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Effect of Age on the Structural Strength of Timbers Commonly Used in Nigeria

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Article

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Abstract

Timber is a material used for structural purposes in construction. Therefore, it is crucial to understand the characteristics of timber, particularly its strength and the factors that influence it. In this study, timbers studied were *Brachystegia eurycoma* (Eku), *Entandrophragma cylindricum* (Sapele) and *Gmelina Arborea* (Melina). A personal visit to the forest where they were freshly retrieved allowed for the collection of samples of timber from varied ages. By counting the number of annual growth rings, which are a combination of early wood and late wood, it was possible to establish the age of the wood. The acquired samples were cut to standard sizes in accordance with BS 373 1957 (Imprint 1999), 20mm X 20mm X 60mm for determining the maximum compressive strength parallel to grain, 20mm X 20mm X 300mm for determining the bending strength, and 20mm X 20mm X 20mm for static stress strength. Results obtained showed that Eku is better in compressive strength and Sapele is worthier in bending strength. The maximum compressive strength value was 49.31kN/m^2 (at 45years), 45.89kN/m^2 (at 60years) and 11.30kN/m^2 (at 25years), maximum bending strength were 187.55kN/m^2 (at 35years), 278.79kN/m^2 (at 70years) and 176.36kN/m^2 (at 20years) and shear strength were 10.05kN/m^2 (at 50years), 9.22kN/m^2 (at 70years) and 10.91kN/m^2 (at 25years) for Eku, Sapele and Melina timbers respectively. In conclusion, it was determined that the strength of wood is influenced by the age of the wood.

1. Introduction

Timber has been used and adapted by humans since the time human has recognized that they could make use of materials found around them. It is one of oldest construction materials [1]. It has been in use since early Paleolithic times, both for building, manufacturing of tools, weapon and furniture [2].

Timber is one of the environmentally friendly building materials [3]. Although natural and renewable building materials are readily available, they have some restrictions when used for general construction, carpentry, and upholstery [4]. Additionally, since wood is an organic material that degrades over time [5], it must be used as efficiently as possible, particularly when used as a structural material.

Since new trees can be grown where old ones have been cut down, wood is referred to as the only renewable natural resource available for construction in the world. [6] estimates that the world's forests total just under 4 billion hectares, or around 20% of its total land area. According to [7], Nigeria's forest reserves cover roughly 10 million hectares, or 10% of the country's total land area, which is estimated to be 96.2 million hectares. In contrast, Nigeria has an abundance of lumber [8] that, if used appropriately, will be of great advantage to the nation in terms of lowering the cost of construction [9, 10, 11].

Because of its diversity in species and complexity, timber is a complicated building material. The qualities of wood vary depending on the species, age, location, and environmental factors [12], hence they are not constant, predictable, reproducible, or uniform [13]. A surge in the building construction industry in Nigeria has increased the need for high-quality timber for construction. Builders and Engineers have resorted to using wood that was not initially utilized as structural materials due to the over-exploitation and

unavailability of traditional timber species like Mahogany, Iroko, and other timber species, which has become a problem [13].

Different wood species have varying strength properties, this property is affected by Age of timber. Therefore, this study evaluated the impact of timber age on the structural integrity of various timber species. The timbers studied are *Brachystegia eurycoma* (popularly called Eku in South Western Nigeria), *Entandrophragma cylindricum* (Sapele) and *Gmelina Arborea* (Melina).

Brachystegia eurycoma is called by different names by different tribe in Nigeria, such as Okuen (Edo), Okung (Efik), Achi (Igbo) [14], Dewen (Bini), Akpakpa or Apaupan (Ijaw) and Eku or Akalado (Yoruba) [10]. It is economically valuable tree mostly grown in tropical rain forest of West Africa [15]. It is a large tree and its branches are spreading in nature and are either irregular or twisted in shape [14]. Studies on *Brachystegia eurycoma* includes determination of its physical properties [15], Isolation, Characteristics and anti-oxidant activity of a Furo- Chromen-4-one from its seed [16], anti-diarrheal activity of the stem bark extract [14] and its characterization and grading [10]. However, none has compared the age and strength of the timber.

The mahogany species sapele (Entandrophragma Cylindricum) is commonly produced in West and Central Africa. Although it doesn't react to burning, it can be found in drier habitats like abandoned fields. It is a tall tree that can reach a height of 50 meters, and its trunk and main branches are covered in blooms. Literature on Entandrophragma Cylindricum is scarce.

Gmelina Arborea (Melina) is a fast-growing forest species that produces high quality timber used for manufacturing [17]. This species is widely used in commercial quantity in tropical countries in Africa and South America for lumber, pulp, and energy production [18, 19]. It has been used for commercial purposes in countries like Costa Rica [18] and Nigeria for structural purposes.

2. Materials and Methods

All methods were carried out in accordance with relevant guidelines.

The results from the previous Forest Product Research Laboratory, which was presented in bulletin 50, indicated that strength rises with density [20]. The age of timbers is significantly influenced by the same density. As a result, ring width fluctuation will alter the density of the wood and consequently its strength. Given the relationship between a material's density and strength, there will also be a relationship between a material's age and strength.

2.1 Source of timber used

A reconnaissance survey was carried out to various forest-reserves and sawmills in Ekiti State (Nigeria) environs to gather information on available hardwood timbers commonly used in building construction. Ado-Ekiti and Igede-Ekiti being a major place for timber, sawmills were later identified as source

information area for the samples of timber and other social parameters. Lots of hardwood species were discovered, out of which permission were sort and obtained from the saw millers for three most utilized timber for the research study; they are Eku (Brachystegia), Sapele (Entandrophragma cylindricum) and Melina (Gmelina arborea).

2.2 Fortitude of age of timber

Conduction was the dominating function when seasonal growth first started, whereas support was dominant in the later stages. The occurrence of thin-walled tracheid (about 2 micrometer) in the initial part of the season (the wood is known as early wood) and thick-walled (up to 10 micrometer) and somewhat longer (10%) in the latter part of the season (the late wood) is one indication of this shift in concentration.

The annual growth ring is created every year from the combination of early and late wood. The annual growth rings (composed of early wood and late wood) of each sample of timber used in this investigation were counted. If the logs were freshly retrieved, the annual growth rings could be counted with ease.

2.3 Evaluation of the Mechanical Properties

Sequential sampling was employed in this study's sample strategy. This is because different ages of timber were chosen in succession, albeit a modicum of five years' separation was given for each timber in order to give a noticeable change in strength value.

According to BS 5268: part 2 (2002), the mechanical characteristics of timber sections were determined with the suitable sizes. For all specimens, timber section samples were taken at the species' breast height.

The samples were examined by the Hounse field Tensiometer apparatus at the Timber Mechanics Unit of the Forestry Research Institute of Nigeria (FRIN) in Jericho, Ibadan, Oyo state.

2.4 Compressive Strength Parallel to Grain Calculation (MCS//)

The forces at the point of failure were immediately measured after loading wood samples at a rate of 0.01mm/sec. To determine the figure for maximum compressive strength parallel to grain, this was divided by the test specimen's cross-sectional area.

The maximum compression strength parallel to grain was calculated using the calculation in Eq. (1) below, using a standard dimension of 20 x 20 x 60 mm. [21]. For Brachystegia eurycoma, different timber ages tested range from 30, 35, 40, 45, and 50 years, 20, 30, 40, 50, 60 and 70 years for *Entandrophragma cylindricum* (Sapele) and 5, 10, 15, 20 and 25 for *Gmelina Arborea* (Melina).

The calculation of the compressive strength was done in accordance to BS 5268: part 2 (2002).

MCS//$= \frac{p}{bd} N/mm^2$ (1)

Where: p represents the load (N)

b represents the breath of the sample (mm)

d represents the thickness of the sample (mm)

bd is noted as cross-section area(A)

2.5 Measurement of Bending Strength

MOR, the equivalent fibre stress, is typically used to express the bending strength of wood. The expression of Eq. (2) below was used to compute the specimen's fibers at the point of failure. Brachystegia eurycoma, Entandrophragma cylindricum (Sapele), and Gmelina Arborea (Melina) were tested for compressive strength at the same ages. Test dimensions are 20 x 20 x 300 mm.

MOR = $\frac{3pl}{2bd^2} N/mm^2$ (2)

p represents the load in Newton (N)

l represents the length of sample in (mm)

b represents the breath in (mm)

d represents the width in (mm)

2.6 Shear Strength Determination

Using the formula in Eq. (3) below, the shear strength was calculated using a sample size of 20 x 20 x 20 mm [20]. The identical lumber samples and timber ages were used as for compression and bending strength tests.

Shear Strength = $\frac{p}{bd} N/mm^2$ (3)

Where p represents load (N)

b signifies breath of the sample (mm)

d denotes thickness of the sample (mm)

3 Result and Discussion

3.1 Mechanical Properties

3.1.1 Compressive Strength Corresponding to Grain (MCS//)

Results of the mean compression strength parallel to grain for Brachystegia eurycoma, Entandrophragma cylindricum (Sapele), and Gmelina Arborea (Melina) can be seen in Tables 1, 2, and 3. The studied maximum value were 49.31kN/m^2 (at 45 years), 45.89kN/m^2 (at 60 years), and 11.30kN/m^2 (at 25years) for *Brachystegia eurycoma*, *Entandrophragma cylindricum* (Sapele) and *Gmelina Arborea* (Melina) respectively. Brachystegia eurycoma performs better in compression from observation. Nevertheless, from other results, Iroko 47N/mm^2, Nigerian Mahogany 41N/mm^2 and Ita 44N/mm^2 [12], Bush Mango 65.58N/mm^2 and Ire 19.32N/mm^2 [22], Apa 28.59N/mm^2 [23]. The outcomes were within 71.97N/mm^2 > 20.01N/mm^2 except for *Gmelina Arborea* (Melina) where the ages tested are low.

Table 1
Test for Compressive, Bending and Static Shear for *Brachystegia eurycoma* (Eku)

S/N	Age of Timber	Type of Wood	Compressive Test		Bending Test		Shear Test	
			Max. Load (kN)	Max. Strength (kN/m^2)	Max. Load (kN)	Max. Strength (kN/m^2)	Max. Load (kN)	Max. Strength (kN/m^2)
1	30	Heartwood	13.87	34.69	1078.73	60.68	3.53	8.83
2	35	Sapwood	18.38	45.97	3334.26	187.55	2.00	5.00
3	40	Sapwood	19.61	49.03	2157.46	121.36	3.38	8.46
4	45	Sapwood	19.72	49.31	1569.06	88.26	3.18	7.97
5	50	Heartwood	15.93	39.84	2059.40	115.84	4.02	10.05

Table 2
Test for Compressive, Bending and Static Shear for Sapele

S/N	Age of Timber	Type of Wood	Compressive Test		Bending Test		Shear Test	
			Max. Load (kN)	Max. Strength (kN/m^2)	Max. Load (kN)	Max. Strength (kN/m^2)	Max. Load (kN)	Max. Strength (kN/m^2)
1	20	Heartwood	11.98	29.97	1563.70	87.96	2.08	5.21
2	30	Sapwood	15.01	37.53	2083.63	117.20	2.36	5.90
3	40	Sapwood	17.76	44.42	2836.70	159.56	2.79	6.99
4	50	Heartwood	16.62	41.55	3254.25	183.05	3.22	8.07
5	60	Sapwood	18.35	45.89	4067.34	228.79	3.42	8.57
6	70	Sapwood	17.37	43.45	4956.26	278.79	3.68	9.22

Table 3
Test for Compressive, Bending and Static Shear for Melina

S/N	Age of Timber	Type of Wood	Compressive Test		Bending Test		Shear Test	
			Max. Load (kN)	Max. Strength (kN/m^2)	Max. Load (kN)	Max. Strength (kN/m^2)	Max. Load (kN)	Max. Strength (kN/m^2)
1	5	Sapwood	2.34	5.70	1001.73	56.35	9.52	5.21
2	10	Sapwood	2.91	7.30	1178.73	66.30	1.13	5.90
3	15	Sapwood	3.62	9.10	1023.64	57.58	1.66	6.99
4	20	Sapwood	4.16	10.40	3135.36	176.36	1.80	8.07
5	25	Sapwood	4.52	11.30	2589.40	145.65	4.36	10.91

3.1.2 Bending Strength or Modulus of Rupture (MOR)

According to Tables above (1, 2, and 3), the utmost Bending Strength at 35years is 187.55kN/m^2 for *Brachystegia eurycoma*, at 70years is 278.79kN/m^2 for *Entandrophragma cylindricum* (Sapele) and at 20years is 176.36kN/m^2 for *Gmelina Arborea* (Melina). Entandrophragma cylindricum (Sapele) has the highest bending strength of the three, measuring 278.79N/mm^2. Other results include Iroko (95.90 N/mm^2), Nigerian Mahogany (52.00 N/mm^2), and Ita (77.20 N/mm^2) [12], Bush Mango (190.40 N/mm^2), Ire (60.33 N/mm^2), Black Afara (50.13 N/mm^2) [24], D. Fusca (65.14 N/mm^2), and D. Rappa (61.32 N/mm^2) [25], and Ahun (39.36 N/mm^2) [26].

3.1.3 Shear Strength

Brachystegia eurycoma (50 years): 10.05 kN/m^2, Entandrophragma cylindricum (Sapele) (70 years): 9.22 kN/m^2, and Gmelina Arborea (Melina) (25 years): 10.91 kN/m^2 were the results for the three timber samples (Tables 1, 2, and 3). Melina, or Gmelina Arborea, has superior shear resistance. Other results include Bush Mango 4.48 N/mm^2 and Ire 3.69 N/mm^2 [22], Iroko 14.00N/mm^2, Nigerian Mahogany 8.14N/mm^2, and Ita 13.40N/mm^2.

3.2 Eku

Figure 1 showed the graphical representation of the compressive, bending and shear strength of *Brachystegia eurycoma* (Eku in Yoruba) timber at different ages. There is no significant difference in the compressive and shear strength values as observed in the graph. However, the maximum bending strength is at the peak (that is; 30) years above which there is a decline in the bending strength value.

3.3 Sapele

The graphical results of compressive, bending and shear strength of Sapele timber is shown in Fig. 2 below. Similar to Eku timber, the compressive strength and shear strength does not show any significant

difference as the age increases. In the contrary, the bending strength increases as the ages increases.

3.4 Melina

Melina timber has a better maximum bending strength at 20 years above which there is a decline in strength value, but the compressive and shear strength results showed no significant difference as seen in Fig. 3 above. In Contrast, this study showed that timber is good in bending strength.

4 Conclusion

One could draw the conclusion that the strength qualities of wood improve with age. However, timbers are generally good in bending strength. Eku timber is better among the three timbers studied in compression, Sapele is better in bending strength and there is no significant difference in the shear strength. When compared to other timber samples used in earlier studies, the three timbers also demonstrated good strength characteristics. When choosing one of these three timbers to utilize as a structural part, this information about their strength properties could be helpful. Further, there is a need for more test at higher age for Sapele timber to ascertain the age of the true maximum strength above which there will be a decline.

Declarations

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Conflict of Interest

Authors declare no conflict of interest

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Data Availability Statement

All data generated or analysed during this study are included in its supplementary information files

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Figures

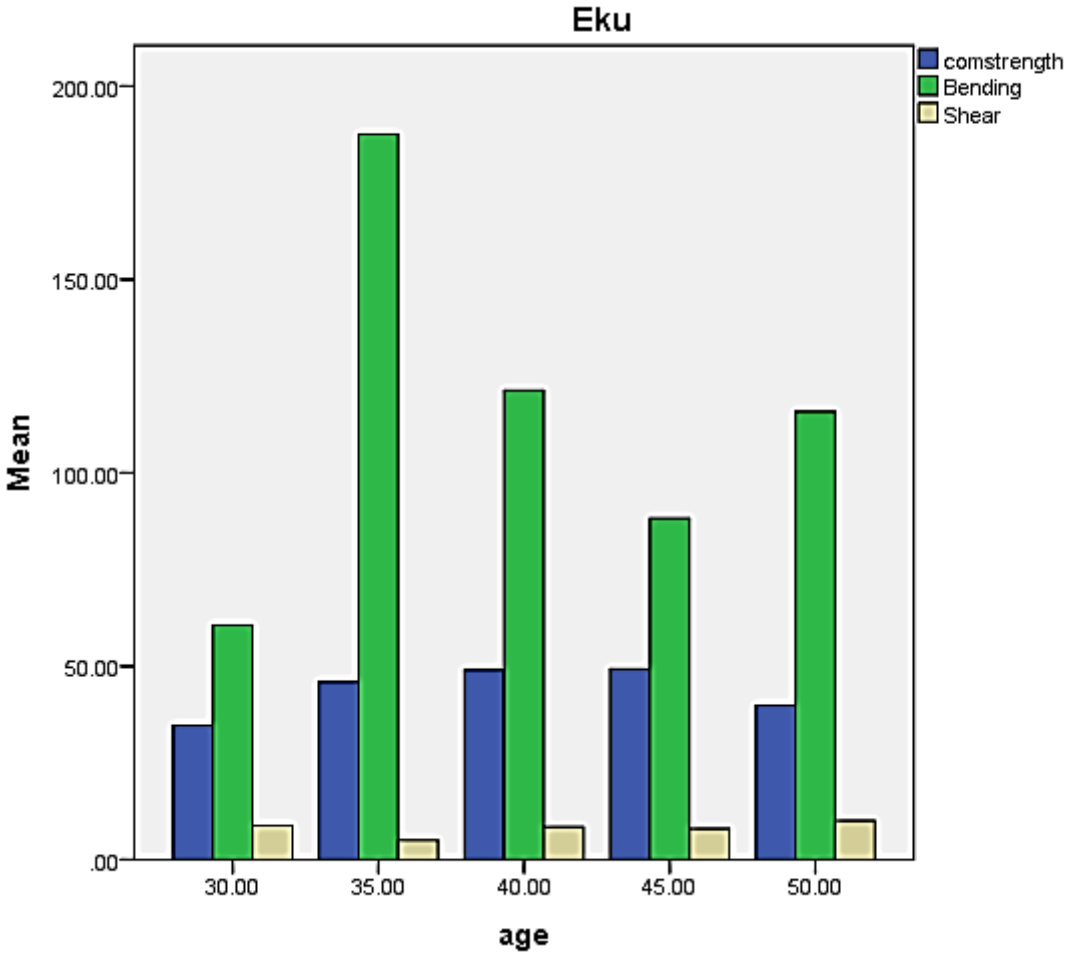


Figure 1

Compressive, Bending and Static Strength for Eku

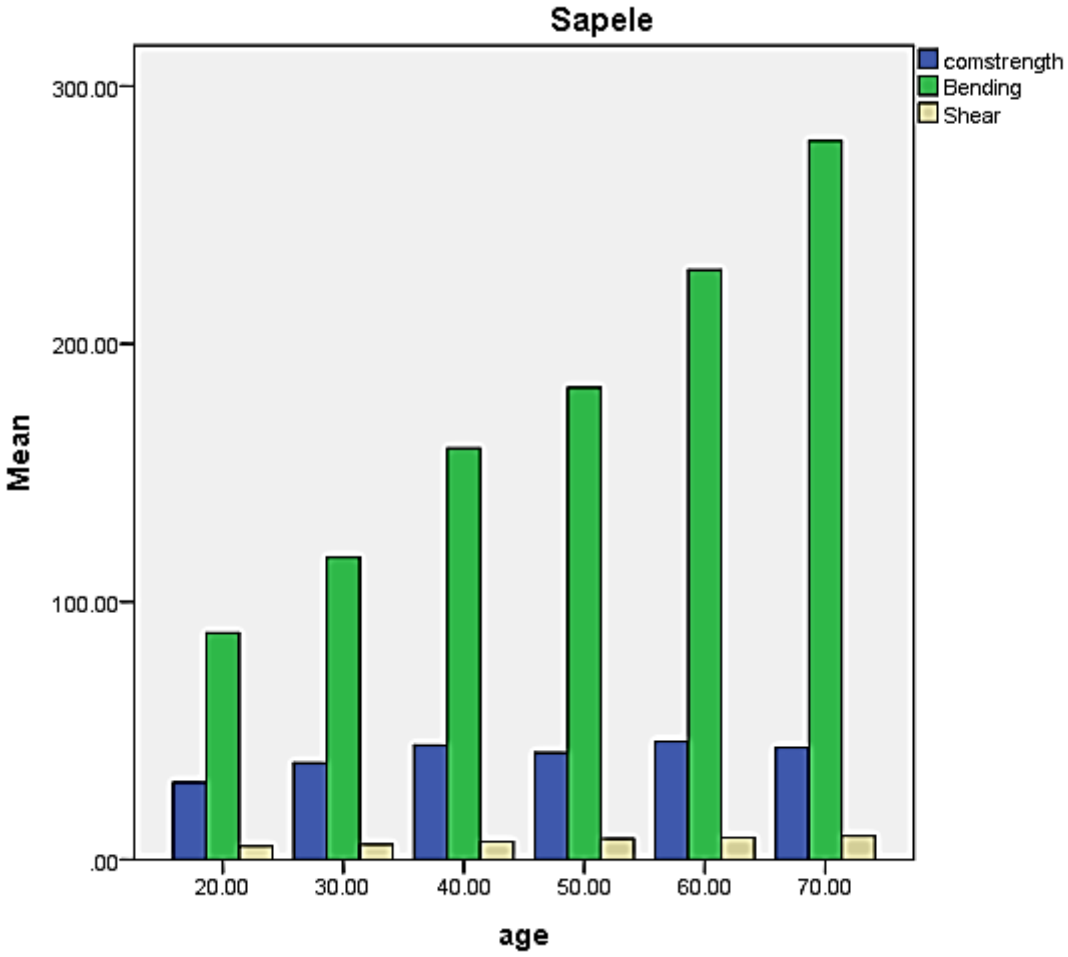


Figure 2

Compressive, Bending and Static Strength for Sapele

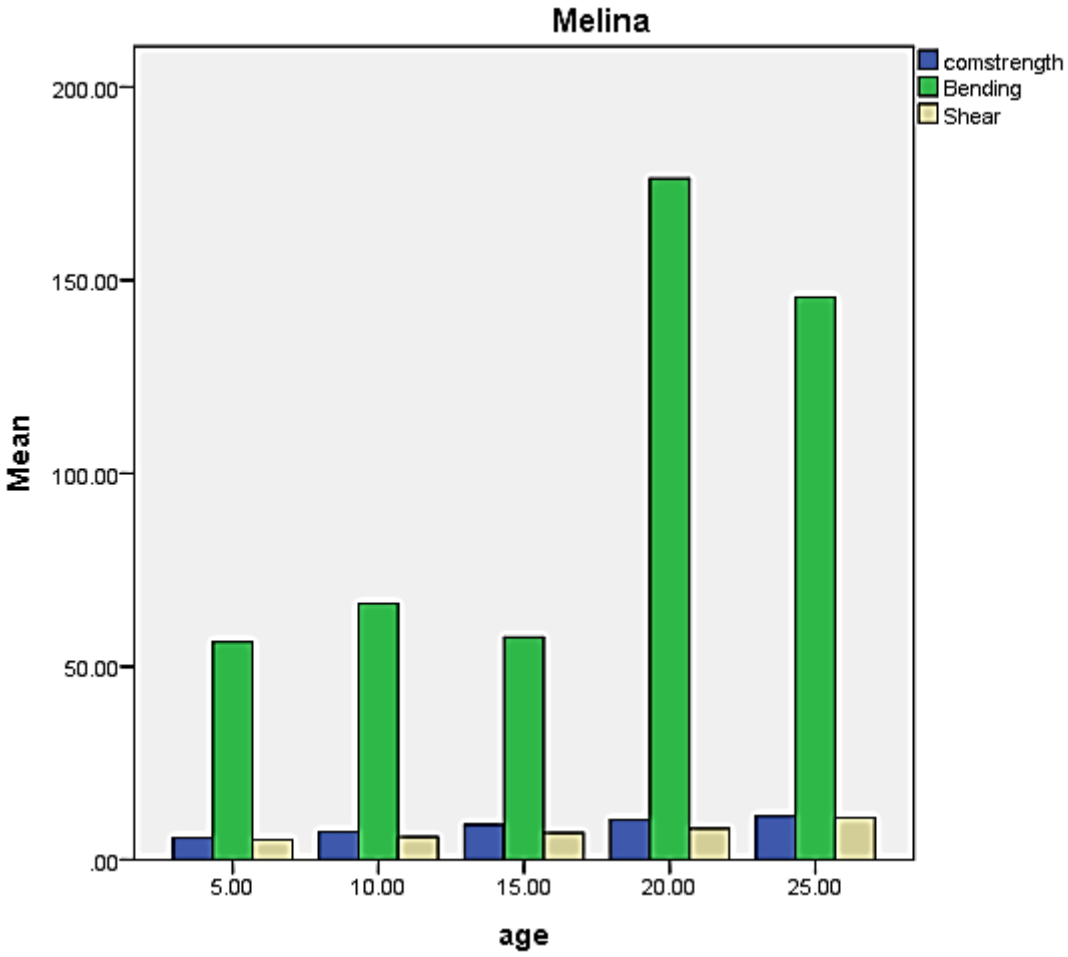


Figure 3

Compressive, Bending and Static Strength for Melina

Supplementary Files

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- SourceofTimberUsed.docx