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EFFECT OF PARTICLES SIZE OF RAW MATERIAL ON PHYSICAL AND MECHANICAL PROPERTIES OF IROKO PARTICLEBOARD

KADJA Komi*, DROVOU Soviwadan, KASSEGNE Komlan Assogba, BANNA Magolmèèna & SANDA Komla
[*] National Advanced School of Engineers, University of Lomé, (ENSI – UL) Lomé, Togo

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ABSTRACT

The objective of this research was to investigate the influence of particles size on physical and mechanical properties of particleboard made with iroko raw material using organic binder of the African locust husk (Parkia Biglobosa). For this study, four granular (g) classes were used: G1 (raw sawdust, not sieved); G2 ($g \leq 0.8$ mm); G3 (0.8 mm $< g \leq$ 1.6 mm) and G4 (1.6 mm $< g \leq$ 5 mm) with five different binder rates (5%, 7.5%, 10%; 12.5% and 15%).
The panels produced from these different elements were characterized. The mechanical properties (MOE, MOR, E and MOT) determined by the bending and tensile strength tests met the threshold set by ANSI A208.1 (2009). The density values showed that all particleboard were medium density panels except for the ones made with particles size G3 (1.6 mm $<g \leq$ 5 mm).
This study revealed that mechanical and physical properties of such experimental panels were influenced by the particle size. Particles with smaller size provide high density and decrease void inside the panels improving physical properties by reducing swelling rate and water absorption. On the other hand, decreasing particles size decrease the mechanical properties

KEYWORDS: Particleboard; Iroko; grain size; Physical and mechanical properties

1. INTRODUCTION

Until the beginning of twentieth century, wood as a building was used only in its natural and massive form. Technical and industrial developments have led to the development of new wood-based materials, particularly wood-based board. Various types of board have been designed, including plywood boards, fiberboard and subsequently particleboard. Particleboard research began with the desire to recycle or enhance woody material from woodworking waste or agricultural sector. Particleboard are materials made up of an agglomerate small pressed wood particle bonded together by a binder. The have been in consumables since 1940s and since their field of application is continuously increasing. Their consumption has increased by more than 14 million m^3 in 1998 and more than 32 million m^3 in 2004 according to FAO [1,2].

In Togo, these materials are used in furniture, building and their average consumption rose from 574 tons between 2000 and 2003 and increased by 46% between 2004-2005. All these particleboards are imported from outside with a cost price that varies daily [3]

The most particleboards well known are made using formaldehyde-based glue that can be either phenols formaldehyde (PF), urea formaldehyde (UF), melamine urea formaldehyde or polyisocyanate. All these binders pose health and environment problems.

Formaldehyde phenols not only have a high cost but also emit phenol in the environment with a high potency of toxicity[4–6]. Urea formaldehyde-based panels do not withstand water and emit formaldehyde hazardous to humans and their environment [7,8] since it is classified as carcinogen by International Agency for Research on Cancer (IARC) [9].

These problems of conventionnel binders have led to the search for other, less polluting, less toxic alternatives to replace the formaldehyde-based binders. Therefore, biological glues derived from animals and plants are

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explored such as the tannin of the African locust bean pod that is presented in this work. Here, particleboard panels are made using carpentry wastes of Iroko (M. Excelesa sawdust), with an unconventional organic binder of the African locust husk (Parkia Biglobosa).

Under what experimental conditions should organic binder of the African locust husk be used to produce particleboard with good physical and mechanical properties that meet the standards. This is the question we are trying to answer by using four granular group of Iroko carpentry wastes with five different rates of binder.

The effect of particles' granulometry and binder rate on the panels' characteristics have been investigated.

2. MATERIALS AND METHODS

2.1 Panels processing

Iroko (M. Excelesa) dusts was obtained from Lomé (Togo) carpentry wastes, and the pods of the locust bean come from several traditional mustard production units in North Togo (9.2 ° to 10 ° north latitude and 1 ° to 1.5 ° east longitude).

The iroko sawdust and the pods of the locust bean once collected were dried with the drier of MEMENT type 100, of the LARASE, at a temperature of 70 °C for three days and ground with a grinder RETSCH SK 100 type equipped with a sieve of 5 mm. After grinding iroko sawdust was sieved with two sieves. The first is of 1.6 mm and the second of 0.8 mm. Four kinds of particles are therefore manufactured; G1 (the raw sawdust, non-sieved); and the sieved G2 ($g < 0.8$ mm); G3 ($0.8 \text{ mm} < g \leq 1.6$ mm) and G4 ($1.6 \text{ mm} < g \leq 5$ mm).

The African locust been pod ground, was sieved with a sieve of 2.5 mm to separate the fibers from the husk. The passer by part, is retreated with the 0.125 sieve to obtain the tannic powder.

To fabricate the particleboards, the pod powder was mixed with the sawdust at 5%; 7.5%; 10%; 12.5% and 15% for ten minutes. The obtained homogeneous mixture was pressed at 160°C with a pressure of 11 bars for 15 minutes. A manual hydraulic press of CARVER type (11 bars as a maximum pressure), with thermoregulated heating plates, equipped with a square steel mold of 30 cm side, was used for the panels formatting. The wood particles mixed with the binder were gravitarily cast into a mold located between two heating plates. The thermal regulation was done by an electric box and the pressure was obtained by an operating lever.

The resulting particleboards were cut into specimens for physical and mechanical tests. Six panels of 300 x 300 mm thickness varying from 7.5 to 10 mm of each rate and granulometry are then manufactured.

a. Mechanical tests

The resulting finished particleboards were cut into specimens for mechanical tests. The samples were of: (a) 150 mm x 100 mm for bending; (b) 150 mm x 20 mm for tensile. The mechanical properties tests were performed according to the standards EN 312-2 2004 and EN 310 [10–12]. The standards NF B51-124:1993 and EN 310:1993 [10,11] were used to calculate, key mechanical properties such as elasticity modulus in bending (MOE), and in traction (E), modulus of rupture in bending (MOR) and in traction (MOT). For the determination of these characteristics it was assumed that the particleboards were homogeneous and isotropic materials since the particles were of only one type of wood [13]. Figure 1 show the experimental setup for bending test and Figure 2 the sample dimensions used for tensile tests. The values of MOE, MOR and MOT where giving by the following expressions:

$$\mathrm{MOE} = \frac{F.l^3}{4be^3y} \quad \text{or} \quad \mathrm{MOE} = \frac{(F_{12}-F_1).l^3}{4be^3(y_2-y_1)}$$

$\mathrm{MOR} = \frac{3Fl}{2be^2}$, in these expressions: l, was the distance between the supports, e, the thickness of the sample, b, the sample width, F, the strength at break, F_1=10%.F, F_2=40%F, y_1, arrow corresponding to F_1 and y_2,the one corresponding to F_2.

$\mathrm{MOT} = \frac{F_m}{be}$; where F_m was the high strength and b and e respectively the width and thickness of the sample.

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Figure:

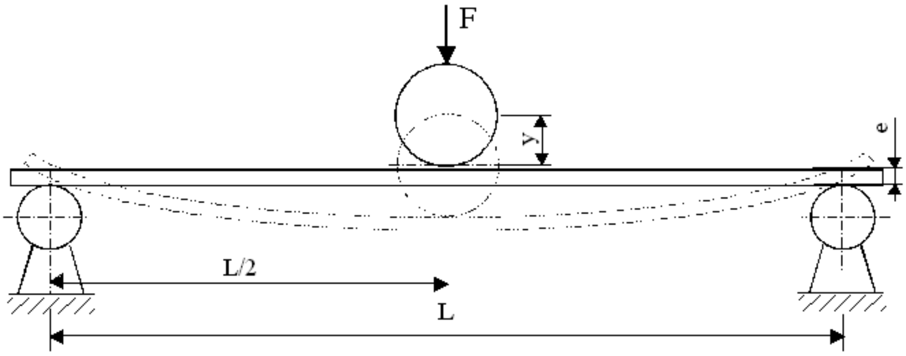

Figure.1: Experimental setup for bending test

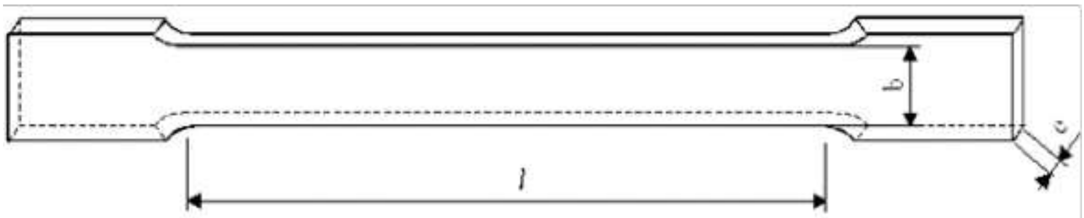

Figure.2: Sample dimensions used for tensile test

2.3 Density and swelling test

The density was assessed according to EN 323 standard on ten pieces of 50 mm x 50 mm for each panel developed. The density was then calculated according to the following expression: $\rho = \frac{M}{V}$ where ρ was the density, M the panel mass and V its volume. The water absorption and swelling tests consists of immersing the specimens in the water and then measuring the thickness or the weight to calculate the swelling rate (in thickness) or the water absorption rate (in mass). The swelling rate and water absorption were measured on specimens immersed in water after 2 hours or 24 hours according to standards EN 317-1993 [14] and using the following expressions:

$TS(\%) = \frac{e_0 - e}{e_0}.100$, where TS was swelling rate, e_0 and e the thickness before and after immersion.

$TA(\%) = \frac{m_0 - m}{m_0}.100$, where TA was the rate of water absorbed, m_0 and m the mass before and after immersion.

3. RESULTS AND DISCUSSION

In terms of density, all the particleboards are of medium density. This density is an decreasing function of the particle size and in other hand an increasing function of binder content (Figure.3). The highest value (680 Kg / m^3) was obtained for a binder rate of 15% and particle size of G2 (g < 0.8 mm).

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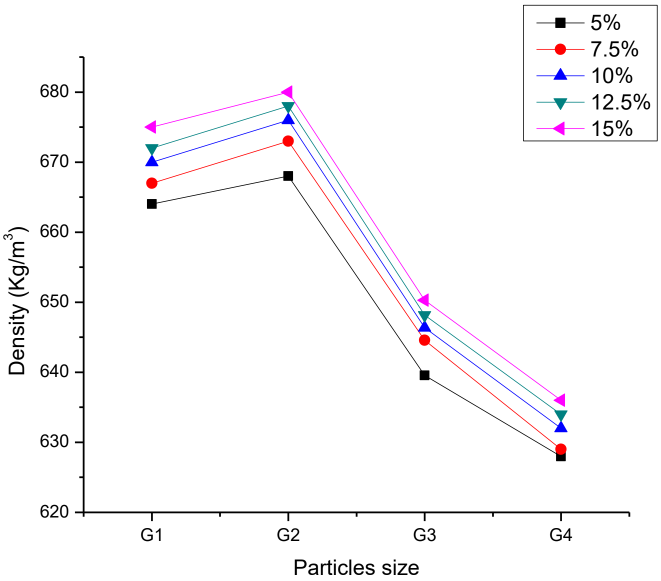

Figure 3: Density as a function of particles size

For raw sawdust the density values are located between those of the G2 and G3 particle sizes. This result is in agreement with the fact that the density of the aggregates decreases when the particle size increases. Small and thin particles provide high density panel due to their flexibility and ability to fill void spaces and greatly determines the degree of contact among particles. According to Maloney et al [15] particle geometry (size and shape) affects the characteristics and properties of particleboards, as well as the type of raw material used, type and amount of adhesive and additives, and the panel structure, defined by the conditions in which the mattress is formed and the pressing conditions. Particle geometry intimately interacts with all these parameters, determining the particleboard properties [15]. Indeed, according to Suchsland et al[16], the geometry of the particles is more significant in the development of the panel's properties than the mechanical properties of the fiber itself. The particle geometry is closely related to the compression ratio and the density of the panel [17,18]. Maloney [19] showed that, the combination of different types of particles as well as their geometric shapes significantly affect the quality of particle boards.

It appears from the results of the swelling test (Figures 4 and 5) that the particleboards of high density are those which have the lowest swelling rate. Thus, the lowest density values 10.2% and 14.5% respectively for 2H and 24H were obtained for a binder rate of 15% and a G2 particle size.

Generally, the swelling rate decreases when the size of the particles used for manufacturing decreases due to the fact that small and thin particles provide high density and decrease void inside the aggregate. The particle boards obtained from raw sawdust which are a mixture of the different particle sizes have an average swelling rate between those of particles G2 and G3 as in the case of density. The high swelling rate was obtained for particleboards made with G4 particles size.

The swelling rates (Figures 4 and 5) found for all the particleboard were slightly lower than the threshold set by ANSI A208.1 (2009) [20] but far from those reported by Maloney [19], Chow [21] and Singh et al [22]. This difference could be due to the binder used. Indeed, Maloney [19] reports swellings varying between 3.3 and 4.5% for a UF binder content of 10%. Chow and Singh et al. [21,22] report swellings of 4.0 to 4.8% and 1.0 to 6.9% respectively.

It appears that for the panels developed with tannic powder of African locust been pod husk (Parkia Biglobosa), the high swelling rate panels were those of G4 granulometry (1.6 mm <g ≤ 5 mm). and the least swelling one those made with G2 granulometry (g ≤ 0.8 mm).

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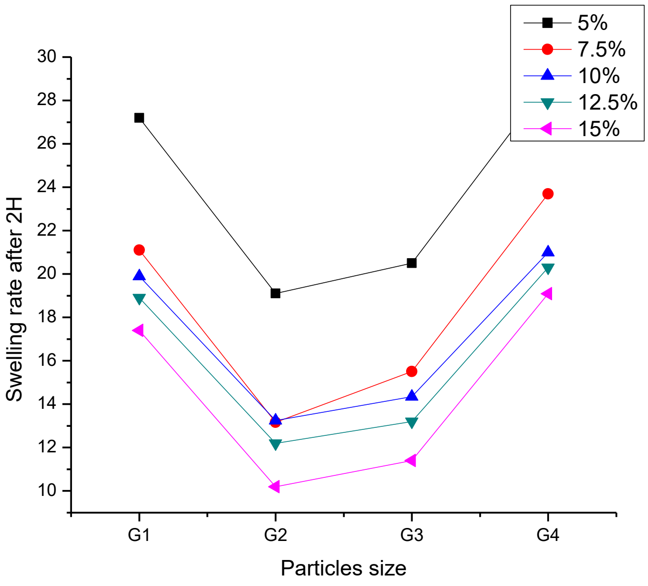

Figure 4: Swelling rate after 2H

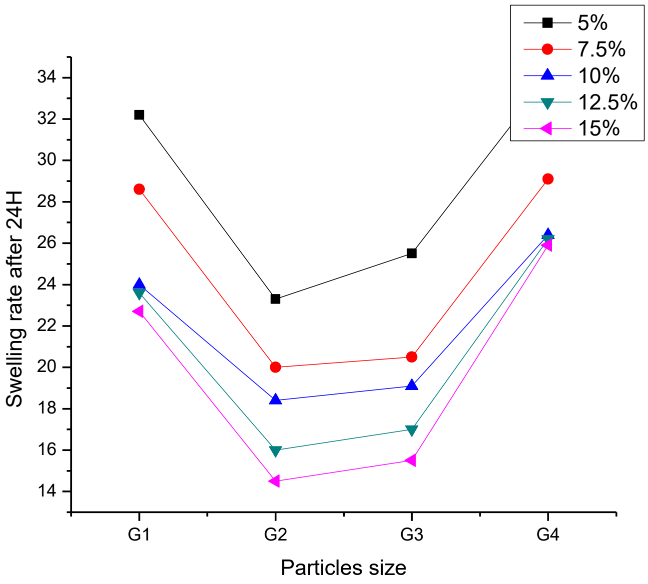

Figure 5: Swelling rate after 24H

From the results of water absorption showed in Figures 6 and 7 it was observed that all the particleboards absorbed a lot of water and increasing binder rate decrease water absorption rate. On the other hand, increasing particles size increase the water absorption rate.

Also, the classification of the high values obtained for the water absorption rate according to the type of particle size was similar to that of the swelling rate studied previously. It should be noted that decreasing the particles size clearly improves the behavior in water absorption of the panels produced. In fact according to Bazzetto et al [23] part of the swelling occurs when water starts to occupy the absorption sites. It could be assumed that the

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Adhesive content, may not have been sufficient to cover the larger particle surface area of treatment panels; therefore, not forming a barrier to water entry into cell walls in the same magnitude as smaller-size particles due to their possible greater coating capacity.

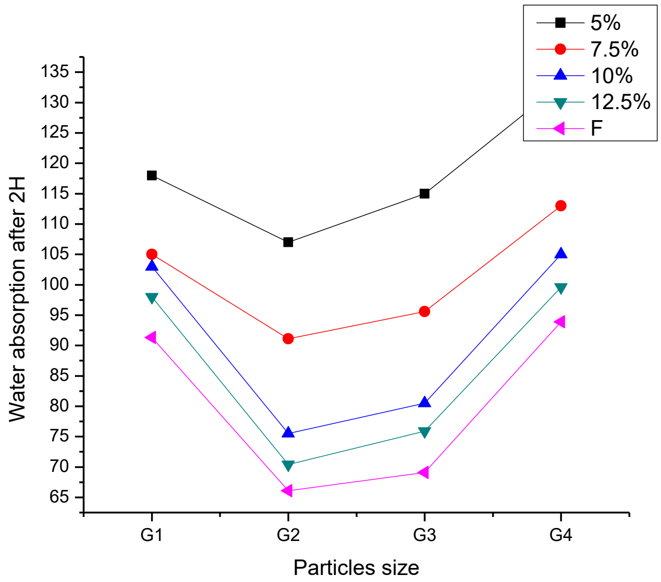

Figure 6: Water absorption after 2H

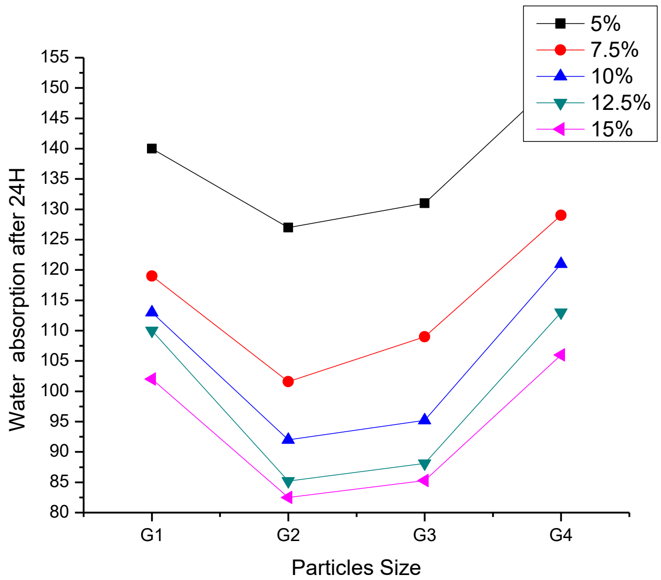

Figure 7: Water absorption after 24H

Mechanical properties were also assessed as a function of the particle size, these are the elasticity modulus and the ultimate strength in bending, MOE and MOR (Figure 8 and Figure.9) and in tension, E and MOT (Figure 10 and Figure 11). The results showed that the particleboard produced with raw sawdust G1 have the highest modulus of elasticity in bending, followed by those of G4 and G3 particleboards and finally those with particle size G2. All the MOE are greater than 1725 MPa, thus satisfying the requirements set by ANSI A208.1 (2009)

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[20], (MOE = 1725 MPa,). These results were clearly superior to those obtained by Sellers et al [24] (MOE = 125 MPa), and Xu et al.[25] (MOE varying from 950 to 1,750 MPa) in the case of panels without binder, treated by injection of water vapor, under a pressure of 6 MPa, at a temperature of 190 ° C.

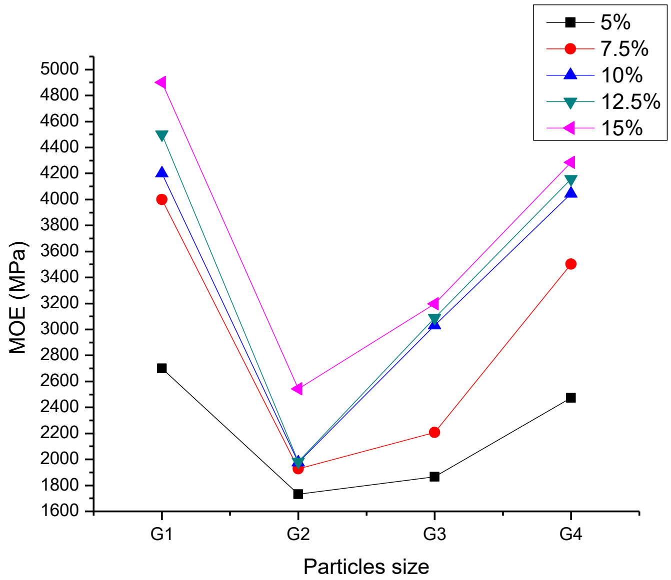

Figure 8: Elastic modulus in bending as a function of particles size

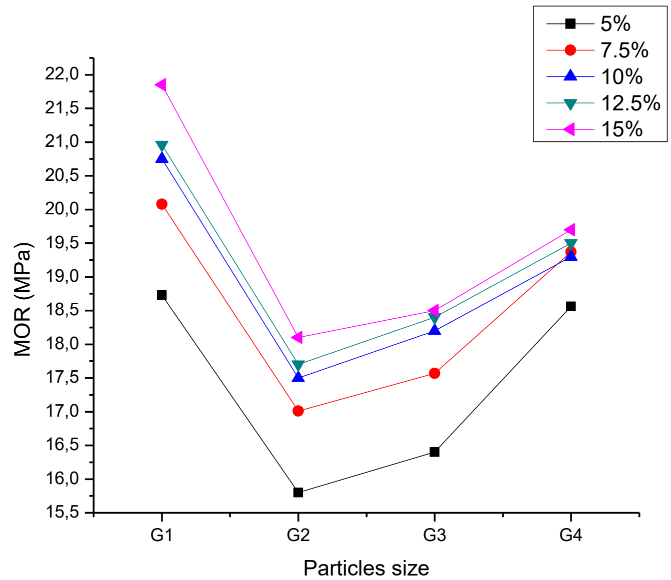

Figure 9: Ultimate strength in bending MOR as a function of particle size

The values measured for modulus of rupture (MOR) showed the same trends as the ones observed for the MOE. MOR increased with increasing particles sizes and binder rates. The highest value was 21.85 MPa obtained for raw sawdust particleboard (G1) using 15% binder rate and the lowest was 15.8 MPa obtained for G2 particles size and 5% binder rate.

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The bending modulus rupture (MOR) complied with the minimum values required by standard ANSI A208.1 (2009) [20] which are from 11 MPa for medium density of class 1 (M–1) and 5 MPa for those of low density of class 2 (LD–2).

The MOR values obtained in this work are in accordance with those obtained by Chow [21], with panels containing red oak sawdust and with panels based on bark of poplar and those obtained by Villeneuve, [26]. They noted that the mechanical properties are improved with the increase in the binder content and particle size. For the elastic module in tension E and ultimate strength in traction MOT there was a huge difference between raw dust particleboard and the others (Figure 10 and 11).

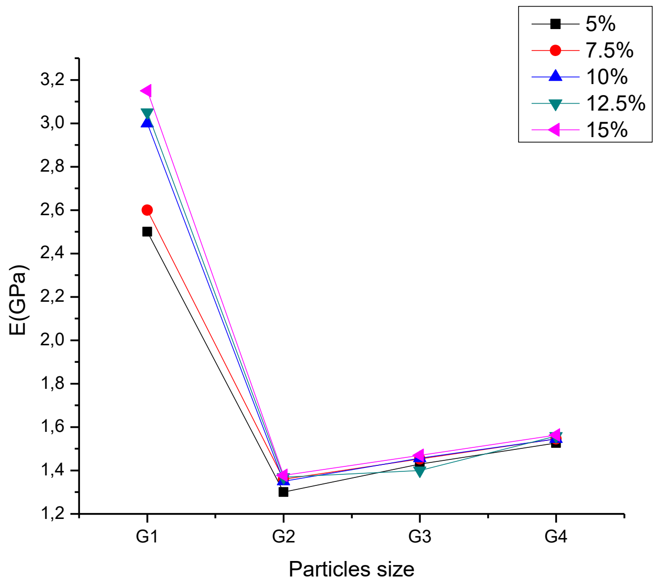

Figure 10: Elastic modulus in tension E as a function of particles size

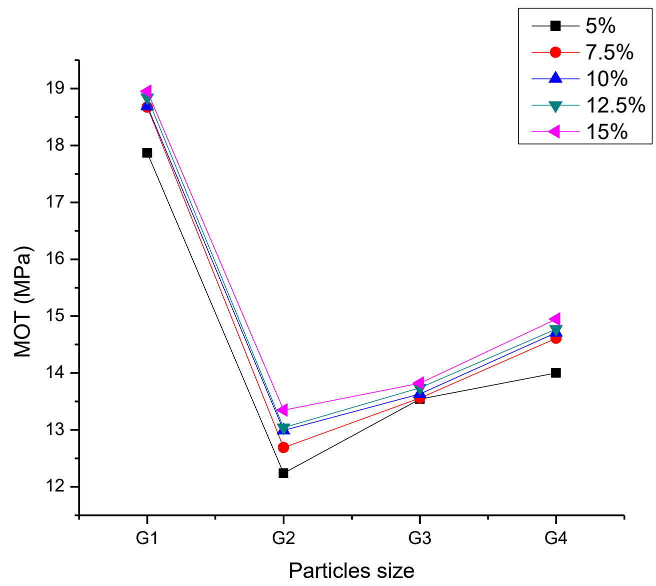

Figure 11: Ultimate strength in tension MOT as a function of particles size

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The results show that the E and MOT increased with the binder rate and particle size and reaches a maximum of 3.15 GPa for E and 18.95 for the MOT at 15% binder rate and for raw sawdust particleboard. The lowest values of E and MOT were respectively 1.3 GPa and 12.24 MPa for G2 particleboard. It appears that MOT and E values obtained for all particleboards complied with the minimum values required by standard ANSI A208.1 (2009) [20].

These results correspond to those obtained by Chow [21] with panels containing sawdust from red oak and Villeneuve [26], with panels of poplar bark base, trembling aspen. They noted that the mechanical properties are improved with the increase in the binder content and particles size.

By analyzing data for mechanical properties in Figures 8 to 11, it was possible to observe that as the proportion of binder increased in panels (especially for binder rate higher than 10%), there was a tendency for the mean MOR, MOE, MOT and E values to get closer. It was assumed that the adhesive content higher than 10% applied does not have impact on mechanical properties.

4. CONCLUSION

The mechanical characteristics, in bending, traction (MOE, MOR, E and MOT) of the Iroko particleboards, determined, respected the requirements of the ANSI A 208.1-2009 standard. This study revealed that mechanical and physical properties of such experimental panels were influenced by the particle size.

The resulting boards fulfilled the mechanical requirements for ANSI A 208.1-2009, and their performance measured in terms of MOR, MOE, MOT, E, thickness swelling, and water absorption was like that of conventional wood particle boards. The board composed of small particles showed a high-density level.

The panels are of medium density (MD-1). The mechanical properties are improved with the increase in the particle size. The best mechanical properties are obtained for the particleboard made with raw sawdust particles, but the water absorption test showed that they could only be used as thermal and acoustic insulation for building.

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