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Effect of Finger Profiles on Maximum Tensile Stress of Eucalyptus Sections

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Abstract—*An experiment was conducted to study the effect of finger parameters on the tensile strength of finger jointed sections of Eucalyptus wood. Three different finger profiles F1 F2 and F3 were used in the study. The sections were joined using UF adhesive. The results showed* that the profile with highest finger tip thickness resulted in the least MTS value of 32.5 N/mm^2. The other two profile with the comparable thickness to pitch ratios gave significantly higher MTS values (>44 N/mm^2). *The study illustrates the necessity of adopting suitable finger profile when making finger jointed sections out of eucalyptus species so that economic utilization can be made possible of this precious natural resource.*

Keywords*: Eucalyptus, Finger joint, Finger profile, Tensile strength, Urea Formaldehyde*

1. *INTRODUCTION*

Wood joint is the operation of joining two pieces of woods by various means to improve its strength and modify it according to different end uses. Finger joints are acceptable methods to end-join lumber and they have necessary requirements for satisfactory performance for structural glue laminated timbers which finally contributes production of Quality Lumber or Furniture. In the replacement of Scarf joints, Finger Joints had come in place to mainly reduce the waste of high quality lumber. Finger Joints were proved to possess superior and reliable strength properties in furniture industries than any other joints. Thus they play an important role in saw mill recovery by reducing the wastage. Strength values indicate that finger joints can be used as replacement for Mortise and tenon joints. They contribute significant roles in the production of quality Furniture and gave solution to the failure of dowel joint.

Finger geometry plays an important role in the strength performance of joints. Parameters such as the tip thickness (t), pitch (P), finger length (L) and slope (S) are interrelated and can influence positively or negatively the performance of the joint. Jokerst (1980) indicated that the geometry of the joints is the most important aspect for good finger-jointing performance. Considerable work related to the influence of geometrical joint parameters has been done on several species (Madsen and Littleford 1962; Richards 1963; Selbo 1963; Biblis and Carino 1993 and Ayarkwa et al. 2000).

According to Jokerst (1981) and Selbo (1963) certain geometrical properties are particularly important for the strength of finger-joints. For example, strength increases with a larger finger length/pitch width ratio and a lesser finger tip width. Selbo (1975) showed that the tensile strength of various types of end joints depend on the geometry of the assembled parts. Richards (1962) reported that thinner tip will have more strength than a thicker one. Finger length to pitch ratios between 3:1 and 5:1 produced satisfactory joints in tension parallel to the grain or in static bending (Richards 1958; 1963; Selbo 1963 and Strickler 1967). Strickler (1967) reported excellent strength values for end-to-end grain joints with finger lengths of 7 mm and 3 mm.

Castro and Paganini (1997) conducted a study to analyse the different mechanical performance by three finger lengths (7.5mm, 15mm and 20mm). Their results show that 7.5mm finger joint, gives the best performance, with low value of t/p (0.08).

Eucalyptus spp. (E. tereticornis) has been classified as a moderate timber with respect to its weight, strength and toughness (Sekhar and Rajput, 1968). Working quality index of this timber has been reported to be comparable to teak (Jaitly et al. 1983). Its timber finds use in rural and urban India for furniture making, as rafters, beams, purlins etc. It is reported to have strength indices comparable to teak (Luna, 2005). Eucalyptus hybrid from Punjab and Haryana was found suitable for construction, joinery crates, furniture, poles etc (Rajput et al. 1992).

This paper reports the results of a study on the tensile strength of two different profiles of finger jointed sections of Eucalyptus wood jointed with UF adhesive so that the utilization of this natural resource can be bettered.

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2. MATERIALS AND METHODS

Eucalyptus Planks of 38 mm thickness, kiln seasoned up to Moisture content (MC) of 12 % were used to prepare samples for the study. The sections were selected from visually inspected defect free portions. Three types of Fingers were profiled on a commercial finger shaping machine using three different cutters. The finger parameters (L and t) were estimated on the profiled fingers as the mean of values measured on 100 random fingers on different samples. For pitch (P) 75 random readings of distance between adjacent fingers were averaged. Slopes (S) of the fingers were calculated using the formula

$$S = \frac{(P-2t)}{2L} \qquad (1)$$

The Urea Formaldehyde (UF) adhesive was applied to the profiled fingers using a brush. Immediately after adhesive application, the sections were mated and pressed on a pneumatic pressing vice at an end pressure of 6 MPa. The sections were made in such a way that the joint occupied the central position of the specimen. The jointed samples were left at room temperature for curing for 48 hours. Before performing the tensile test, the samples were given a light planing to remove any adhesive ooze out during pressing operation. The samples were dimensioned approximately to 50x15 mm^2 cross-sections and 325 mm in length. 15 jointed samples were prepared with F1 and 10 each were prepared with F2 and F3.

The test was conducted on a universal testing machine provided with suitable types of grips to hold the specimen firmly without any slip during the test. The load was applied continuously during the test such that the movable head travelled at a constant rate of 1 mm/min for clear wood as well as finger jointed samples. This procedure was continued till the maximum load was observed. The number of samples which failed due to wood break were noted in each case. Maximum Tensile Stresses (MTS) for the samples which failed at the joint were determined using the following formula:

$$MTS = \frac{P}{A}\ N/mm^2 \qquad (2)$$

Where

P = Maximum Load in N

A = Cross-Sectional area in mm^2

3. RESULTS AND DISCUSSION

Table 1: Finger parameters of the three profiles

Parameters	Finger Profiles		
	F1	F2	F3
Length (L mm)	19.2	19.8	13.2
Pitch (P mm)	6.6	4.8	3.9
Tip Thickness(t mm) (mm)	1.5	0.8	0.6
Slope (S)	0.09	0.08	0.10

Table 1 shows that the three finger profiles F1, F2 and F3 have different geometries. It can be seen that profiles F1 and F2 have almost similar lengths whereas profile F3 has shorter length. In the case of pitch and tip thickness, all three profiles are different. These random values which were taken from profiled samples were analyzed to check for their similarity/ dissimilarity in the mean values. The analysis showed that each of the three finger parameters are significantly different for each of the three profiles ($p < 0.001$). The Duncan's homogeneity test showed that the finger lengths followed a pattern of F2>F1>F3. On the other hand, the pitch and tip thickness followed a pattern of F1>F2>F3. The tip thickness of F1 is more than 2 times that of F3. Their slopes however, do not seem to be very different (calculated with Eqn. 1).

Table 2: Gives the number of samples which broke away from the joint.

Profile	Total no. of samples	Samples with wood break	Samples with break at the joint	% of samples with wood break
F1	15	7	8	46.7
F2	10	5	5	50.0
F3	10	4	6	40.0

Table 2 shows that more 40 % of the samples failed in wood. It is pertinent to note that the samples did not show any particular pattern during wood break. Hence, it is presumed that hidden damages inside the wood might have caused most of the wood failure. Pereira et al. (2016) also reported about 50% wood break during tensile tests of finger jointed eucalyptus hybrid wood. Thus, because of wood break, the number of samples available for calculating the MTS of the joint were rather limited (8 for F1, 5 for F2 and 6 for F3).

The tensile strengths parallel to grain of finger jointed sections of eucalyptus were computed by calculating the Maximum Tensile Stress (MTS) as discussed in the previous section. Table 3 gives the mean values of MTS calculated for the finger jointed sections made with the three profiles.

Table 3: Mean MTS of finger jointed sections using the three profiles

Profile	MTS (*N/mm²*)	Standard Deviation (*N/mm²*)	CV (%)
F1	32.5	11.1	34.2
F2	47.8	9.4	19.7
F3	44.3	7.3	16.6

Table 3 indicates that the profiles have some effect on the MTS of the jointed samples. With F1, the MTS ranged from 17 N/mm2 to 50 N/mm2 with a mean of 32.5 N/mm2. F2 had higher length for its fingers and its MTS is considerably high with a mean value of 47.8 N/mm2. This could be due to the lower tip thickness of F2 (0.8 mm) as against that of F1 (1.5 mm). However, F3 with lowest finger length and tip thickness gives almost similar MTS as that of F2. Thus, the results of MTS seem to be interesting. Hence, the MTS values of all the 19 samples belonging to the three profiles were analysed through one way ANOVA and it was found that the MTS values indeed differ significantly (p = 0.026). Duncan's homogeneity test distributed these mean MTS values into two distinct subsets in the order F2= F3>F1. For obtaining better strength for finger joints, Strickler (1980) had proposed that the finger tips should be virtual knife edges. In the present study, the profile with the widest finger tips (F1) has indeed yielded the least MTS.

On the other hand, Selbo (1963) had suggested lowering of the tip thickness to pitch ratio (t/P) of fingers for improving the joint strength. In the present study, these ratios are 0.23, 0.17 and 0.15 for F1, F2 and F3 respectively. The present results are in agreement with Selbo's suggestion also. The profile with highest t/P value (0.23) gave the least MTS (32.5 N/mm2). Profiles with comparable t/P values (0.17 and 0.15) resulted in comparable MTS values (47.8 N/mm2 and 44.3 N/mm2). Thus we see that there is a significant bearing of finger parameters on the finger joint strength.

Pereira et al. (2016) reported an MTS value of 24.21 N/mm2 for hybrid of Eucalyptus grandis and Eucalyptus urophyla when sections were finger jointed with Polyurethane-based adhesive. Singh et al. (2016) had reported an almost similar MTS of 23.5 N/mm2 for the species under study when joined with a less effective PVA adhesive and using a profile similar to F1. The values obtained in the present study with UF adhesive are higher than these reported values but seem to have a dependence on the geometry of the finger profile used.

Singh et al. (2016) reported an MTS value of 99.7 N/mm2 for unjointed clear wood eucalyptus samples. Considering this value as the MTS of joint-free eucalyptus, the efficiencies of the jointed samples in the present study with the three profiles were calculated as:

$$Efficiency\ of\ finger\ joint = \frac{MTS\ of\ jointed\ wood\ X\ 100}{MTS\ of\ clear\ wood}$$

The calculated efficiencies are given in table 4.

Table 4: E*fficiencies of MTS of* finger jointed sections of eucalyptus using the three profiles

Profile	Average MTS (N/mm²)	Efficiency of finger joint (%)
F1	32.5	32.6
F2	47.8	47.9
F3	44.3	44.4

Table 4 shows that the efficiency of the finger jointed samples with respect to the tensile strength values of eucalyptus clear wood is less than 50 %. Further, the efficiency is lowest with joints of F1 profile.

The study points to the fact that profiles with lower tip thickness and lower values of tip thickness to pitch ratio would help in making better finger joints of eucalyptus using UF adhesive. However, using this adhesive, the efficiencies of such joints are less than 50 % compared to clear wood sections which could be enhanced by using better adhesives.

4. CONCLUSIONS

The three profiles used in the present study had statistically different finger parameters. About 50% of the samples failed in wood during application of tensile load. The profile which had the thickest finger tips (F1) resulted in least tensile strength when sections were joined with UF adhesive. The profile with highest t/P value yielded the least MTS and higher MTS values were obtained with profiles with lower t/P values. The study illustrated the fact finger parameters have a significant effect on the finger joint strength.

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