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Assessment of Strength Properties of Timbers used as Alternative to Conventional Timbers in Ekiti state South-western Nigeria

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Abstract
Despite the decreasing quantity of timbers available in the market, most especially timbers commonly used for structural purposes in building construction, the demand for housing is inversely proportional to the quantity of timber available for construction and due largely to higher deficit in provision of housing. *This has led to construction professionals and sellers of timbers source for alternative, thereby using timbers originally not used for structural purposes. This study was carried out to examine the mechanical properties of these non-conventional timbers and compare with the conventional timbers. The timber samples tested were Mango (Mangiferaindica), Cassia (Cassia fistula) and Kolanut (Cola nitida). The mechanical properties tested were compressive, tensile and shear strength according to EN 338 (2016).This showed that Mango, Cassia, and Kolanut have compressive strength of 15.39N/mm^2, 23.5 N/*mm^2, 21.9, *N/mm ^{2}, Bending strength of 42 N/mm^2, 191 N/mm^2, 100 N/mm^2 and shear strength of 54 N/mm^2, 272.5 N/mm^2, 86.88 N/mm^{2}respectively.* The *results were compared with conventional timbers, the three timbers have good bending strength of the same value as conventional timbers, shear strength of these timbers were better but they were all low in compression when compared with conventional timbers. This showed that whenever bending and shear strength were required these three could be used.*

Keywords: Bending strength, Cassia, Compressive strength, Kolanut, Mango, Shear strength

Introduction
Timber, a ubiquitous material and ancient building construction material, is second only to stone as the most used resources in the world (Young, 2009). Timber is a natural material and its uses please the users as it brings warmness and attractive fixtures. The demand for higher strength in non-conventional timber to serve as alternative to commonly used timber is on the rise in Nigeria due to boom in the building construction industry (Ojo and Idieunmah, 2021) and less available commonly used timber species. Deforestation is on the rise and afforestation is very low or not available at all (Ojo and Idieunmah, 2021). Several state governments in Nigeria including Federal government have proposed several programmes to encourage afforestation even to the extent of placing embargo on deforestation. This has yielded little result as some still go and harvest the diminishing timbers illegally (Yusuf and Rasaq 2024; Kalu *et al*., 2014; Ibrahim and Muhammad 2016).
Timber usage is on the rise due to several developments and demand for shelters. The construction professionals and stakeholders have resulted into using timbers that ordinarily were not used before for structural purposes in construction industry. It is generally believed that non-conventional timbers are not as strong as the conventional timbers but these timbers have flooded the market (Ojo and Idieunmah, 2021; Jimoh and Aina, 2017). In view of this, it is imperative to examine the strength properties of these timbers and compare it with conventional timbers whose strength properties had been tested and belief to be good for structural purposes. The timbers studied were mango, cassia and Kolanut.

Materials and Methods

Materials Used

The timbers used for this study were obtained from a local sawmill in Ado-Ekiti, the capital of Ekiti state in Nigeria. The samples obtained were for Mango, Cassia and Kolanut, the timber used were natural seasoned and timber samples were prepared in accordance with EN 338 (2016). The obtained samples were cut to 50mm x 50mm x 300mm for compressive strength perpendicular to grain and bending strength (Plate 1) and 12mm diameter by 250mm for shear strength. The density of each samples were determine in accordance to EN 338 (2016).

(a)

(b)

Plate 1: (a) timber specimen (b) Compressive strength test perpendicular to grain

Mechanical Property Test

Compressive strength test perpendicular to grain

The samples were cut into required sizes of 50mm x 50mm x 300mm, weight of the samples were determined and the samples were inserted into universal testing machine for determination of its compressive strength perpendicular to grain using:

$$Compressive\ Strength = Force/Area \tag{1}$$

Three consecutive tests were carried out and the average determined.

Bending strength test

The length of the samples were measured and the center point determined, the samples were fixed on a detachable beam apparatus with simply supported beam format, a beam clamp was attached to the samples at the center point and a dual guage was fixed under the beam clamp. A load of 2N was applied and the corresponding deflection was recorded from the dialogue. As the load increased, the deflection was recorded. The load was increased up to 10N. This was done three times and the average strength was determined.

Shear strength test

The samples used for shear strength were cut into a circular shape of 12mm diameter, an overall length of 250mm and a gauge length of 222mm. Digital meter used in measuring applied torgue was connected to the source light. Put on and set at zero. The samples were inserted with a socket of the square diameter and fixed to a torsional testing machine. Different angle of twist were used at every angle of twist, applied torgue reading were observed from the digital meter. The process was carried out three times and the average of the three samples determined.

Results and Discussion

Average density: the average density of Mango, Cassia and Kolanut samples used for this study were 695.95kg/m^3, 982.86kg/m^3 and 859.59kg/m^3 respectively (Table 1). This showed that cassia wood has highest density, followed by kolanut and mango timber has the least average density. This might be an indication of the width of the vessels in each timber or an indication of their moisture content. However, the results are within the range specified in the EN 338 (2016) for the strength classes within the range of C14-C30, the density must be between 290kg/m^3 – 380 kg/m^3 density.

Table 1: Average Density of Mango, Cassia and Kolanut

S/N	Samples	Average Density (kg/m^3)
1	Mango	695.95
2	Cassia	982.86
3	Kolanut	859.59

Average weight of samples

The average weight of the three samples were determined by putting each samples on a weighing balance, the values were 292g, 413g and 361g for mango, cassia and kolanut respectively as stated in Table 2.

Compressive strength

Table 2 shows the average compressive strength value for mango, cassia and kolanut wood. They were 15.39N/mm^2, 23.5N/mm^2 and 21.9N/mm^2 respectively. Cassia has the highest compressive strength. These compressive strength values are within the range specified by EN 338 (2016) for strength classes C14, C16, C18, C20, C22, C24, C27 and C30 (15 N/mm^2 - 30 N/mm^2). However, in comparison with other commonly used timbers, these three timbers are poor in compression. For instance, Iroko, Nigerian Mahogany, and Ita have a compressive strength of 47N/mm^2, 41N/mm^2 and 44N/mm^2 respectively (Ojo and Idieunmah, 2021), Bush Mango 65N/mm^2 and Ire 19.32N/mm^2 (Rahmon *et al*., 2020) and Apa 28.59N/mm^2 (Adefemi, 2015).

Table 2: Compressive Strength Value of Mango, Cassia and Kolanut perpendicular to grain

Samples	Weight of samples (kg)	Average Weight (kg)	Volume of samples (m^3)	Area of samples (m^2)	Density of samples (kg/m^3)	Load at Failure (N)	Average Load at Failure (N)	Compressive Strength N/mm^2
Mango								
A	0.283	0.292	0.00042	0.005625	695.95	76900	86466.67	15.3
B	0.255					95200		
C	0.339					87300		
Cassia								
A	0.425	0.413	0.00042	0.005625	982.86	132300	132300	23.5
B	0.408					132300		
C	0.376					132300		
Kolanut								
A	0.367	0.361	0.00042	0.005625	859.59	122400	123233.33	21.9
B	0.366					126400		
C	0.349					120900		

Bending strength

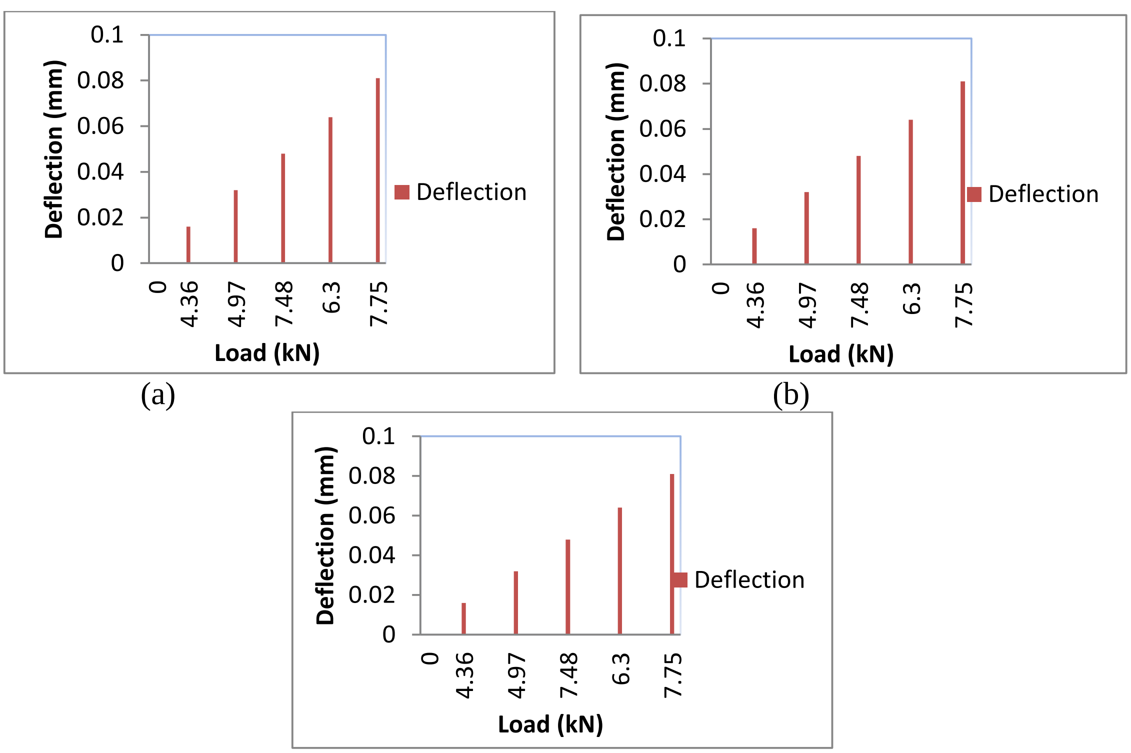
Table 3 shows the bending strength of timbers. They were 42 N/mm^2, 191N/mm^2 and 100N/mm^2 for Mango, Cassia and Kolanut timbers respectively. These values were above the minimum specified in the EN 338 (2016) which is 14N/mm^2. In comparison with other timbers in used such as Iroko, Nigerian Mahogany and Ita that have the strength values of 95.90N/mm^2, 52.00N/mm^2 and 77.20N/mm^2 (Ojo and Idieunmah ,2021), Bush Mango 190.40 N/mm^2 and Ire 60.33N/mm^2 (Rahmon et.al.,2020), Black Afara 50,13N/mm^2 (Kaura *et al*., 2015), D. Fuscu 65.14N/mm^2, and D. Rappa 61.32N/mm^2 (Duju and Badorul, 2002) and Ahun 39.36N/mm^2 (Mohammed, 2014), that the three timbers studied in this study have bending strength values similar to the conventional timbers. Figures 1 shows the graphs of the deflection against applied load for all the three samples. The slope of the graphs is what was used in arriving at the bending strength using the expression below;

$$Bending\ Strength = Slope\ x\ L^3/48\mathrm{I} \quad (2)$$

Where,
L= Length of Timber sample
I= Timber Stiffness calculated from $bd^3/12$
Slope= Difference in slope along YY axis/Difference in Slope along XX axis

Table 3: Bending Strength Value of Mango, Cassia and Kolanut

Samples	Applied load (N)	Mango Deflection (mm)	Average Deflection (mm)	Cassia Deflection (mm)	Average Deflection (mm)	Kolanut Deflection (mm)	Average Deflection (mm)
A	2	1.54	1.38	0.14	0.67	1.36	1.18
B		1.05		1.86		1.03	
C		1.55		0.00		1.15	
A	4	2.05	2.22	3.34	4.49	3.06	1.85
B		1.58		7.07		0.95	
C		3.03		3.06		1.54	
A	6	0.69	3.07	5.15	5.35	5.95	3.83
B		2.73		8.00		2.90	
C		5.78		2.90		2.63	
A	8	1.96	5.15	7.89	7.86	8.93	6.09
B		3.87		9.85		4.90	
C		9.61		5.83		4.44	
A	10	3.15	6.42	10.87	10.17	11.99	8.25
B		6.11		12.65		6.36	
C		10.0		7.04		6.41	



(a) (b)

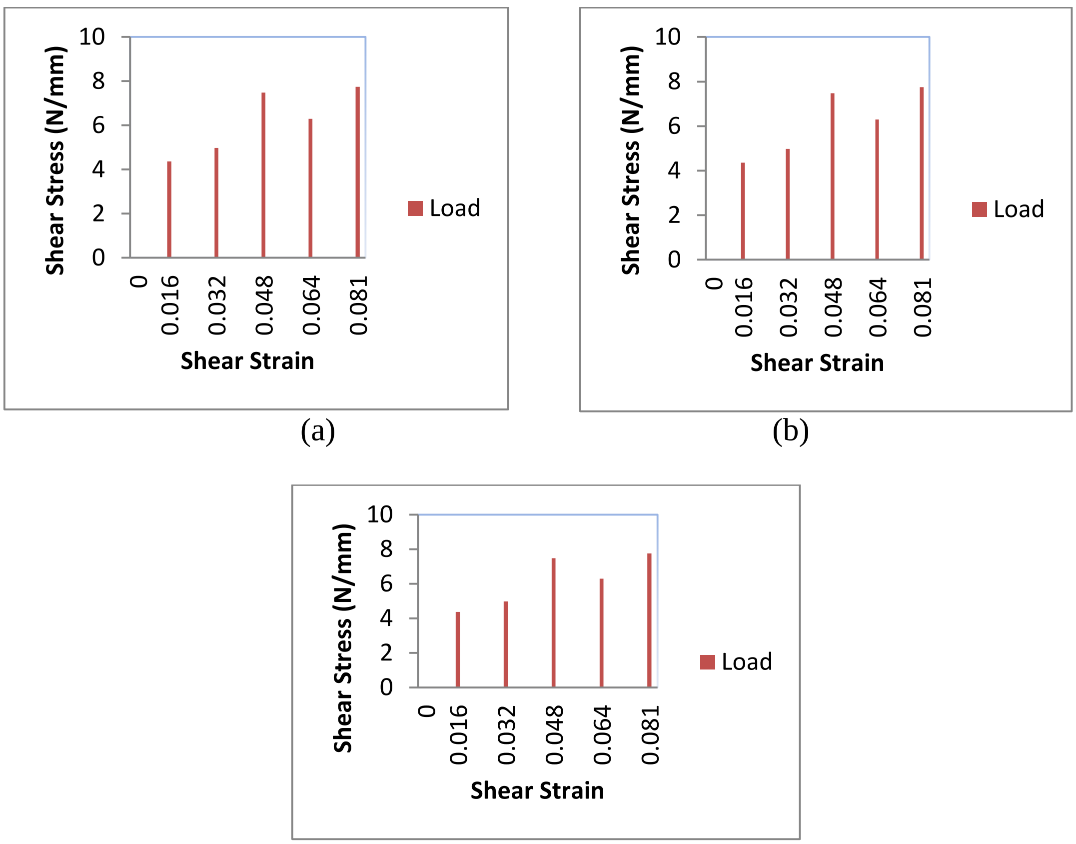
(c)

Figure 1: Deflection against Applied Load for (a) Mango timber (b) Cassia timber(c) Kolanut timber

Shear Strength

Figure 2 is the graphs of Shear stress against shear strain for mango, cassia and kolanut timbers studied. The expression below is the formular used in obtaining the shear modulus. The shear strength results for mango, cassia and kolanut were shown in Table 4 and the values were 54.38N/mm^2, 272.5N/mm^2 and 86.88N/mm^2. The cassia has shown to have good strength properties above other three samples and in this case, it has the highest strength. According to EN 338 (2016), the three results are well below the range specified in the code which is 440N/mm^2 and 1250N/mm^2. The values obtained for other conventional timbers were Iroko 14.00N/mm^2, Nigerian Mahogany 8.14N/mm^2 and Ita 13.40N/mm^2 (Ojo and Idieunmah, 2021), Bush mango 4.48N/mm^2 and Ire 3.69N/mm^2 (Rahmon *et al.*, 2020). Take note that all timbers are below the specified amount in EN 338 (2016). However, mango, cassia and kolanut performed better in term of shear strength than most conventional timber in use.

$$Shear\ Modulus = Slope\ = \frac{\text{change in shear stress}}{change\ in\ shear\ strain} \tag{3}$$



(a) (b)

(c)

Figure 2: Shear Stress against shear strain for (a) Mango timber (b) Cassia timber (c) Kolanut timber

Table 4: Shear Strength Value of Mango, Cassia and Kolanut

Samples	Angle of twist (ϕ) Rad)	Mango Applied Torgue T (Nmm)	Average Applied Torgue T (Nmm)	Shear Stress ɣ=$16T/\pi d^3$	Cassia Applied Torgue T (Nmm)	Average Applied Torgue T (Nmm)	Shear Stress ɣ=$16T/\pi d^3$	Kolanut Applied Torgue T (Nmm)	Average Applied Torgue T (Nmm)	Shear Stress ɣ=$16T/\pi d^3$	Shear Strain Ø=$\phi d/2L$
A	0.6	1591.2	1174.13	3.46	1074.4	1480.7	4.36	707.2	716.27	2.11	0.016
B		1060.8			1713.6			734.4			
C		870.4			1654.1			707.2			
A	1.2	1700	1468.8	4.33	1278.4	1686.4	4.97	367.2	1187.73	3.50	0.032
B		1400.8			1863.2			2067.2			
C		1305.6			1917.6			1128.8			
A	1.8	272	942.93	2.78	1142.4	2538.7	7.48	818	1451.33	4.28	0.048
B		1604.8			3060			2597.6			
C		952			3413.6			938.4			
A	2.4	1360	1187.73	3.50	1088	2139.7	6.30	924.8	1804.27	5.32	0.064
B		612			2733.6			1822.4			
C		1591.2			2597.6			2665.6			
A	3.0	1319.2	1863.2	5.49	1047.2	2629.3	7.75	965.6	1795.2	5.29	0.081
B		1931.2			3481.6			1727.2			
C		2339.2			3359.2			2692.8			

Conclusions

This article has shown that the timbers used in this study as alternative to conventional timber are not totally poor in strength when compared to hard wood timber like Iroko, mahogany and ire. However, from the results of analysis, the compressive strength of these three timbers was below the compressive strength of commonly used timbers in Nigeria. Therefore, it can be said that these timber; Mango, Cassia and Kolanut are not good for structural members are like column and kingpost. Although this study showed that these timber; Mango, Cassia and Kolanut are good for structural members such as beams, tie beam and strut. In conclusion, the structural members or the area in timber is to be used should guide the choice of choosing these timbers.

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