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The Effect of Direction of Load on Bending Strength of *Melia compositae*

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Abstract: In this paper, empirical study of stiffness (modulus of elasticity-MoE) and Bending strength/flexural strength (modulus of rupture-MoR) in wood, mainly on radial and Tangential surface of *Melia compositae* wood were evaluated. Here loading in the radial direction means that load is applied to the tangential surface and loading in the tangential direction means that load is applied to the radial surface. The strength properties vary with species to species and also application of direction of load. Loading direction appreciably affects the bending properties remarkably due to the anisotropic /orthotropic nature of timber. It was observed that always MoE and MoR have greater value in Radial surface. The direction of application of load has an appreciable effect on strength properties of wood. While this is generally attributable to the presence of medullary rays in the radial direction. The bending strength of timber when loaded parallel to the direction of load is greater than that of timber loaded perpendicular to the direction of load. The ratio of flexural strength values varied from13% to 14% for *Melia composita.*

Keywords: Bending Strength, Modulus of Rupture (MoR), *Melia compositae*

1. Introduction

From beginning to now, timber is one of the mostly used construction materials. It is non-homogeneous and [6] orthotropic in nature having 3D figure. Although nowadays it is largely replaced by the concrete, steel, plastic and fiber etc., but the use of timber remains quite extensive. Timber is subjected to the various types of loading condition such as bending, compression, tension, shear, hardness, toughness, stiffness etc. In packing case of spruce wood impact strength was studied and it was shows that strain rate increase led to significantly higher compression strength, stress and strain energy at a strain level of 50%. Lateral strain restriction had no effect on compression strength [9]. The Variations in mechanical behavior is to changes not only in the inherent qualities of wood and conditions of testing, but also in size of specimens and direction of load applies. In one of the study it shown that compressive kinking strength of wood is governed mainly by its yield strength in shear and by certain features of its anatomy related to the so-called ray cells [4]. The capability of timber to resist this loading condition is measured by the strength properties. It is the mechanical properties that make wood suitable for different purposes i.e construction and building and number of other uses of which furniture, vehicle, flooring etc. are few examples. Dependence of mechanical properties on factors like specific gravity, moisture content and temperature has attracted considerable attention of a few workers but dependence on size and shape of specimens and on the direction of application of load has not received as much attention though it is fairly recognized in evaluating standard for tests. The study evaluated that in wood, direction of the load and the species of the tree had significant effects on the bending properties [3]. Properties that may be significantly different from other materials normally encountered in structural design. Although it not necessary for the engineer to have a general understanding of the properties and characteristics that affect the strength and performance of wood. The direction of application of load has an appreciable effect on strength properties of wood. While this is generally attributable to the presence of medullary rays in the radial direction and the difference in the alignment of cells, as viewed in the radial and tangential direction, it is interesting to note that in a large number of cases the properties in one direction can be predicted with a fair amount of accuracy from the properties in the other direction [14].

Now the question is how to use the timber for particular purposes? The answer is, where less surface area required, we can select longitudinal direction. For example, as poles or posts or columns. The same way while using wood for more surface area supporting to load bearing structure as a beam or joist, we have to go for radial or tangential direction. In this care there are no proper results which can insist the best direction (radial or tangential) in wood which can hold maximum load. But in one review paper it was stated that fracture toughness perpendicular to the grain is greater than that parallel to the grain [5]. Wood is an orthotropic material with unique and independent properties in different directions. Because of the orientation of the wood fibers, and the manner in which a tree increases in diameter as it grows, properties vary along three mutually perpendicular axis: longitudinal (L), radial (R), and tangential (T). Although wood properties differ in each of these three directions, differences between the radial and tangential directions are normally minor compared to their mutual differences with the longitudinal direction [13]. In Sri Lanka similar type of study was conducted in Ambalam structures; a cherished heritage structure originated from the vernacular architecture in Sri Lanka [10].

Due to changes in the anatomical structure, it's essential to know that, is there any particular direction (radial or tangential) to be used? If use. There will be good opportunities in making the best use of wood. If no then without any effort wood can be used.

In the wooden board it was evaluated that integration over cross-sections along the wooden board, an edgewise bending stiffness profile and a longitudinal stiffness profile, respectively, were calculated. A new Indicating Property and bending strength was defined as the lowest bending stiffness determined along the board [12]. But the magnitude of the strain is influenced by a wide range of factors. Some of these are property dependent, such as density of the timber, angle of the grain relative to direction of load application and angle of the micofibrls with the cell wall [11].

To address the above problem. In this paper, empirical study of stiffness (modulus of elasticity-MoE) and Bending strength/flexural strength (modulus of rupture-MoR) in wood, mainly on radial and Tangential surface of *Melia compositae* wood were evaluated. Here loading in the radial direction means that load is applied to the tangential surface and loading in the tangential direction means that load is applied to the radial surface

2. Methodology

2.1. Sample Preparation

The study was undertaken on *Melia composite* wood species, now days these spp are widely used for furniture and construction sector. For standard evaluation of physical and mechanical properties, it is necessary to adopt a fixed methodology for selection of material, preparation of test samples and evaluation of results. The method of sampling model trees and logs for timber testing, followed at Forest Research Institute has since been standardized at national level (IS: 2455-1974). Normally 5 to 10 trees of the species to be evaluation are selected from a locality randomly and one log of length 3 meters is taken from each tree. Logs are converted in the manner shown in Figure 2 and the scantlings so obtained are marked and numbered accordingly.

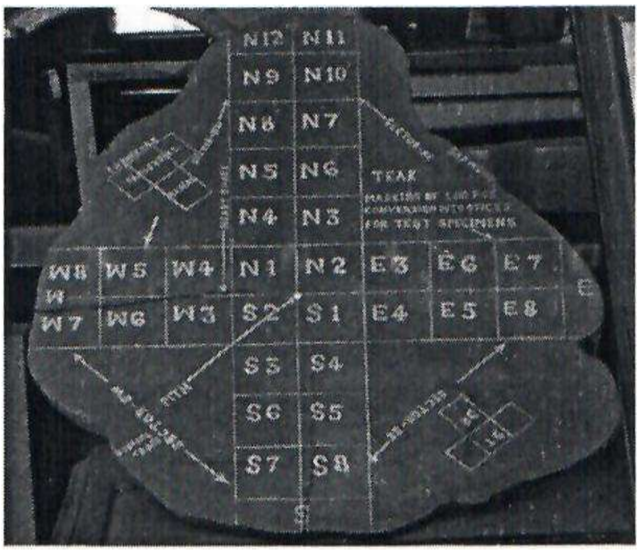

Figure 1. *Marking and Conversion of Logs into Sticks.*

2.2. Marking and Conversion of Logs into Sticks

All logs shall be marked on the small end (top end) into 6 x 6cm squares as shown in Figure 1 and sawn into nominal 6 x 6cm scantlings parallel to pith to pith axis. Each log shall be divided into bolts of 1.5m length and each bolt shall be indicated by a letter of the alphabet in order, beginning with the one nearer the stump. (Thus the 1.5cmbolt above the stump shall be designated as bolt 'A' and the next above it as bolt 'B' and so on). When sticks as marked out in Figure 2 are taken out, each test stick shall have the complete identity mark of consignment number, tree number, the bolt designation and the stick number. All the connected sticks shall be matched for tests in the green and dry conditions as follows:

Green: All even numbered sticks from upper bolt and odd numbered sticks from lower Bolt.

Dry: All even numbered sticks from lower bolt and odd numbered sticks from upper Bolt.

From these sticks small clear specimens are selected for conducting the physical and mechanical tests in green, kiln dry and/or air-dry conditions

1. Here the specimens are prepared from the materials available in Laboratory considering the different specific gravity range. The care was taken that the moisture content of all the species may nearly be same to avoid the effect of moisture in strength. And converted in to the desired size for testing purpose as per IS: 1708 (part 1-18) -1986 [7] "Indian Standard-Method of testing of small clear specimens of timber" and also by ASTM-D-143 [1]. Each specimen is initially weighed correct to nearest gram and its dimensions measured correct to two decimal place of a centimetre.
2. Before testing, four small discs of about 2x2x6cm were taken for determination of specific gravity and moisture content of *Melia compositae* wood.

2.3. Moisture Content of the Samples

2.3.1. Procedure:

Melia compositae specimen was weighed to accuracy of.001 gm in a weighing balance and dried in oven. The specimens were dried in an oven at a temperature of 103 ±2° C. The weight was recorded at regular intervals. The drying was considered to be complete when the variation between last two weighing, does not exceed 0.002 gm until the mass is constant to ± 0.2% between two successive weightings made at an interval of not less than one hour.

2.3.2. Calculation

The moisture content expressed as percentage of the oven dry mass is given by the formula:

$$\text{Moisture content} = intialweight - \frac{Finalweight}{finalweight} \times 100$$

2.4. Specific Gravity of Samples

2.4.1. Procedure

The specimen shall be weighed correct to.001 gm. The Dimensions of rectangular specimen shall be measured correct to.01 gm and volume shall be calculated.

2.4.2. Calculation

$$\text{Specific gravity} = \frac{weightofspecimen}{volumeofthespeciment} \times \frac{100}{100 + MoistureContnet}$$

2.5. Rate of Loading

The load shall be applied continuously during the test such that the movable head of the testing machine travels at a constant rate of 1mm per minute irrespective of direction. The speed of the movable head of testing machine as calculated by the following formula.

$$N = ZL^2/6D$$

Where:

N= Rate of loading in mm/min.

Z= Unit rate of fibre strain of outer fibre length /min=0.0015

L= Span in cm

D= Depth of the specimens

2.5.1 Recording of data and calculations-Static Bending Test (As per IS: 1708 (Pt-5)-1986.

Size 5 x 5 x 75cm, Span -70 cm,

Size 2 x 2 x 30cm, Span - 28cm

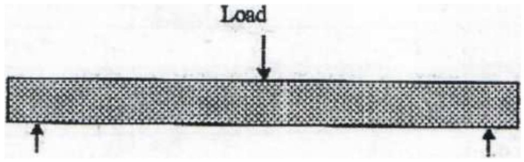

Figure 2. *Direction of loading.*

Continuously increasing load is applied centrally on the specimen such that the movable head of the testing machine moves at a constant rate of 2.5 mm/min in case of standard size specimen and 1.0 mm/min in case of small size specimen (as shown in figure 2). Deflection is measured at suitable load intervals up to the maximum load. Beyond max. load the test is continued until a deflection of 15cm for standard size and 6cm for small size is attained or the specimen fails to support 100 kg load (standard size) or 20 kg load (small size) whichever is earlier. From load deflection data, load and deflection at proportional limit and maximum load are noted.

2.6. Test Procedure

1. Bending tests were undertaken on testing machine as per the standard test procedure. For *MeliaCompositae* eight replicates (total 64 samples) were tested.
2. The size of sample is 30 cm in length and *2x2* cm cross - section. The distance between points of supports (span) is 28cm.
3. Test specimen were so placed on a rig that the load was applied through a loading block. The specimen was supported on the rig in such a way that it will be quite free to follow and the bending action will not be restrained by friction.

1. Modulus of rupture (MOR)=$3p^1l/2bh^2$

2. Modulus of elasticity (MOE)=$pl^3/4Dbh^3$

Where,

p - Applied load in kg at elastic limit

1. Test span in cm
2. b - Breadth of specimen in cm
3. h - Height of specimen in cm
4. P^1 - maximum load in kg
5. D - Deflection at elastic limit in cm

3. Results and Discussion

Table 1. *Moisture Content and Specific Gravity of Meliacomposita.*

SI No.	Dimension (cm)			Initial	Oven Dry	Specific	Moisture
	Length (cm)	Width (cm)	Thickness (cm)	Weight (gm.)	Weight (gm.)	Gravity	Content%
1	5.99	1.94	1.99	11.14	10.35	0.448	7.6
2	6.10	2.03	1.99	12.92	11.98	0.486	7.8
3	5.96	2.06	2.10	13.23	12.29	0.477	7.6
4	6.04	2.02	2.09	13.50	12.50	0.490	8.0

Species: Meliacomposita
Surface: Radial
Direction: Tangential

Table 2. *MOR and MOE values of Meliacomposita (Radial).*

Sample No.	Load at E. L.	Def. at E. L.	Max. Load	Span	Width	Thickness	MOR	MOE
1	85	0.28	150	28	1.97	2.02	784	102.6
2	130	0.35	210	28	1.99	2.1	1005	110.6
3	145	0.38	250	28	1.97	2.1	1209	114.8
4	158	0.46	240	28	1.88	2.11	1204	106.7
5	115	0.51	190	28	1.95	1.99	1033	80.5
6	98	0.33,	122	28	2.04	2.06	592	91.4
7	145	0.5	244	28	2.02	2.03	1231	94.2
8	133	0.38	182	28	1.99	2.08	888	107.3
Avg.							993	101.0

Species: Meliacomposita
Surface: Tangential
Direction: Radial

Table 3. *MOR and MOE values of Meliacomposita (Tangential).*

Sample No.	Load at EL	Def. at EL	Max. Load	Span	Width	Thickness	MOR	MOE
1	113	0.5	192	28	1.98	2.06	960	71.7
2	87	0.52	142	28	1.93	2.1	701	51.4
3	132	0.52	230	28	2.1	2.04	1105	78.1
4	77	0.43	100	28	1.93	1.92	590	71.9
5	75	0.34	106	28	2.09	2.17	452	56.7
6	145	0.49	244	28	1.92	2.06	1258	96.8
7	86	0.49	156	28	1.95	2.01	832	60.8
8	147	0.6	232	28	2.06	2.05	1126	75.8
Avg.							878	70.4

From the data of bending test, the modulus of rupture and modulus of elasticity have been determined by using the given formula on both the surface (radial and tangential surface). Our study it is evident that a strength property depends upon the species and force direction of load. Direction of loading on laminated wood was also studied and it shows laminated materials was found to be approximately 10% higher for MOR and MOE in a parallel direction to the PU4 glue line compared to the perpendicular direction [8]. The test results have been presented in tables 1 to 3. From the table it is observed that Modulus of rupture is consistently higher on radial surface from tangential surface. The similar observation was also observed in within the stem of *Melia azedarach*, the radial position was a highly (p<0.001) significant source of variation in mechanical properties. MOR, MOE, and E_d increased from pith to bark [15]. Modulus of elasticity is also shows the same trend. But over all values of both the properties are higher, when load applied on radial surface. The similar result was also shown in poplar, fir, pine and hornbeam commonly used in Turkey, when investigated. The compressive strength, flexural strength and toughness were determined both perpendicular and parallel to the grain. It was found that loading direction affects all mechanical properties remarkably [2].

4. Conclusion

The strength properties vary with species to species and application of direction of load. Loading direction appreciably affects the bending properties remarkably due to the anisotropic /orthotropic nature of timber. The bending strength of timber when loaded parallel to the direction of load is greater than that of timber loaded perpendicular to the direction of load. The ratio of flexural strength values varied from13% to 14% for *Melia composita.* The statistical analysis shows that non-significant of MoR is difference between radial and tangential direction i.e there is no much difference in direction of tangential and radial direction MoR but in the case of MoE it was significantly different. The t- test has been applied for analysis of data to check whether there is a significant difference of effect of force on loading directions from our results it is observed at 95% confidence level that the application of force direction of load shows the non-significant difference in radial and tangential direction

From our study we can conclude that for all construction purposes there is significant difference is exist if we placed the timber on the tangential or radial faces when we calculated strength and deflection of timber. But for safety point of view it is better to apply load on tangential surface in lab. As the samples take the less loads in this direction. However more attention should be placed on knots, sloping grain, shakes and other timber defects which have more effect on the strength of a timber.

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