NIGERIAN JOURNAL OF ENGINEERING RESEARCH UNICROSS (NJERU)
Volume 1, Issue 2, 1st June, 2024

INFLUENCE OF ADHESIVE BRANDS AND MIXING RATIO (WOOD/ADHESIVE) ON PHYSICO–MECHANICAL PROPERTIES OF WOOD COMPOSITE PANELS

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Received: 7th July, 2024 Reviewed: 21th July, 2024 Accepted: 2nd August, 2024

Abstract:
This study looked at how the mechanical and dimensional stability features of wood composite panels affected by decreasing adhesive to/wood ratios from 2:2.0 to 2:1.5 and 2:1.0. Furthermore, two adhesive brands—Top-bond and Vinko-bond—were used in order to see if there were any differences in the two brands' qualities over time. In order to determine whether there are any appreciable decreases in these attributes, the cure durations were shortened from 28 to 14 days.
The obtained results show that as the adhesive/wood proportion is dropped, the modulus of rupture increases. The ideal bending strength was determined and achieved with an adhesive/wood ratio of 2.0. On the other hand, modulus of elasticity rose linearly as adhesive/wood ratios increased. The wood-adhesive panels produced in this investigation generally showed good dimensional stability after being submerged in water for 24 and 48 hours. The glue brands utilized in this investigation did not differ significantly from one another, which is thought to be related to their similar component compositions. Reducing cure times from 28 to 14 days often had no effect on boarding attributes.

Keywords: Adhesive brands, composites, dimensional stabilities, properties.

I. INTRODUCTION

In this last century, world had grown faster than before; now people need more furniture than in the past century. More furniture means, more particleboards and more adhesives. Wood adhesives are used in every step of furniture manufacturing. Wood adhesives aim to bond wooden materials with each other or with different materials. Today, production with a faster pace is more important. Furniture production lines could be more productive with fast curing glues. Wood adhesives are used in more than70% of wood products today in the world. The main reason is their use in gluing furniture joints and wood composite materials Gavrilović-Grmuša *et al*. (2016).

Anisotropic and porous, wood has a lot of hereditary anatomical characteristics. Major characteristics include vessel elements and longitudinal fibers in hardwood species, and longitudinal tracheids in softwood species. Their cells have sufficiently large lumens to offer a suitable conduit for the flow of liquid resin. Connecting trenches are frequently sufficient to allow resin to flow. Nevertheless, flow may be impeded by high molecular weight resins or occlusions in the pits or lumens. The term "interphase region" refers to this mixture of wood material and resin. The "bond line" is made up of the interface between the two substrates, each of which has an individual interphase. Numerous parameters, including wood anatomy, permeability, porosity, resin viscosity, surface energy, consolidation pressure, and others, affect the interphase region's geometry. Kamke (2007). However, the forces of adhesion between the different molecules, ions, functional groups, and atoms present on the surface layers of the substrates that are in contact determine the bonding of the materials by glues. These forces are known as adhesion forces, and the term "adhesion" refers to the occurrence. The coexistence of mechanical, physical, and chemical forces is a prerequisite for adhesion. A complicated physical-chemical process is adhesion. It is hard to describe adhesion, and no description that fully satisfies the requirements has been discovered (Kaelblea 1964, Landrock A. 2008, Silva *et al.* 2011). [Online] Silicone Adhesives (2016). Using Gmelina at various adhesive/wood ratios, the work described here aimed to investigate features such bending strength and dimensional stability. Determining whether the type of adhesive matters in influencing the strength qualities was a secondary goal.

II. METHODOLOGY

A. *Sample collection*

Sawdust of Gmelina was collected from wood processing workshop at the Department of Forest Products Development and Utilizatioin in FRIN Ibadan, while the adhesive used was bought from Dugbe market, Ibadan, Oyo State.

The sawdust were then spread out in rows 2 to 4 inches under ambient temperature conditions (approx. 29.5^0 C and 50% RH) until an average EMC of 9% (oven-dry basis) was realized. This step was included to minimize fungal degradation during storage before panel formation.

B. *Board formation*

The quantities of Gmelina sawdust was measured based on the mixing ratio by weight, boards were manufactured based on the experimental design which includes two brands of adhesive (Top bond and Vinko-bond), board density at 1000 kg/m^3, with mixing ratio 2:2.0, 2:1.5 and 2:1.0 of adhesive to wood for both brands.

C. *Laying of the mat*

A plywood plate was used to pre-press the produced mat and covered with another polythene sheet before the top metal caul plate was placed on it. A wooden mold measuring 350 mm by 350 mm by 10 mm was placed on a wooden caul plate covered with polythene sheet, on which the mat was formed. The formed mat was moved to the cold press, where it was compressed for a full day. Several mats were created simultaneously and clamped together in the press condition.

Each sample was preserved for final curing immediately after the 24-hour setting period. Specimens were misted with distilled water, wrapped in cellophane, and then kept at room temperature.

The panel manufacturing processes were done four times for each of the two adhesive brands (Vinko-bond and Top-bond), at adhesive/wood ratios of 2:2.0, 2:1.5, and 2:1.0 (by weight).

In order to prevent edge effects on test specimens, boards were trimmed and then kept in a laboratory setting for 21 days at 20 ± 2 °C. Test samples of 50 mm by 50 mm were used to examine thickness swelling and water absorption. The samples were submerged in water at 30 °C for 24, and 48hours. To ascertain the MOR, however, test samples measuring 195 mm by 50 mm were employed; the tests were conducted in accordance with the standardized protocols outlined in the American Standard (ASTM D1037, 1979).

D. *Board Properties testing*

The selected physical properties tested are Water absorption (WA), Thickness Swelling (TS), and Mechanical properties are Modulus of Rupture (MOR) and Modulus of Elasticity (MOE).

E. *Test for physical properties*

Board sample of 50mm x 50mm x 10mm for the physical properties tests were taken randomly from different parts of the board according to British standard 373(1989). The parameters that were tested are thickness swelling and water absorption.

F. *Thickness swelling and water absorption*

The specimens, measuring 50 x 50 x 10 mm, were utilized to measure water absorption and thickness swelling. British standard 379 (1989) was followed in taking the initial thickness and weight measurements. After that, the sample was immersed in distilled water for 24 and 48 hours. After that, the final weight and thickness were determined in the manner described below to determine the increase in weight and thickness:

$WA\% = \frac{W2-W1}{W1} X\ 100$ ....equation 2

Where: WA = Water absorption (%), W_2 = Final Weight after treatment (g)

W_1 = Initial Weight before treatment (g).

Thickness Swelling was calculated with formula

$TS\% = \frac{T2-T1}{T1} X\ 100$ .... equation 3

Where: TS = Thickness swelling (%), T_2 = Final thickness after treatment (mm)

T_1 = Initial thickness before treatment (mm).

G. *Test for mechanical properties*

The mechanical properties tested were modulus of rupture (MOR), modulus of elasticity (MOE) the samples were cut into 10mm x 50mm x195mm dimension according to British standard.

H. *Modulus of Rupture (MOR)*

The maximum load carrying capacity of a wooden part is known as its modulus of rupture. Test specimens with dimensions of 10 mm for thickness, 50 mm for width, and 195 mm for length were used to calculate the boards' modulus of rupture (MOR). Two rollers at either end supported the test specimen, which was loaded in the middle of the span until failure. The force applied to the specimens that caused them to fracture was noted at the site of failure, and the following formula was used to determine the modulus of rupture:

$MOR = \frac{3pl}{2bd^2}$ .... equation 4

Where MOR = Modulus of rupture ($4/mm^2$)

P = the ultimate failure load (N),

L = the board span between the machine supports (mm)

b= Width of the board sample (mm), d= Thickness of the board sample (mm).

I. *Modulus of Elasticity (MOE)*

Modulus of Elasticity (MOE) which is the measure of the stiffness properties of the board was determined from the bending test carried out on the specimen. The Modulus of Elasticity of the boards were calculated using the formula below

$MOE = \frac{PL^3}{4bd^3h}$ .... equation 5

Where: MOR = Modulus of elasticity (N/mm^2), P = Load (N)

L = the board span between the machine supports (mm)

b= Width of the board sample (mm), d= Thickness of the board sample (mm).

h = slope from the graph

III. RESULT AND DISCUSION

TABLE I

MEAN VALUES OBTAINED FOR WATER ABSORPTION, (WA) (%)

ADHESIVE	MIXING RATIO	SOAKING PERIOD		POOLED MEAN
		24hrs	48hrs	
TOP-BOND	2:2.0	56.10±5.16	58.19±4.55	57.14±4.64
	2:1.5	17.83±2.87	19.70±2.42	18.77±2.65
	2:1.0	19.25±0.90	22.09±1.58	20.67±1.93
	POOLED MEAN	31.06±18.76	33.32±18.60	32.20±18.31
VINKO-BOND	2:2.0	13.73±4.41	15.88±3.89	14.80±4.02
	2:1.5	20.16±5.57	9.19±11.58	19.68±8.43
	2:1.0	11.37±2.71	12.35±2.94	11.86±2.67
	POOLED MEAN	15.09±5.55	15.81±7.18	15.45±6.29

Values are mean of five replicate

In Table 1 above, the water absorption properties of boards (at varying mixing ratios) immersed in water for 24 and 48 hours were displayed. For boards made with top bond as the binder, the lowest and maximum WA reported were 18.77±2.65 (mixing ratio of 2:1.5) and 57.14±4.64 (mixing ratio of (2:2). This suggested that at a mixing ratio of 2:1.5, the resistance of the boards to water entry was at its maximum. Furthermore, the outcome showed that boards soaked for 24 hours had a lower WA value (31.06±18.76), but boards soaked for 48 hours had a higher WA value (33.32±18.60).

After soaking for 24 hours and 48 hours, respectively, the WA values for vinko-bonded boards ranged from 11.86±2.67 (mixing ratio 2:1.0) to 19.68±8.43 (mixing ratio 2:1.5). The least amount of water absorbed (WA) at a mixing ratio of 2:1.0 suggested that the boards were most resistant to water intake when the largest percentage of vinko-bond was used in their manufacture. The overall result (pooled mean) showed that the vinko-bonded boards' WA was 15.45±6.29 and the top bond-bonded boards' WA was 32.20±18.31. In summary, vinko bond performed better than top bond as a binder for board formation. This supports the claim made by Guo and Wang (2016) that the superior water resistance of vinko-based wood glue is a result of its bonding abilities. This enables it to tolerate exposure to water in specific situations or at room temperature.

TABLE II

ADHESIVE	MIXING RATIO	SOAKING PERIOD 24hrs	48hrs	POOLED MEAN
TOP-BOND	2:2.0	19.17±3.07	20.21±3.09	19.69±3.08
	2:1.5	8.68±1.70	9.34±1.53	9.01±1.62
	2:1.0	11.11±5.00	35.52±46.25	23.32±25.63
	POOLED MEAN	12.99±3.26	21.69±16.96	17.34±19.39
VINKO-BOND	2:2.0	17.31±1.90	18.00±2.11	17.66±2.01
	2:1.5	24.91±3.76	27.31±6.87	26.11±5.32
	2:1.0	18.76±7.00	19.62±7.93	19.19±7.47
	POOLED MEAN	20.33±4.22	21.64±5.64	20.98±6.19

ANALYSIS OF VARIANCE (A NOVA) FOR WATER ABSORPTION PROPERTIES

SOURCE OF VARIATION	DF	**SS**	**MSS**	F-VALUE	SIG.
ADHESIVE	1	3364.50	3364.50	143.90	0.00*
MIXING RATIO	2	3614.71	1807.35	77.30	0.00*
SOAKING PERIOD	1	26.70	26.70	1.14	0.29ns
ADHESIVE * MIXING	2	4119.48	2059.74	88.10	0.00*
ADHESIVE * PERIOD	1	7.15	7.15	0.31	0.58ns
MIXING * PERIOD	2	6.67	3.33	0.14	0.87ns
ADHESIVE * MIXING * PERIOD	2	4.37	2.18	0.09	0.91ns
ERROR	36	841.71	23.38		
TOTAL	47	11985.28			

Note: * represents significant while ns represents not significant at $p \leq 0.05$,

ANOVA for water absorption properties was presented in Table 2. Result revealed that effect of adhesive was significant on WA properties. This implied that there was significant difference between WA properties of Top-bond and Vinko-bonded boards. More so, mixing ratio significantly influenced WA absorption properties of the boards produced while interaction between adhesive and mixing ratio also influenced dimensional stability significantly.

TABLE III
POST HOC TEST FOR ANOVA OF WATER ABSORPTION TEST

MIXING RATIO	MEAN VALUES
2:2.0	35.97a
2:1.5	19.22b
2:1.0	16.27b

Note: Values with same letters are the same

According to Table 3 (Post Hoc Test for ANOVA of Water Absorption Test) it was observed that WA property of boards produced at mixing ratio 2:2.0 was not the same with 2:1.5 and 2:1.0

TABLE IV
MEAN VALUES OBTAINED FOR THICKNESS SWELLING (TS, %) PROPERTIES

replicas Values are mean of four replicates

The findings presented in Table 4, which denotes the swelling qualities of the board after soaking in water, indicate that the TS of particle boards with top bond bonded ranged from 9.01±1.62 (mixing ratio 2:1.5) to 23.32±25.63 (mixing ratio 2:1.0). Additionally, it was noted that boards soaked for 24 hours had lower TS (12.99±3.26), whereas boards soaked for 48 hours had greater WA (21.69±16.96). The least TS was found at the mixing ratio of 1:2, which is comparable to the result for the WA property in Table 3. This suggested that, as compared to 2:2.0 and 2:1.0, the top-bond-bonded' physical properties (with regard to the water reaction) were at their finest at 2:1.5.

For Vinko-bonded boards, TS ranged from 17.66±2.01 (mixing ratio 1:1) to 26.11±5.32 (mixing ratio 2.: 1.5). TS of boards were 20.33±4.22 and 21.64±5.64 for 24hrs and 48hrs, respectively. The result implied that the boards’ water intake property slightly increased as period of soaking increased.

TABLE V
ANALYSIS OF VARIANCE (ANOVA) FOR THICKNESS SWELLING (TS) PROPERTIES

SOURCE OF VARIATION	DF	SS	MSS	F-VALUE	SIG.
ADHESIVE	1	159.52	159.52	0.81	0.38ns
MIXING RATIO	2	301.35	301.35	1.53	0.23ns
SOAKING PERIOD	1	114.84	57.42	0.29	0.75ns
ADHESIVE * MIXING	2	163.51	163.51	0.83	0.37ns
ADHESIVE * PERIOD	1	1094.54	547.27	2.77	0.08ns
MIXING * PERIOD	2	350.05	175.02	0.89	0.42ns
ADHESIVE * MIXING * PERIOD	2	394.12	197.06	1.00	0.38ns
ERROR	36	7110.43	197.51		
TOTAL	47	9688.35			

Note: * represents significant while ns represents not significant at p≤0.05

In Table 5 (ANOVA for thickness swelling properties), result revealed that none of treatment effect (Adhesive, Mixing Ratio and Soaking period) or interaction had significant influence on TS property. Consequently, no follow up test was conducted for the analysis.

TABLE VI
MEAN VALUES OBTAINED FOR MODULUS OF ELASTICITY (MOE,)

ADHESIVE	MIXING RATIO	VALUES
TOP-BOND	2:2.0	3590.51±1998.73
	2:1.5	2573.65±282.71
	2:1.0	1896.54±478.33
	POOLED MEAN	2686.90±1304.78
VINKO-BOND	2:2.0	3777.09±1723.44
	2:1.5	2510.62±436.63
	2:1.0	4951.93±2508.42
	POOLED MEAN	3746.54±1913.70

Values are mean of four replicates

For MOE test, result (Table 6) revealed that MOE of top-bond-bonded boards ranged from 1896.54±478.33 (mixing ratio 2:1.0) to 3590.51±1998.73 (mixing ratio 2:2.0). Highest strength property (MOE) recorded at 2:2.0 implied that boards with lowest proportion of top-bond had highest strength property. Hence, as proportion of top-bond glue increased, strength property reduced. This could be attributed to weak cohesive forces of attraction within the molecules of the binder. However, for Vinko-bonded boards, least and highest MOE recorded were 2510.62±436.63 and 4951.93±2508.42 for mixing ratio 2:1.5 and 2:1.0, respectively. Contrary to top-bond-bonded boards, MOE of Vinko-bonded boards was highest at mixing ratio 2:1.0. This implied that with highest proportion of Vinko-bond in board MOE property was improved, this implied that better intermolecular forces was enhanced at higher proportion of binder. Consequently, the *cohesion strength* co-formed by polymerized vinko-bond *was* enhanced by bulk network and improved bonding strength. This corroborates Guo and Wang (2017)

This is a desirable property in board production, especially in applications where resistance to moisture intake and high strength properties are required. This corroborates Guo and Wang (2017) that bonding strength is determined mainly by the adhesion strength (interphase force between adhesive and adherent) and cohesion strength (the chemical and physical forces hold a mass of adhesive molecules together). The cohesion strength refers to the strength of the bulk network co-formed by polymerised.

TABLE VII
ANOVA FOR BOARD'S MODULUS OF ELASTICITY (MOE)

SOURCE OF VARIATION	**DF**	SS
ADHESIVE (AD)	1	6737079.712
MIXING RATIO (MR)	2	5730313.604
AD*MR	2	12011260.800
ERROR	18	41270131.458
TOTAL	23	65748785.574

Note: * represents significant while ns represents not significant at p≤0.05

According to Table 7, treatment effects (and interaction) did not significantly influence boards' MOE. Hence, follow up test was conducted for the analysis.

TABLE VIII

MEAN VALUES OBTAINED FOR MODULUS OF RUPTURE (MOR)

ADHESIVE	MIXING RATIO	VALUES
TOP-BOND	2:2.0	9.36±4.60
	2:1.5	8.54±1.89
	2:1.0	7.61±1.92
	POOLED MEAN	8.50±2.88
VINKO-BOND	2:2.0	5.0310±1.50
	2:1.5	5.7330±1.04
	2:1.0	7.7220±3.21
	POOLED MEAN	6.1620±2.27

MIXING RATIO	VALUES	MEAN
2:2.0		7.1370a
2:1.5		7.1955a
2:1.0	7.6635a	

Values are mean of four replicates

Result on MOR (Table 8) revealed that for top-bond-bonded boards, the MOR ranged from 7.61±1.92 to 9.36±4.60 for mixing ratio 2:1.0 and 2:2.0, respectively. It was observed that MOR reduced as proportion of top-bond used for board production increased. This implied that the higher the binder, the lower the MOR property. However, for vinko-bonded boards, MOR ranged from 5.0310±1.50 (mixing ratio 2:2.0) to 7.7220±3.21 (mixing ratio 2:1.0). It was observed that MOR increased with increase in mixing ratio. That is, as proportion of vinko-bond in board increased, MOR also increased (increase in vinko-bond application increased MOR property). This observation is contrary in top-bond application as its increase during boards production influenced MOR negatively.

TABLE IX
ANOVA FOR BOARD'S MODULUS OF RUPTURE (MOR)

SOURCE OF VARIATION	DF	SS	MSS	F-VALUE	SIG.
ADHESIVE (AD)	1	32.85	32.85	4.69	0.04*
MIXING RATIO (MR)	2	1.33	0.67	0.10	0.91ns
ADHESIVE AND MR	2	20.42	10.21	1.46	0.26ns
ERROR	18	126.16	7.01		
TOTAL	23	180.77			

Note: * represents significant while ns represents not significant

ANOVA presented on Modulus of Rupture-MOR (Table 9) revealed that treatment effect (adhesive) significantly influenced boards' MOR.

TABLE X:
Post hoc Test for ANOVA of Mechanical test

CONCLUSION

Values obtained in this study for strength and dimensional properties of both top bond and vinko bond bonded particleboards compared favourably with all other studies on particleboard research. It shows that the production variables (adhesive) examined in this study had significant influenced on strength and dimensional properties of the boards. This implies that adhesive/wood ratio have significant impact on characteristics of the boards towards utilization.

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