe, Melina and Bamboo are very low compared to that of steel rebar.
6. Hardness strength of all three materials of Opepe, Melina and Bamboo are satisfactory compared to that of steel rebar.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

American Society for Testing of Materials (ASTM) (2014) ASTM – D638. Standard Test Method for Tensile Properties of Plastics. *ASTM International*, West Conshohocken, PA, 2014.

Choi, M. and Ahn, K. (2014). Antibacterial effect of Bamboo charcoal on Streptococcus mutans. *Journal of Korean Society of Dental Hygiene*, 14 (1), pp. 95-100.

Cole, R. J. (2000) Editorial: Cost and value in building green. *Building Research & Information*, 28(5-6), pp. 304-309.

Ezeagu, C.A. and Nwokoye, S.O. (2009). *Design in Structural Timber.* MUFTI books; Nigeria

Ezeagu, C.A., Eromosele, A.F., Okoro, H., Chukwujekwu, U. J. and Emetomo, T. B. (2015). Flexural Strength of Solid and Glue Laminated Timber Beams. *American Journal of Engineering Science and Technology Research*, 3(1), pp. 1-14.

Gerhards, C.C. (1982). Effect of Moisture Content and Temperature on the Mechanical Properties of Wood: An analysis of immediate effects. *Wood and Fiber*, 14(1), pp. 4-36.

Ghavami, K. (2009). Non-conventional materials and technologies: applications and future tendencies. In: *Proceedings of the 11th international conference on non-conventional materials and technologies,* University of Bath, September 6-9, Bath, UK.

Howe, J.C. (2010). Overview of green buildings. National Wetlands Newsletter, 33(1)

Koleosho, H. and Adeyinka, A. (2006). Impact of Environmental Degradation on Growth and Development: Case Study of Iwaya Community, Lagos. In: *International Conference on Environmental Economics and Conflict Resolution,* University of Lagos, July 25-28, Lagos, Nigeria

Liese, W. (1985) Anatomy and properties of Bamboo. In*: Proceedings of the International Bamboo Workshop.* October 6-14, Hangzhou, China. pp. 196-208.

Loffer, L. (2018). Acceptable Moisture Levels in wood - Knowing the moisture content. [Online], Available: www.wagnermeters.com/moisture-meters/wood-info/acceptable-moisture -levels-wood/. Accessed 28th April, 2021.

Mehra, S. P. and Mehra, L. K. (2007). Bamboo cultivation - potential and prospects. *Technical Digest*, 10, pp. 26-38.

Mehta, G., Mehta, A. and Sharma B. (2014). Selection of Materials for Green Construction: A Review. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE),* 11(6), pp. 80-83

Merritt, F.S., Loftin, M.K. and Ricketts, J.T. (1995) *Standard Handbook for Civil Engineers*. 4 Ed., McGraw-Hill Book Company, p. 8.17.

Nduka, D.O. and Sotunbo, A.S. (2014). Stakeholders Perception on the Awareness of Green Building Rating Systems and Accruable Benefits in Construction Projects in Nigeria. *Journal of Sustainable Development in Africa.* 16(7), pp. 118 -130.

Okafor, K.K. and Ezeagu, C.A. (2020) The Analysis of Bending Stiffness and Strength of Glue Laminated Nigerian Timber. *European Journal of Engineering Research and Science (EJERS),* 5(2), pp. 196- 200.

Ross, S. and Meadows, D. (2006). *Green Building Materials*. 2 Ed., Hoboken, New Jersey: John Wiley & Sons, Inc., pp. 10-15.

Shi, Y and Liu, X. (2019). Research on the Literature of Green Building Based on the Web of Science: A Scientometric Analysis in CiteSpace (2002–2018). *Sustainability (MDPI)*, 11(13), 3716

Umar, U.A. and Khamidi, M.F. (2012). Determined the Level of Green Building Public Awareness: Application and Strategies. In: *International Conference on Civil, Offshore and Environmental Engineering (ICCOEE 2012)*, June 12-14, Kuala Lumpur, Malaysia.

U.S. Environmental Protection Agency (USEPA) (2009). Green Building Home. [Online], Available: http://www.epa.gov/. Accessed 28th November, 2020

U.S. Environmental Protection Agency (USEPA) (2009). Buildings and the Environment: A Statistical Summary. [Online], Available: https://archive.epa.gov/greenbuilding/web/pdf/gbstats.pdf. Accessed 19th April, 2021.

Winandy, J.E. and Rowell, R.M. (1984). The Chemistry of Wood Strength. *Advances in Chemistry,* 201, pp. 303-343.