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The Compression Test on the Lap Joints Made of *Meliaazedarach* to Evaluate Their Suitability for Various End Uses

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Abstract—*Compression strength is said to be that particular phenomenon of a woody material which represents the ability of that material to resist the impact of forces or loads acting on it and trying to shorten its dimensions or reduce the volume of the same, along the same axis. Wood used for structural purposes in its service is constantly interacting with so many forces, of which compression forces are the most prominent. Higher compression strength is required in cases where timber is being used as a construction material, so as to prevent the structure from buckling or collapsing altogether when substantial load is applied. Adhesive joints such as the lap joints are said to be more advantageous than mechanical assemblies because of minimal increase in weight and ease of assembling and many other similar features. In the present study such parameters of lap joints are examined under identical set up so as to determine the feasibility of Melia azedarach to be used as a species for manufacturing the same. Compression tests were performed parallel to grain on test specimens made from Melia azedarach spp. Three lap lengths of 5cm, 7.5 cm and 10 cm were prepared so as to determine the impact of length on the joints. The bearing strength of lap joint was found promising which can be used for high MCS (Maximum Crushing Stress) purpose. The lap lengths of 5 cm, 7.5 cm & 10 cm did not show any effect on the compressive parameters. The mean efficiencies of MCS, CS@EL (Crushing Strength at Elastic Limit) and MOE (Modulus of Elasticity) were 74.5%, 36% & 32.5% respectively. Since, the MOE was found to be very poor for lap jointed samples, such members made from this species and glued with UF adhesive are not suggested to be used in members exposed to substantial amount of compression, while in use.*

Keywords*: Lap joint, Lap length, Compression stress, Modulus of elasticity (MOE), Melia azedarach, Urea Formaldehyde (UF), Maximus Crushing Stress (MCS).*

1. INTRODUCTION

Lap joints are one of the joints where two pieces of stocks meet or cross over each other. They are halved in their thickness so that when assembled, they use to flush. Use of these joints are widespread in furniture and upholstery manufacturing. They are quick and easy to make and provide reasonable strength through gluing the surface parallel to the grain. These characteristics led to its continued use in woodworking industries. Depending on material type and strength requirements, different adhesives and fasteners can be used in the construction of lap joint. The strength of glued joint depends on the adhesion & cohesion, which significantly influence the resultant joint strength. Using fixed bond technology, the knowledge of its technological principle is important as they influence the qualitative properties of final joint. With these types of regular improvement & inventories and quest of advanced technologies make the manufacturing process easier and effective.

For effective joint and constructional purposes, tough bond creation is essential. The structural arrangement is a fundamental factor for the bonding of plane surfaces, which have to lap over. Bonded joints are capable of bearing enormous amount of loads. Usually the combined tensile and shear stress occur on the joint. Here the non- uniform stress distribution occurs on the whole bonded surface. According to **[1]** owing to the non-uniform distribution, the different adhesive deformation occurs through adhesive layer thickness. The ends of lapping are the most deformed, where maximum stress is created. The destructive causes of single lapped adhesive bond were only rarely mentioned because most of the authors (Goland, Reissner, Cooper, Sawyer, Ojalvo, Renton, Vinson, Erdogen, Ratwani, Givler, Pipes) were interested in lapped adhesive bonds in which the specimen profiles had been changed in order to decrease the bending moment effect**[8]** The stress concentration increases with the bending moment action of the forces acting on it.

The linear material behaviour of wood is generally observed in the longitudinal and transverse sections, while the stress-strain relationships in compression and shear, exhibit significant non-linearity and ductility. When loaded in compression, the response for the three main directions (L: longitudinal, R: radial, T: tangential) can be characterized by an initial elastic region, followed by a plateau region and finally a region of rapidly increasing stress. To simulate wood non-linearity in shear and compression, **[9]** used bilinear functions for wood nonlinear modelling. For some selected end uses such as railway sleepers, rollers, wedges, bearing blocks and bolted timbers, resistance to crushing is an important property. Timbers which are high in density have high compression strength across the grain **[2].** Studies revealed that wood is weaker in compression perpendicular to the grain than it is in compression parallel to the grain**[5,10].** Accurate determination of the stress at critical location within a joint would require detail numerical computation. Consequently, considerable effort has been devoted to develop simple yet accurate analytical evaluation for various lap joints including double overlap joint, single lap joint & single strap joint.

Such information provides, required and necessary tools for both designers and manufacturers, enabling them to engineer better ways to optimize the rational design of joint to meet maximum load capacity, connector type and wood material type to bear different types of stresses acting on lap joints under compression stress.

2. MATERIALS AND METHODS

2.1 Specimen description

For performing compression tests half lap joint samples and control samples (without lap joint) were made. The test specimens were 5 X 5 cm^2 in cross-section and 20 cm in length. The widths of the specimen were 5cm. A listing of various half lap joint dimensions, species and adhesives used in each experiment is given below.

2.1.1 Specimen dimensions

The samples with 5 cm, 7.5cm and 10cm lap lengths were tried (Figure 1) as follows-

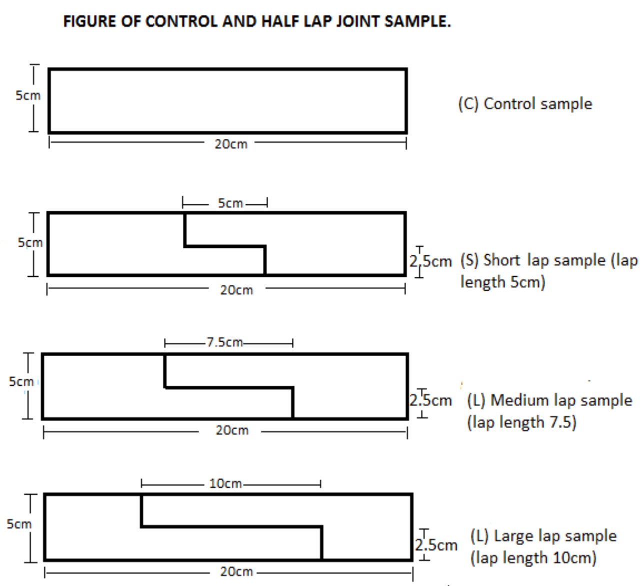

Figure 1: The control and half lap joint samples

2.1.2 Species

Bakain (an Indian species *Meliaazedarch*, Linn.) were cut into required dimensions. Kiln dried specimens, considered for the study had no defects and were free from any visible insect attack.

2.1.3 Adhesive

For joining the half lap samples, commercial urea formaldehyde (UF) adhesive was used. The resin (100%) was available in the powder form. 100 gm of this powder of UF resin and 2 gm of hardener (Ammonium chloride NH_4Cl) were mixed in 75 ml of water to get a viscous solution to obtain better adhesion. The adhesive obtained was used for jointing purposes. A brush was used to apply the adhesives to the lap sides. The samples were assembled to complete the joints. Then the samples were clamped immediately after adhesive application and left for 48 hours for curing.

2.2 Preparation of jointed samples

The sections with 5cm, 7.5cm and 10cm lap length were considered for making half lap joint and controls were without any lap. So, 6 sample of each lap length (5cm, 7.5cm and 10cm)were prepared. The sections were cut at a depth of 2.5cm. These were cut in a way such that the face surface was flat when they were assembled to make joint as depicted in figure 2.

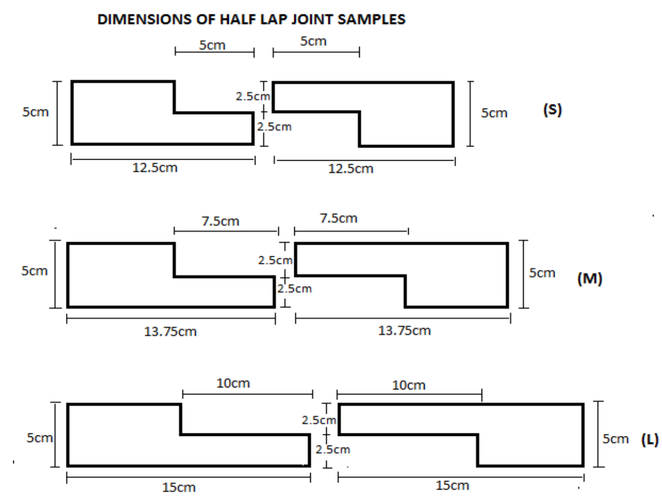

Figure 2: The geometry of the half lap joint samples

2.3 Description of test

The compression test was conducted following The Indian Standard[7] methods of testing of small clear specimens of timber part 8 determination of compressive strength parallel to grain (second revision) IS: 1708 (part 8) – 1986 [7].

2.3.1 The compression test

In the compression test one platen of the testing machine was equipped with a hemispherical bearing to obtain uniform distribution of load over the ends of the specimen. The platen width was 5.08cm. The specimen was placed at the centre of the movable head vertically above the centre of the cross-section of the specimen. The load was applied during the test with the movable head of the testing machine traveling at a constant rate of 0.6 mm per minute. Initially a load of 250 kg was applied to set the sample. Deformation under compression were measured correct to 0.002 mm by means of a suitable compress meter over a central gauge.

In the first set of test, 6 control samples were tested to determine the effect of compression parallel to grain to assess the maximum load capacity and joint flexibility. The control samples were held with compression force by getting maximum crushing load. In the second set of test, 6 samples of small laplength (5cm lap) were tested. In the third set of the test, 6 samples of medium lap length (7.5cm) were tested. In the fourth set of the testing, 6 samples of large lap (10cm of lap length) were tested. Deflections were duly noted for increasing loads and the testing. All tests were carried out on the Riehle Universal Testing Machine at the Timber Mechanics Discipline, Forest Products Division, Forest Research Institute, Dehradun, India.

Figure 3: Preparation of Test Samples

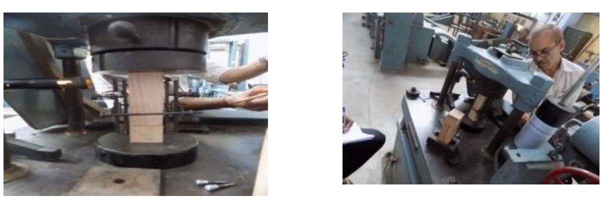

Figure 3: Set up of Samples for Testing

Figure 4: Testing on the samples for Compressive Stress Evaluation

2.4 Calculation

Load deflection curves were drawn observing the rules explained in 4.1 of Part 5 of **The Indian Standard[7]**standard. Load and deflection at limit of proportionality noted accordingly. The various parameters were determined by the following formulae

2.4.1 Compressive Stress at Limit of proportionality

$$\textbf{CS} = \frac{P}{(\text{Width of the specimen} \times \text{Width of the metal used})}$$

2.4.2 Compressive Stress at Maximum Load

$$\text{MCS} = \frac{P'}{A}(\text{MPa})$$

2.4.3 Modulus of elasticity (MOE) in Compression Parallel to Grain

$$\text{MOE} = \frac{Pl}{AD}(\text{MPa})$$

P = Load at elastic limit in N

A = Cross-sectional area in mm²

P' = Maximum crushing load in N

D= Deflection at limit of proportionality in mm

l = Effective length in mm

(MPa) = Mega Pascal.

2.5 Statistical Analysis

Statistical analysis was carried out using SPSS software and the result obtained was used for further calculations.

3. RESULTS AND DISCUSSIONS

3.1 CS@ EL

Table 1 summarizes the compressive strength parameter of the 4 sets of sample. The standard deviation of the mean value is also given in the table.

Table 1: Mean of Compressive Strength Parameters of Control and Lap Samples

Compression Parameter	Short Lap (N/mm^2)		Medium Lap (N/mm^2)		Large Lap (N/mm^2)		Control (N/mm^2)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CS@EL	10.7	3.4	8.1	2.0	10.6	3.1	27.2	1.2
MCS	30.7	2.3	30.5	2.5	28.0	4.0	39.9	4.2
MOE	295.3	91.4	320.3	121.2	394.0	135.4	1034.7	86.9

Table 1 suggests that the mean CS@EL of control sample (27.2 N/mm^2) is much higher than the jointed ones. However, the values of lap jointed samples seemed to be not very different among them (8.1 to 10.7 N/mm^2). On the other hand, the MCS does not have much difference in the mean values of the short, medium and large lap with the control sample. However, MOE of lap samples has got large difference in their mean values with the control sample which was nearly 3 times greater.

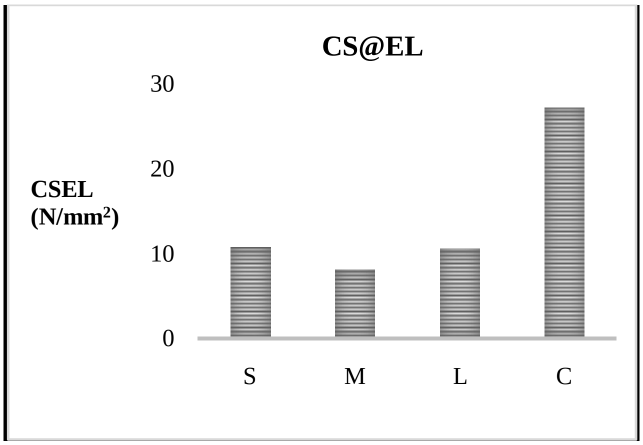

Figure 6: Mean Value of Crushing Stress at Elastic Limit of Samples

Note: S- Small lapped samples; M- Medium lapped samples; L- Large lapped samples, C- Control samples.

The figure 6 depicts that CS@EL of controls is very high. The lap length did not seem to have much effect on the CS@EL. The value of the CS@EL of six samples of the short lap ranges from 6.8 N/mm^2 to 15.7 N/mm^2. The six samples of medium lap showed range from 6 N/mm^2 to 10.8 N/mm^2. The six samples of large lap ranged from 6.9 N/mm^2 to 12.7 N/mm^2. To check for differences between CS@EL values of each set, the individual values were analyzed through one-way ANOVA and the results are given in table 2.

Table 2: One way ANOVA of CS@EL of the Samples

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Between sample sets	1379.955	3	459.985	69.294	<0.001
Error	132.763	20	6.638		

Results show (Table 2) significant differences in CS@EL. To understand individual performance, Duncan's subgroups were formed which are given in table 3.

Table 3: Duncan's Subsets of CS@EL of the Samples

Lap	N	Subsets of CS@EL (N/mm^2)	
		1	2
M	6	8.1	
L	6	10.6	
S	6	10.7	
C	6		27.2
Sig.		0.110	1.000

Table 3 shows that the three lapped samples lie in the first subset while the control sample in the second subset. Crushing stress at elastic limit of control sample was significantly greater than lap samples. However, in the first subset there was no significant difference between the large, medium and small sized lap sample. Thus it can be inferred that the lap lengths of 5cm, 7.5cm &10cm do not have any significant effect on their CS@EL values. Therefore, if the product does not demand for higher CS@EL, any of the lap lengths can be used for the purpose.

3.2 MCS

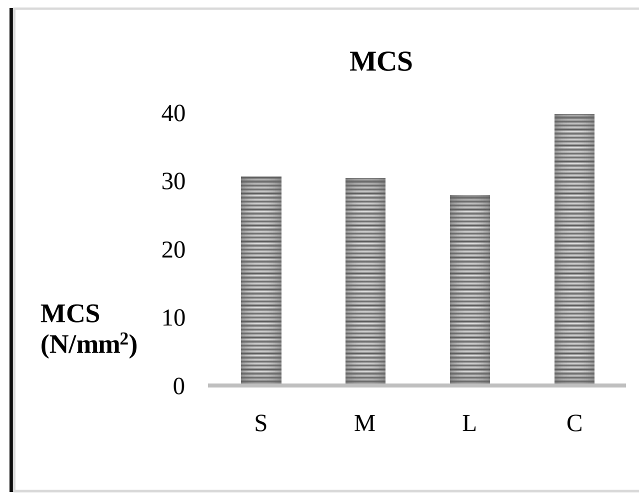

Figure 5: Mean Value of Maximum Crushing Stress Samples

The Figure7 suggests that MCS does not have much difference statistically between the lap samples. But, the control samples have slightly higher MCS compared to lap samples. The MCS of six samples of small lap was found to be ranging from 28.8 N/mm^2 to 35 N/mm^2. The six samples of medium lap ranged from 29.4 N/mm^2 to 33.4 N/mm^2 whereas the large lap samples have values ranging from 24.1 N/mm^2 to 34.2 N/mm^2. The six samples of control ranged from 35.9 N/mm^2 to 43.9 N/mm^2. For understanding any differences, one-way ANOVA was conducted and the results are given in table 4.

Table 4: One way ANOVA of MCS of the Samples

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Between sample sets	495.340	3	165.113	14.801	<0.001
Error	223.113	20	11.156		

Results indicated significant differences in MCS. To understand individual performance, Duncan's subgroups were formed which are given in table 5.

Table 5: Duncan's Subsets for MCS of the Samples

Lap	N	Subsets of MCS (N/mm^2)	
		1	2
L	6	28.0	
M	6	30.5	
S	6	30.7	
C	6		39.9
Sig.		0.200	1.000

Table 5 clearly displays that the three lap samples lie in the first subset. On the other hand, the control samples lie in the second subset. This result is very similar to CS@EL. Maximum crushing stress of control is significantly higher than that of lapped samples. While in first subset the crushing stress of all lapped samples are shown to be statistically similar Thus it can be concluded that the lap lengths of 5cm, 7.5cm &10cm do not have much difference in their MCS values. Therefore, if the product does notdemand for higher MCS, any of the lap lengths can be used for the purpose.

3.3 MOE

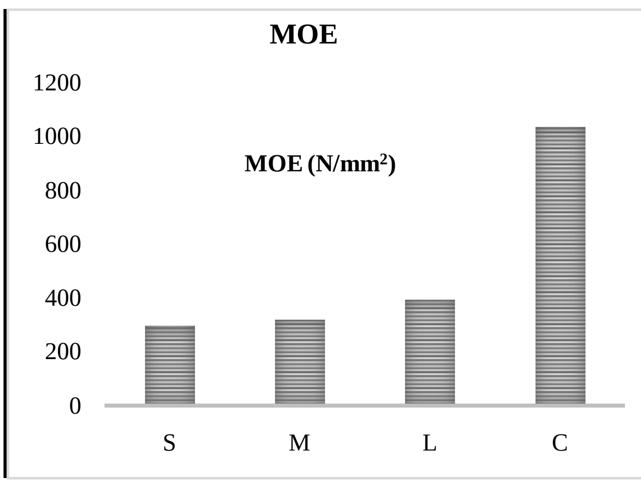

Figure 8: Mean Value of Modulus of Elasticity Under Compression

The figure 8 shows that MOE of control samples are very high compared to lap samples. The small, medium and large lap samples are only slightly different from each other. The MOE of the 6 samples of short lap values ranged from 215 N/mm^2 to 468 N/mm^2.The samples of medium lap ranged from 224 N/mm2 to 531 N/mm^2.The large lap samples have ranged from 269 N/mm2 to 624 N/mm2 and the control samples are found to be in the range of 929 N/mm^2 to 1168 N/mm^2.

Table 6: One way ANOVA of MOE of the samples.

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Between sample sets	2224689.833	3	741563.278	60.629	<0.001
Error	244622.000	20	12231.100		

Results showed significant differences in MOE of the samples belonging to different sets. To understand individual performances further, Duncan's subgroups were formed which are given in table 7.

Table 7: Duncan's Subsets of Table of MOE of the Samples

Lap	N	Subsets of MOE (N/mm^2)	
		1	2
S	6	295.3	
M	6	320.3	
L	6	394.0	
C	6		1034.6
Sig.		0.159	1.000

Table 7 depicts that lapped samples lie in the first subset and control samples in second subset. This result is very similar to MCS and CS@EL. The MOE of control is significantly greater than the lap samples. It was observed that without any notch the MOE of control samples are higher. On the other hand, the MOE of lapped samples has sharply declined. Thus it can be concluded that lap jointed samples have much lower MOE under compression. However, lap lengths of 5cm, 7.5cm &10cm did not show much difference in their MOE values. Therefore, if the product does not demand for higher MOE, any of the lap lengths can be used for the purpose.

Thus, we find that changing the lap length between 5 & 10 cm do not alter any of the three compression parameters studied. However, using lap joints for members under compression will have a negative effect on the parameter compared to un-jointed clear members. This reduction is quite drastic in the case of MOE than MCS. This situation warns us not to adopt such members for use which are under compression since, retaining size and shape may prove be a problem.

3.4 Comparative study of the Efficiency of Lap Joints

The efficiencies of the compression parameters of the three lap types with respect to the control ones were evaluated for a comparative analysis and the results obtained are briefed in Table 8.

Table 8: Efficiency of the Lap Joints

Lap type	MCS (%)	MOE (%)	CS@EL (%)
S	76.9	28.5	39.3
M	76.4	30.9	29.8
L	70.2	38.1	39.0

Table 8 exhibits that the mean value of 74.5% efficiency of MCS of lap sample is considerably greater as compared to other compressive parameters. But in the case of MOE, the mean efficiency is just 32.5 %. The CS@EL of lap sample has mean efficiency of 36 %. Figure 9is the graphical representation of the same.

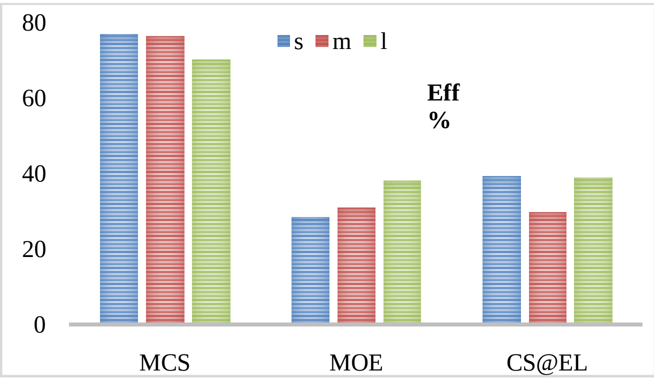

Figure 6: Efficiency of the lap lengths of Compression Parameter

The figure 9 shows that the efficiency of MCS of lap sample is quite good. But the efficiencies of lap samples in case of MOE and CS@EL are very less making such joints unacceptable for compression uses in general for structural purposes.

4. CONCLUSION

From the study it can be inferred that the lap lengths of 5cm, 7.5cm &10cm do not have any significant effect in their compressive parameters. However, it is very pertinent to mention that lap joints made from Bakain for compression members are generally not suitable due to very low MOE efficiencies when joined with UF adhesives even though the joints showed an excellent crushing strength under compression. However, for small scale woodworking, these joints may be found suitable where enormous amount of force is not exercised. Further the compatibility of these joints can be studied for smaller accessories as the results obtained were satisfactory for the cases where optimum load is applied on the joints.

It must be mentioned that during the study the amount of force exerted on the joints was very high so standardization of the process parameters may produce different outcome, suitable for specific end uses.

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