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Physio-Mechanical Properties of Cement Bonded Particle Board (CBPB) Manufactured from Three Wood Species in Cross River State, Nigeria

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ABSTRACT

The study was designed to evaluate the physical and mechanical properties of the Cement Bonded Particle Board (CBPB) produced from the residues of three indigenous trees species in Cross River State, Nigeria with sole aim that, the wood waste generated in sawmills can be as an alternative material in particleboard industry. The species were, Achi-gum *(Brachystegia eurocoma)*; Rubber *(Hevea-brasiliensis)* and white afara *(Terminalia superba)*. Production of the board was carried out systematically. A mixture of 1:1:1 (500g of wood-flour, 500g of cement and 2 litres of water) was used. Boiling, Blending, Chemicalization respectively; Moulds and mat were formed. Pressing was carried out at 50k/N. Finally, CBPB was produced. The physical properties of the boards: for Moisture content: *Braschystegia eurocoma*= 34.7%, *Hevea brasiliensis*=34.6% and *Terminalia superba*=28.6%, Density: *Braschystegia eurocoma* =0.948g/cm^2, *Hevea brasiliensis*=0.886g/cm^2 and *Terminalia superba* 0.854g/cm^2. Water absorption: *Braschystegia eurocoma*=58.9%, *Hevea brasiliensis* 57.9% and *Terminalia superba*-=0.8%. For the mechanical properties: Compressive strength for *Brachystegia eurocoma*=19.73N/mm^2, *Hevea brasiliensis*=19.84N/mm^2 and *Terminalia superba*=22.6 N/mm^2. Modulus of rupture: 1.73, 2.83 and 1.66 N/mm^2 respectively. The particle boards manufactured was dimensionally stable with low absorption and swelling rate. The strength properties were low and not comparable to other boards as read in literature. This results shows that residues of the endemic tree species could be used for particle board production and also waste in the wood based industries could be turned to wealth creation. Further research should be carried out for panel production with rubber residues that can be more structurally stable.

Keywords: Wood properties, *Brachestegia eurocoma, Hevea brasiliensis, Terminelia catarpa*, wood waste.

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I. INTRODUCTION

Production of particleboard was forecasted to be on the increase in 1917 (Oyagede, 1991). Eusebio 2004, point out “that particleboard still be an excellent engineered wood based product and the utilisation of wood waste for particleboard production gives more advantage due to its carbon emissions”. According to Iwakiri 2012, Wood as a raw material contributes significantly in improving a nation’s economic base, industrialisation and comfort of its teeming population”. Iwakiri 2012, “In 1993 made it known that, the consumption of sawn wood and wood based panel products in Nigeria was put at 2.866 and 0.121 million m3 respectively and was projected to increase to 4.704 and 0.688 million m3 by the year 2010.’ Sekaluvu et al., (2014) opined that, “high demands for wood and wood-based products has resulted in over exploitation and the unregulated harvesting of trees in both the natural and plantation forest, thus leading to recent interest in lesser known timber species. FAO (2011) reported that, despite these efforts, demand for wood products still exceeds timber supply resulting in continued cutting without replacement. Anonymous, (2004) observed that, “only about 50-55% of the original wood harvested becomes marketable after processing in sawmills and plywood mills in Nigeria”. Similarly, (Guru et al., 2006) said that, “a critical study of sawmills should be scattered across the country shows large volume of sawdust and wood flakes waste burnt on a daily basis, thus constituting a major environmental problem” (Guru et al., 2006). “The acceptance of CBPB is based on its reliability and resistance to fire, insect attack, decay and their perceived performance during natural disasters such as earthquakes and tropical storms” (Wang and Sun, 2002; Nemli et al., 2009).

However, its use for exterior purposes is rather limited due to lack of proper information on its behaviour against exposure to moisture and sunlight. The increase demand of raw material in wood-based panel industry, led to researches in the utilization potential of substitute lignocelluloses (Guru et al., 2006). “In addition, the biodegradation of lignocelluloses waste in landfills, emits methane, a green- house gas which has 72 times heating effect relating to that of carbon dioxide (CO2)” (Lather and Banks, 1996). “The release of these gases into the atmosphere changes the climate, thereby resulting in global warming, thus, there is the need to find out uses for both waste hardwood and soft board residues generated in the world, especially in developing countries. Apart from the fact that the use of these waste will serve as an environmental management system, it will also contribute positively to the economic growth of countries”. Wood-cement board is fast becoming an attractive building material in comparison with synthetic resin-bounded boards. This is as a result of its resistance to moisture up-take, decay, noise insulation and high fine resistance (Kimothi and Dasari. 2010). Also, the energy problem which the synthetic resin industries are facing has led to shortage and increase in the price of synthetic resin (Oyagede, 1991). Consequently, alternative binders (adhesives) such as mineral cements that are not petroleum based are being considered for particle-boards production. Therefore, study to determines the technical properties of CBPB made from selected tropical species with a view to identifying critical factors affecting performance of strength CBPB of Achi-gum (Brachestegia eurocoma), Rubber tree (Hevea brasiliensis) and White afara (Terminelia catarpa) wood species in Cross River State becomes very imperatives. The result of this study will greatly contribute to the technological development of Cross River State, Nigeria by introducing a new product in Cross River Market as such this study will be of great help to Engineers, Architects, builders and hence integrating in building construction designs in favour of cost-savings, structural and environmental aspect and economical ideas. The low and cost saving industry will help promote livelihood of the people. Entrepreneurial development will be encouraging by introducing the particle board industries with the use of rubber residue found in Cross River State, Nigeria.

II. MATERIALS AND METHODS

The materials This Research was carried out in the Faculty of Engineering, University of Cross River State, Calabar, Nigeria. Workshop 3 (served as production room) and workshop 4 (served as testing room and exhibition hall). See Fig 1a. Below showing the map of the study location. University of Cross River is a tertiary institution owned by the Cross River State Government, which was established in August, 2002. It was formerly a polytechnic, its “the outcome of the merger of 3 (three) tertiary institutions: The Polytechnic Calabar, Calabar, The College of Education, Awi, Akampka, and The

Ibrahim Babangida College of Agriculture, Ovonum, Obubra". Presently University of Cross River has four campuses in Cross River state, they are located in Calabar which is Cross River State's Capital, Obubra Local Government, Ogoja Local Government and also in Okuku in Yala Local Government.

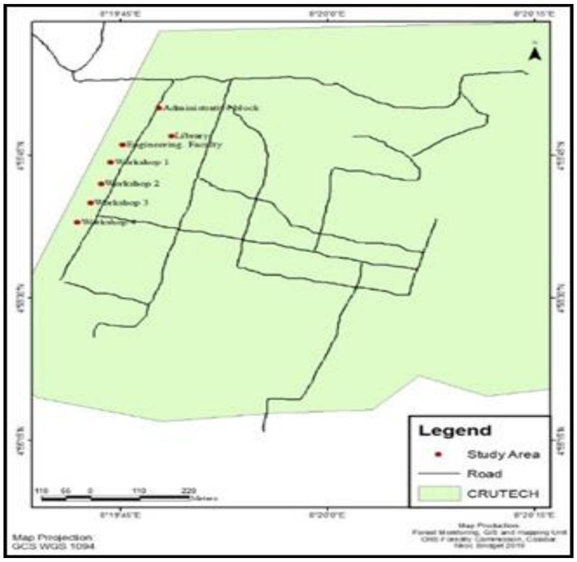

Figure 1. Map showing the study locations in the university

Material collection and pre-treatment

Fig. 2.below showing the map of areas of material collected. This includes wood shavings and saw dust of the three (3) wood species;

- Achi-Gum (*Brachystegia eurocoma*). The residues of this species was collected from Akim Timber Market at No.78 Marian Road, Calabar in Cross River State.
- Rubber (*Hevea brasiliensis*). The rubber residues were collected from Calabar Wood Company Highway Calabar (EPZ), beside Calabar free trade zone in Cross River State.
- White Afara (*Terminalia supaba*). The residues of the species were collected from Ikot Uduak Saw Mill (MCC Road, Calabar). 50kg of the materials were collected, weight and conveyed to workshop No.3 University of Cross River,

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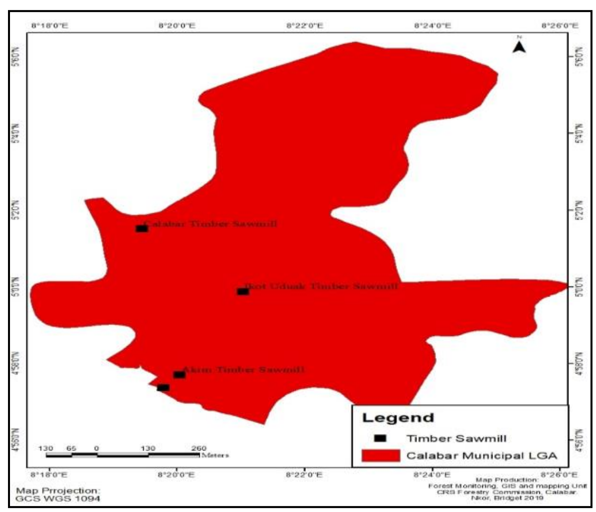

Figure 2. MAP OF CALABAR SHOWING AREAS OF MATERIAL COLLECTION

Material Preparation

The systematic flow chat for CBPB production is shown in table1 and figure 3-10 below.

• Drying: Fig.3 below showing drying of materials and fig 4-6 showing the displayed of wood shaving; Achi-gum, white afara and Rubber also, fig 7-10 showing drying of sawdust of Achi-gum, white afara and Rubber. The entire 50kg of each bag were placed on boards measuring (2400 x 1200) mm. The saw dust board was separated from wood shavings board formed, ceiling fans and electric bulbs of 100 watts were installed in the hall to help circulate air and heat from the bulbs. The shavings and saw dust in the control room remained there for 18-21 days. Within the period, a control open air drying was also carried out.

• Screening: After 21 days, the residues were screened by using metal detector. This was to remove particles of metals and silicon that were in the residues. The screening was carried out for 3 times on different days. During screening, apertures sieve of 3.6 and 2.6 were used. The aperture of 3.6 filters out and particle below 3.6 aperture remained up.

• Weighing: The process of weighing starts immediately after screening. Weighing using electronic weighing balance. Five hundred grams each of the species were weighed and put in cellophane bags and stored

• Soaking of particle: The residues particles of shavings were soaked in boiled water for 48hrs. This helped to remove inhibitory substances like lignin, cellulose in the shavings. The inhibitory substances would have blocked the adhesive (cement) in penetrating the cells of the shavings soaking. It helped to prevent internal heat of hydration (Mohammed *et al.,* 2011).

• Blending: Blending was also done to help reduce the shavings particles to smaller particles. Soaking in boiled water helped to reduce/remove extractives in wood that may also block the penetration of the cement.

• Bleaching: However, after a thorough bleaching for 3 days, it was sure that the inhibitory particles were removed. This was observed in the materials colour. The colour in the bucket became faint.

• Additive application: In the mixture (i.e Cement, wood particles and water) the additive was added by using 2% of pentachlorophenol (PCP) to remove biodeterioration agents. Aluminium sulphate (2%) was added to the mixture to accelerate cement curling (Hong and Lee, 1988; Badejo, 1989).

• Mixing proportion: The cement used was Dangote Cement for the production of the board. The quantities used were as follows: Cement 500g, Wood 500g and Water 2 litres at the ratio 1:1:1 factorial i.e (cement/wood particle and water).

• Formation of paste: The mixing of cement, wood and water was on the ratio 1:1:1. The paste was properly mixed through laboratory blender. After mixing it well the paste was then introduced gradually into the wooden mould (figure 11. below).

• Mould construction: Fig. 12 below is showing mould formed. A wooden mould was formed to serve as a template for the production of the cement bonded particle board. The dimensions of the mould were (200 x 250) mm with a depth of 18mm. A cover plate was also produced to cover the top of the mould after pouring. The top of the mould was little thicker (20mm) than the bottom plate because the top plate bears load from the press.

• Mat forming: The mix of cement, wood particles and water were poured into the mould gradually, the mix were constantly compacted to have a good mass in the mould once the mould is filled with the mix, the mould was covered with cellophane, oil was applied both side of the mould. The top is then covered, allowed to rest for 30 minutes for press-testing of board.

• Pressing of board: When the mixture has set for 30 minutes, the mould and content were taken to the cold press. This is the process of Harding up. After which a pressure of 50KN was applied on the mould to enable water leave the mix completely. This is the period of curling and it remains there for 48 hours.

• Conditioning of board: The pressed boards were kept in the open hall. Inside the hall, two bulbs of 100 watt and ceiling fans were installed. The fans to ventilate the hall and the two bulbs to produce heat for drying. The pressed board was kept under this condition for 48 hrs.

• Demoulding: The mould was demoulded by removing the top layer very carefully not to allow cracks. The sides of the mould were carefully removed; the board then was taken out or separated from the mould. The panel (wood cement board) was dried for seven days. The weight of the specimen was recorded on daily basis to enable. M.C. determination of the board and the process involves in the production is showing in the table1 and figure 1-9 below.

Table 1:
SYSTEMATIC FLOW CHART FOR CBPB MANUFACTURING

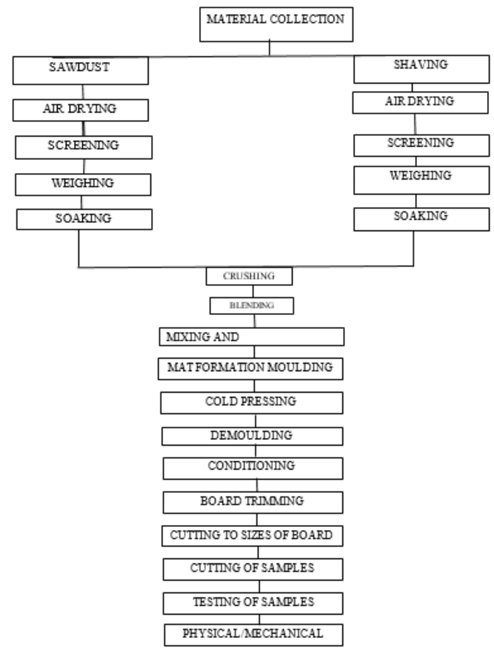

FIGURE 3: Dry process of Sawdust and Shavings Achi-Gum, Rubber and White Afara

FIGURE 4: Achi Shaving

FIGURE 5: White afara Shaving

FIGURE 6: Rubber Shaving

FIGURE 7: Achi sawdust

FIGURE 8: White afara sawdust

FIGURE 9: Rubber sawdust

FIGURE 10: Wooden Moulds for Manufacturing of Board

Figure 10. Detailed Drawing of the Master Jig Add-on

Material Testing: The Universal Testing machine was used to test mechanical strength of specimen by exerting tensile stresses, compressive, hardness, modulus of rupture and elasticity. The SCHMIDT REBOUND HAMMER TEST MACHINE (ASTMC 805-79 and BS 1881 part 20) was used for testing the hardness of the material. Other instrument include;

- Speed meter: for moisture content
- Oven: with temperature 105 degrees for Moisture content (MC)
- High Sensitive Electronic Equipment for absorption and swelling
- Basin of water for absorption and swelling
- The High Sensitive Electronic Equipment was used along with a basin of water for absorption test.
- Calliper for measuring the thickness.

Table 2: Showing various sizes of test samples

S/N	Test samples	No of samples	Size of test samples (mm)
1	Density	15	75 x 75
2	Moisture Content	15	75 x 75
3	Water Absorption	15	75 x 75
4	Thickness Swelling	15	75 x 75
5	Resistance/Impact strength	15	75 x 75
6	Compressive Strength	15	75 x 75

- The experiment design adopted were 1x1x1 factorial with completely randomized design experiment.

- **Determination of Properties of Manufactured Board:**
- Moisture Content:

The three samples; Achi-Gum, Rubber and White Afara were air dried for 24 days and on each day, readings taken and MC calculated according to ASTM 01037, using the formula shown: $\frac{w_1 - w_0}{w_0}\ x\ 100\%$

Where:

W_1 – initial weight

W_0 – Final weight

- Density Determination

The density of the board samples was determined using the relationship below. The specimens were cut into uniform shapes of (75 x 75 x 18) mm i.e. length, width and thickness. Five replicates were cut from each of the samples for the purpose of determining the density of boards. The equation used for the determination was:

Density = The density were calculated as follows:

$P = \frac{w_o}{v_o}$...(2)

Where:

P = Density (kg/m^3)

Wo = Oven -dry weight (kg)

V_O = Volume (m^3)

- **Water Absorption Test Determination**

The water absorption test was carried out by the use of sensitive electronic scale, five replicates from each of the board samples were used. The dimensions were (75 x 75x 18) mm the specimen was immersed horizontally in water, according to (ASTMAD- 190). The absorption after every one-hour weight using equation below;

Water Absorption = $\frac{w_o - w_1}{w_1}\ x\ 100\%$

Where:

1. W_1 – initial weight of specimen
2. W_0 – final weight of specimen.

- **Thickness Swelling Test Determination**

For the thickness swelling of the three species, each of the samples of the species were cut to (75 x 75 x 18) mm. Five replicates were cut from each of the board sample. Dipping of samples for thickness swelling and water absorption is showing in plate 1 below.

- **Compressive Strength Test Determination**

The compressive strength test was carried out in accordance with the specifications of ASTM, D-1037(1978), EN-310 (1993) and EN 319 (1993); the specimen was cut into cubical sizes of 75x75x18mm before being placed on 'Perrier Maurice' compression machine with 2000 KN capacity". The samples were place on the machine platen and loaded at bar per second until crushed, plate 2 below.. The readings of the thickness were carried out with the use of callipers and calculated according to the formula below:

Thickness Swelling = $\frac{T2 - T1}{T1}$ x 100

Where T_1 = Initial thickness

T_2 = Final thickness

- **Hardness Impact Test.**

The test specimens of 75 x 75 x 18mm were used for the rebound hammer of lower impact energy (2.2Nm). Averages of ten readings were in all 30 replicates were produced. The rebound number average was taken for ten times. Fig. 4 below

Plate 1: Dipping During Thickness Swelling and Absorption Test.

Plate 2: The Board Samples after Compression Test

FIGURE 11: Dipping During Thickness Swelling and Absorption

III. RESULTS AND DISCUSSION

Results for Moisture Content of Boards produced

TABLE 3: Moisture Contents of Material Samples of Saw Dust and Wood Shavings

Parts	**Component**	**Qty**	**Specs. (mm)**	**Material**
Sliding Table	Main table	1	12 x 660 x 711	MDF
	Bars	2	9 x 19 x 914	Hardwood
	Crosscut fence	1	38 x 88 x 609	Hardwood
Vertical	Base	1	19 x 304 x 609	MDF
Work	Face	1	19 x 203 x 609	MDF
Support	Brace	2	38 x 140 x 305	Hardwood
Vertical Mitre Guide	Guides	2	13 x 140 x 203	MDF
Right Angle Guide	Guides	1	13 x 152 x 203	MDF

Results of Density

The average density of the board determined for the three species; Achi-gum (*Braschystergia eurocoma*) was 0.95g/m^3; Rubber (*Hevea braciliensis*) was 0.88g/m^3 and white afara 0.85g/m^3 (figure 2 below) shows the average density of the three species.

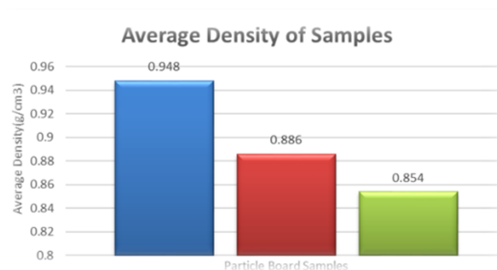

Figure 13**: Shows the average density of particle boards produce**

Water Absorption Results : Figure 6. below shows absorption test carried out on the particle boards produced from Achi-gum, Rubber and White afara. The weight of wood samples before immersion in water was 95.8g, 88.2g, and 85.6g respectively. There was a very sharp increase in weight gain after one hour, there-after, the increase was gradual and reaches 3.5g, 0.6g and 1.9g, respectively Comparatively, all three particle board samples displayed similar absorption characteristic with Achi-gum having higher values than rubber and white afara (Figure 6)

FIGURE 12: The Board Samples after Compression Test

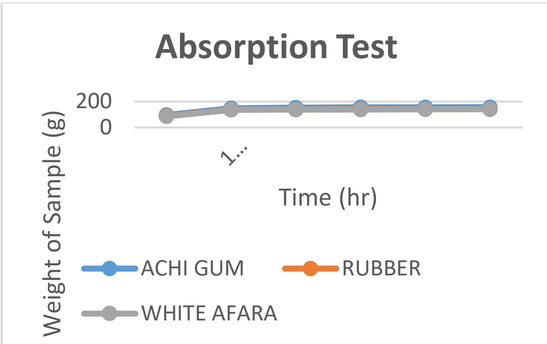

Figure 6: **Comparative Absorption test for Particle Boards of three species.**

Table 5: Thickness Swelling Test

Species	**Weight of Samples (g)**					
	Initial	**1 Hour**	**2 Hours**	**3 Hours**	**4 Hours**	**5 Hours**
Achi-gum	INITIAL	1 HOUR	2 HOURS	3 HOURS	4 HOURS	5 HOURS
Rubber	18	21	21	21	21	21.5
White afara	18	21	21	21	21	22.5

Table 4: Absorption Test Result

Thickness swelling: Table 5 below shows increase in thickness of the particle boards of Achi-Gum, Rubber and White afara respectively. A comparative graph is presented in Figure 4. It was observed that within the period of one hour, the thickness of Achi-gum and Rubber increased by 3mm while White afara increased by 2mm. The thickness remained relatively constant for the next three hours before Achi-gum increased to (21.5mm), Rubber (22.5mm) and White afara (21mm) from the initial 18mm thickness. This is

Species	**Weight of Samples (g)**					
	Initial	**1 Hour**	**2 Hours**	**3 Hours**	**4 Hours**	**5 Hours**
Achi-gum	95.8	148.8	152.3	154.9	155.5	156.8
Rubber	88.2	138.7	139.3	140.3	140.7	140.5
White afara	85.6	135.7	137.6	138.8	140.4	141.1

relatively similar in range to values as observed by meneeis et al., (2007) who noted possibilities in thickness and swelling in some wood species

A. Mechanical properties of manufactured board

- Compressive Strength

Figure 12. Presents compressive strength data for particle boards produced from Achi-gum, Rubber and White afara. The average compressive strength for Achi-gum, Rubber and White Afara was 19.73N/mm^2, 19.84N/mm^2 and 22.60N/mm^2 respectively. The optimum compressive strength of the particle boards produced from three wood species of Achi-gum, Rubber and White afara are 20.44N/mm^2, 20.62N/mm^2 and 22.75N/mm^2 respectively. This range of values is higher comparatively to that of Pablo *et al.*, (1994); (2000) who showed differently at wood materials that exert load.

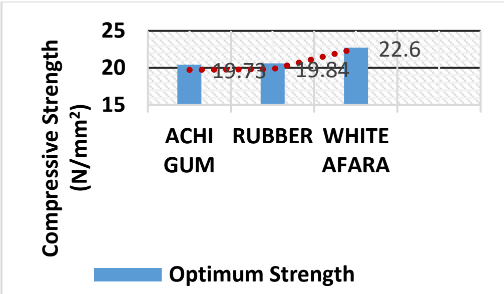

Figure 14: **Showing different compressive strength of the three species samples**

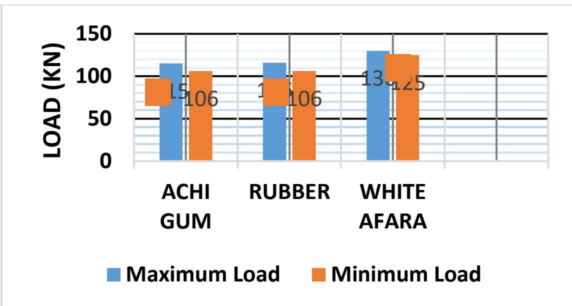

Figure 15: **Minimum and Maximum compressive Strength Result of the three Species**

position	Types of specimen	Rebound number (Hours)										Average rebound no.	Compressive strength (MPA)
90^0		1	2	3	4	5	6	7	8	9	10		
	AC	1	2	3	4	5	6	7	8	9	10		
	RUBBER	10	10	10	10	10	12	12	10	10	12	10.6	10
	WA	13	12	15	13	15	12	12	13	12	14	13.2	13
	Combined	16	12	12	15	15	13	13	12	12	12	13.1	13

Table 6: showing average rebound test of the three species.

Resistance to Hardness: Table 6.above, shows the average rebound number of the three wood species used for the particle board production which indicates the resistance to hardness. The rebound number of Achi-gum, Rubber and White afara were 10.6, 13.2 and 13.1 respectively; therefore, from observation, the range of value are lower compared to that of Mar et al., (2000) in thinner stranded board production. The rebound number for combined species is 11.8 and higher than rebound number for Achi-Gum.

III. Conclusions

From the result obtained in the physical and mechanical properties of the board shows that, the physical properties of the board was smooth due to the methodology used. The blending and removal of lignin from the shaving, made the fine product physically smooth and decoration on the body of the board was not found. The binder used cement did not add color to the board.

The determination of the moisture content of the saw dust and shaving have to bring stability of board. The moisture content of the material used to produce the board was equalized. Other physical properties deduced from the result that affected the board was moisture content determination which help the board moisture in the board to stabilized on Achi-gum 9%, Rubber 10% and White afara 10% respectively. This help in uniformed test of the properties.

Density:
From the result in figure 10. it shows that, Achi-Gum had the highest density of 0.948g/m^{3}which shows that Achi-gum had a greater mass than Rubber 0.89 and white afara 0.82g/m^3 . it clearly shows that penetration of the binder agent and additive was higher than others. Curling took place and remained to increase the weight of board. In all of this, the nature of the board remains the same. The material species of Achi-gum is denser than others.

Absorption
Generally the result shows that absorption rate was higher in the initial hour from all the three species as demonstrated in the figures. However, the absorption slow down and become almost horizontal for the remaining hours. Hence absorption showed a very rapid increased in the first hour in the three species. See the absorption comparative result in figure 11. The rate was very fast and the binder quickly absorbed the water and

after a period, it became saturated and it took no more water into the cells. The result is similar in range to other values in the literature.

Thickness swelling

Thickness swelling was much minimized. The swelling shows that Achi-gum was 3mm, while Rubber shows 2mm. thickness also shows value ranging from 21.5mm, Rubber 22.5 and White afara 21mm from original thickness of 18mm. these value were similar in range to those observed by Mensis *et.al.*,(2007).

Compressive strength

From the result, the capacity of the board to withstand load in the three species read as follow: Achi-gum was 20.25N/mm, Rubber was 19.73N/mm^2 and white afara was 22.70N/mm while the optimum compressive strength was Achi-gum 20.44N/mm^2 Rubber 20.62N/mm^2 and White afara 22.75N/mm^2. The value were higher than found in Pablo et.al (1994 and 2000). Hence white afara curry more load than others.

Resistance to Hardness

The ability to withstand load and the necessary force to cause damages to the board was found to be Rubber having 13.2 rebounds compared to Achi-gum with 10.6 rebounds and 13.1 rebound for white afara. Wet cement as binder has a very low values compared to Mar et.al (2000) on the whole. Wood cement board with cement as a binder, is a very weak material and cannot be used for combination

IV. SUMMARY

Manufacturing cement particle board from three species of Achi-gum (*Brachystegia eurocma*), Rubber (*Hevea brasiliencis*) and white afara (*Terminalia superba*), the physical properties of the three boards were determined and tend to be comparable with other board in the literatures. Some of the physical properties were tend to be higher than others found in the literature; physically, the boards were smooth in texture, but the board of Achi-gum and that of Rubber looked almost similar in colour and in texture but that of White afara glitters. More-so, the mechanical properties like impact tests prove that wood cement board cannot withstand impact strength using the rebound test, it was observed that wood cement board in a none structural materials having rebound less than 20 in number. Even the compressive strength is weaker than the compressive strength of the board using urea/phenol formaldehyde. The uses of cement in manufacturing of board is not encouraging, the binding strength of cement with other material is weak. However this cannot be concluded completely because the ratio of wood cement mixture could have affected the bonding, they could be verified using different mixing ratio between cement and wood. The boards will be mechanically better with the procedure of 50k/N used for initial pressing will be increased. The time was change from 48 hours to 72 hours, were formed with better board while manual mixing method used should be change to mechanical approach as deduced.

V. CONCLUSION

Particle boards using the residue of different wood species, Achi-Gum (*Brachystegia eurocoma*) Rubber (*Hevea brasiliensis*) and White afara (*Terminalia supapa*) were successfully produced using cement as binder. The physical properties (moisture content, density, thickness swelling and water absorption) of the manufactured boards were determined. The particle boards were dimensionally stable with low absorption and swelling rates. The mechanical properties of the boards (compression strength and resistance to hardness) were also measured with the data obtained comparable with those in literature. Particle boards from this result can be used for wood floors, ceiling boards, wall insulation amongst others. The study shows that wood cement board could be manufactured from waste of rubber trees found in a Cross River State forest plantations rather than felling and producing billet for export. It is proven that Rubber tree species can also combine favourably with other species of wood to produce particle boards

Also the use of Dangote cement has proven a suitable binder for the production of CBPB and comparable to other readily used cement types and it is particularly recommended that; The residues used in the production process should be properly crushed before application, Testing apparatus and equipment should be within range to facilitate record taking and minimise errors, Boards for testing should be sealed with cellophane paper in order not to loss or gain moisture before testing for the mechanical properties, The university can undertake the production of such boards to ease flooring and wall partitioning. Thus, helping the department of wood products engineering generate income and showcase it abilities in technology, Materials from rubber whether sawdust, shavings, flake and others have never been used for the production of board or boards composite, but in this project, it has been proven that rubber trees can be used. Hence, waste found in a wood processing industry in C.R.S. be used for board production rather than burning them.

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