Tropical Agricultural Research & Extension 21 (3 & 4): 2018

EFFECT OF FINGER JOINING ON FLEXURAL STRENGTH OF COMMONLY USED TIMBER SPECIES IN SRI LANKA

Muthumala CK [1*], De Silva S[2], Alwis PLAG[3], [4]Arunakumara KKIU [4]

[1]Research, Development and Training Division, State Timber Corporation, Battaramulla, Sri Lanka

[2]Department of Civil and Environmental Engineering, Faculty of Engineering, University of Ruhuna, Hapugala, Galle, Sri Lanka

[3]Department of Agric. Engineering, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka

[4]Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka

ABSTRACT

The variation of flexural strength of seven timber species mainly used for furniture industry in Sri Lanka was studied. Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) were measured without finger joint and with finger joint specimens of timber species. Finger joint technique is used to eliminate wood defects which weaken the strength of sawn wood plank and used. This paper gives comparison study of finger jointed and un-jointed seven wood species, tested under three point bending test. BS 373: 1957 and BS EN 15497:2014 were used as standards for tests. Vertical finger joint orientation and 13 mm finger joint length were used in this study. The tests for mechanical properties were performed by using a Universal Testing Machine (UTM 100 PC). The parameters were analyzed by using ANOVA and means were separated by Duncan's Multiple Range Test at 0.05 significant levels in SAS. It was found that control (un-jointed solid wood) samples gave the highest flexural strength than finger-jointed specimens and it was also observed that Kumbuk timber species was showed the highest MOE in 13 mm finger-jointed specimens comparing control specimens. The highest flexural strength loss percentage was obtained from Satin species. The MOE of finger-jointed Kumbuk was higher than clear Kumbuk specimens and least strength loss percentage of MOR (46.08 %) was obtained from Mahogany species.

Keywords: Flexural strength, Finger joint, Timber, Universal Testing Machine

INTRODUCTION

The forests of Sri Lanka have nearly 400 timber species used as structural and nonstructural purposes (Muthumala, 2013). The wood is an excellent material for non-structural uses such as, furniture, interior decorations, doors and windows, paneling, partition borders, floorings, wood carvings, musical instruments etc. As a result of low quality and strength of the local wood use by some of these ancestral architects and craftsmen most wood creations have not last for long periods which have perished with the time (Ruwanpathirana & Muthumala, 2010). Mechanical properties are very important in case of structural and non-structural purposes of timber.

*Corresponding author: ck_muthumala@yahoo.com

Finger joints are commonly used to produce engineered wood products from short timber planks of lumber. Such joints must have excellent mechanical performance. End jointing of lumber to permit the use of single-piece construction has posed a challenge to wood product manufacturers. When the vessels of wood come together in joint, it reduces the strength of the joint. Around 1950s, further modifications by different wood researchers resulted in the development of finger joints.

Finger joints are described as interlocking end joints formed by machining a number of similar tapered symmetrical fingers in the ends of timber members using a finger joint cutter and then bonded together (BS-15497, 2014). Finger joint is a sustainable, eco-friendly and economically valuable concept for furniture industry. It ensures the sustainable utilization of small wood cut pieces which removed as waste (Sandika *et al.* 2017). The highest bonding strength was recorded from Polyvinyl acetate-SWR glue as a bonding material (Muthumala, 2018a; Muthumala, 2018b).

The mechanical properties of wood are important because they can significantly influence the performance and strength of the timber used in structural applications (Winandy, 1994). Previous studies (Jokerst, 1981; Mohammad, 2004; Yavari,*et al.* 2015) were confirmed that the configuration of a finger joint has a significant influence on the mechanical properties of the timber and finger length and finger orientation are statistically significant for the flexural strength.

Finger- jointed timber production plays a vital role in furniture industry for minimizing the waste generation in furniture manufacturing activities in the world. However, issues related with the strength of the joints are still not fully investigated in Sri Lanka.

MATERIALS AND METHODS

Samples were cut from defects free, Seasoned (Moisture content 10-12 %) timber planks of following timber species from the State Timber Corporation, Galle, Sri Lanka to calculate mechanical properties.

Grandis	- *Eucalyptus grandis*
Jack	- *Artocarpas heteroplyllus*
Kumbuk	- *Terminalia arjuna*
Mahogany	- *Swietenia macrophylla*
Pine	- *Pinus caribaea*
Satin	- *Chloroxylon swietenia*
Teak	- *Tectona grandis*

Vertical finger joint orientation and 13 mm finger length, that is mostly used in Sri Lanka were used in this study. Assembling pressure of 6 MPa was used. Seasoned ten clear wood samples were cut from the planks and used as the controls.

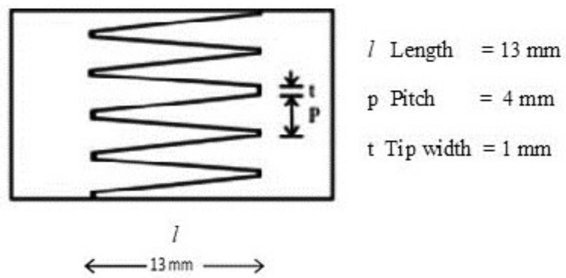


Figure 1: Geometric parameters of Finger joint

Finger Joint specimens preparation -The specimens with 12% moisture content with size of 314 mm × 20 mm × 20 mm were cross cut using a circular saw machine into two pieces for joining with adhesive after the made of finger joint. (Measurement of one joining piece is 157 mm in their length). All the samples were made in Finger joint factory in State Timber Corporation, Galle, Sri Lanka.

The density values were calculated seven timber species using following formulae. Dry weight of the timber samples were taken by placing in 105^{0}C oven for 48 hours (BS EN 373:1957).

Determination of basic density was done based on the green volume and oven-dry weight using a water displacement method (Equation 01).

$$\text{Density} = \frac{\text{Weight of oven dry wood (kg)}}{\text{Volume of wood (m3)}} \ldots 01$$

The prepared samples of 20 mm x 20 mm x 300mm were used for bending tests (BS EN 373:1957). Polyvinyl acetate (PVAc, P-SWR) adhesive was used for making finger joint samples. PVAc is a thermoplastic polymer that has wide acceptance in the adhesive industry as a raw material (Ayhhan & Fatih, 2007). Samples which were placed in normal room temperature conditioned showed good structural performance compared to hot and wet conditioned (Vivek *et al*. 2016).

The span for the bending measurements was kept at 280 mm. The load was applied continuously by Universal Testing Machine which had its loading plate moving at a speed of 1 mm/min. Fig.2 shows the loading setup used in bending measurements.

The Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) were calculated for the bending measurements using the formula mentioned below.

Modulus of Rupture (MOR) (Ultimate flexural strength) and Modulus of Elasticity (MOE) values were calculated by using Equations 02 and 03 corresponding to test data.

$$\mathbf{MOR} = \frac{3FL}{2bd^2} \ldots 02$$

where F= Maximum Force (N) , L = Length of the span (mm), b = Width of the specimen (mm) and d = Depth/Thickness of the specimen (mm)

$$\mathbf{MOE} = \frac{FL^3}{4\delta bd^3} \ldots 03$$

Where F= Maximum load at proportionate stage (N), L= Length of the beam between supports (mm), b = width of the specimen (mm), d= Depth/ Thickness of the specimen (mm) and δ = Maximum deflection (mm)

The parameters were analyzed by using ANOVA and means were separated by Duncan's Multiple Range Test at 0.05 significant level.

RESULTS AND DISCUSSION

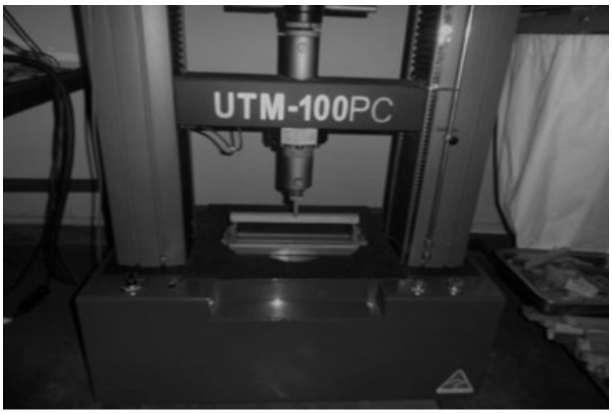
The average moisture content and the average relative humidity of the samples were recorded at 12 ± 3 % and 75 ± 5 %, respectively. The average densities of the seven species of wood in their descending order were 980 kg/m^3 for Satin; 756 kg/m^3 for Kumbuk ; 720 kg/m^3 for Teak ;645 kg/m^3 for Jack, 570 kg/m^3 for Grandis ; 570 kg/m^3 for Mahogany and 465 kg/m^3 for Pine.

MOR values of seven timber species for finger - jointed and un-jointed, strength loss percentage varied as in descending order: Satin, Jack, Teak, Pine, Grandis, Kumbuk and Mahogany (Table 2).

Figure 3 shows that, the highest average MOR values were obtained from control samples.

Table 1: Average dry density values (kg/m^3) of Timber Species.

Timber species	Density (kg/m^3)
Grandis	570
Jack	645
Kumbuk	756
Mahogany	570
Pine	465
Satin	980
Teak	720



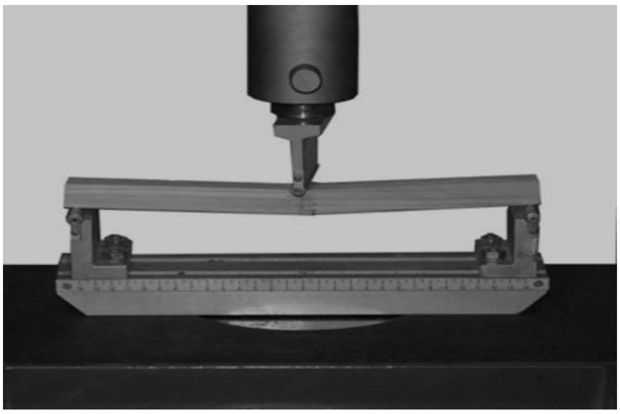


Figure 2 : Set–up used for the bending test on the samples

MOR values of control specimens were varied as of the seven species of wood in their descending order: Satin, Teak, Grandis, Jack, Mahogany, Pine and Kumbuk. MOR values of finger- jointed specimens were varied as in descending order: Mahogany, Teak, Kumbuk, Grandis ,Pine, Jack and Satin.

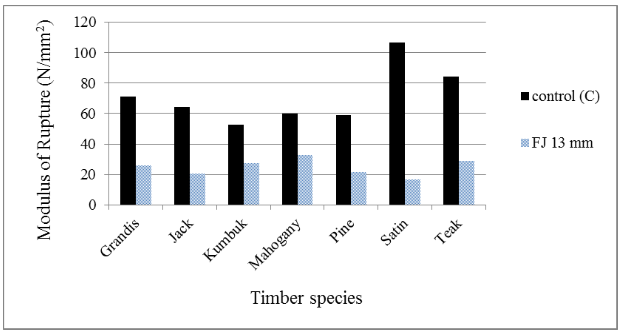


Figure 3: Comparison of average MOR values of control (C) and finger- jointed (FJ 13 mm) specimens.

The highest MOR strength loss percentage (84.35 %) was obtained from Satin species and least strength loss percentage (46.08 %) was obtained from Mahogany species.

MOE values of jointed and un-jointed six timber species (without Kumbuk species) MOE loss percentage was varies as in descending order: Satin, Mahogany, Jack, Grandis, Teak and Pine (Table 3).

According to the Fig.4, the highest MOE values were obtained from control samples without Kumbuk species. MOE values of control specimens were varied as, in descending order: Satin, Teak, Grandis, Pine, Mahogany, Jack, and Kumbuk.

MOE values of finger-jointed specimens were varied as in descending order: Teak, Kum-

Table 2 : Comparison of average MOR values (N/mm^2) of Control specimens and Finger-jointed specimens.

Timber species	control(C) (N/mm^2)	SD	FJ 13mm (N/mm^2)	SD	strength %	Strength Loss %
Grandis	71.13	19.40	25.78	10.21	36.26	63.74
Jack	64.47	14.97	20.32	2.71	31.50	68.50
Kumbuk	52.86	11.64	27.30	9.96	51.61	48.39
Mahogany	60.16	7.82	32.44	8.32	53.92	46.08
Pine	59.09	18.40	21.53	3.12	35.93	64.07
Satin	106.60	31.03	16.70	2.32	15.65	84.35
Teak	84.36	11.29	28.87	7.86	34.21	65.79

Table 3 Comparison of average MOE values (N/mm^2) of control specimens and finger-jointed specimens.

Timber species	Control(C) (N/mm^2)	SD	FJ 13mm (N/mm^2)	SD	strength. %	Strength Loss %
Grandis	8203	1849.69	5326	1748.89	62.74	37.26
Jack	5765	834.91	3445	716.92	54.78	45.22
Kumbuk	4651	1064.63	5437	1551.10	116.90	-16.90
Mahogany	5775	595.19	4429	666.95	51.38	48.62
Pine	7149	2002.75	5331	1384.02	74.56	25.44
Satin	10819	2918.53	3155	750.36	29.17	70.83
Teak	8538	728.89	6158	2185.92	72.12	27.88

buk, Pine, Grandis, Mahogany, Jack and Satin.

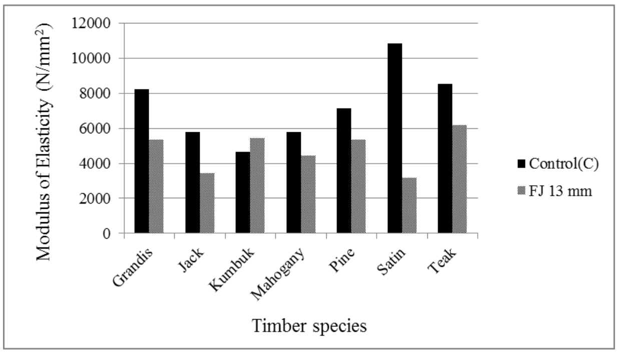


Figure 4 : Comparison of average MOE values of control (C) and finger- jointed (FJ 13 mm) specimens.

Average MOE value of finger-jointed Kumbuk timber specimen was higher than control Kumbuk specimen. Comparing with the 13 mm finger-jointed specimens and un-jointed specimens, the highest strength loss percentage (70.83 %) was obtained from Satin species.

CONCLUSION

According to overall results of the tests, control (un-jointed) samples gave the highest flexural strength than 13 mm finger- jointed specimens and it was also observed that Kumbuk timber species gave the highest MOE value in 13 mm finger-jointed specimen (5437 N/mm^2) comparing control specimen of Kumbuk (4651 N/mm^2).

The highest flexural strength loss percentage was obtained from Satin species. The MOE of finger-jointed Kumbuk was higher than clear Kumbuk specimens and the least strength loss percentage of MOR (46.08 %) was obtained from Mahogany species.

The tests of selected seven wood species depict that strength of a timber depends on its species and hence different wood species have different strength characteristics. The results obtained in this study has provided quantitative information on the mechanical properties of selected hardwood species which can be used in determining the application of these wood for structural and non- structural applications and manufacture of finger joint furniture.

REFERENCES

Abeysinghe LS, Pathirana S & Kumara M 2016 Economic Factors and physical properties of Finger Joint Timber Product to Promote Effective utilization of Natural Resources. Proceedings of the International Forestry and Environment symposium. Dept. of Forestry and Environmental Science. University of Sri Jayewardenepura, Sri Lanka. 60.

Ayhan O and Fatih Y 2007 Structural performance of the finger –jointed strength of some wood species with different joint configurations. Construction and Building Materials. Elsevier Ltd.

British Standard Institution 1999 BS 373: 1957 Methods of testing small clear specimens of timber. British Standards Institution, London.

British Standard Institution 2014 BS EN 15497:2014 Structural finger jointed solid timber-Performance requirements and minimum production requirements. European Committee for Standardization. B 1000, Brussels.

Jokerst RW 1981 Finger-jointed wood products. Res.Pap FPL-382 USDA Forest Service, Madison: Forest Pro Lab; Wis.1981. p 25

Liyanage BLVU, De Silva S, De Silva S & Muthumala CK 2017 Utilization of waste timber in Construction Industry. 8th International Conference on Sustainable Build Environment. Kandy, Sri Lanka. 41-47.

Mohammad M 2004 Finger joint process and product quality, Value to wood project report (FCC3), FP Innovations-Forintek Division, St-Foy, Quebec, Canada.

Muthumala CK & Amarasekara H 2013 Investigation the authenticity of local and imported timber species in Sri Lanka. Proceedings of the International Forestry and Environment symposium. Dept. of Forestry and Environmental Science. University of Sri Jayewardenepura, Sri Lanka. 95.

Muthumala CK, De Siva S, Alwis PLAG & Arunakumara KKIU 2018a Factors affecting the glue strength of finger-joints in commonly used timber species in Sri Lanka. International symposium on Agriculture and Extension. Faculty of Agriculture. University of Ruhuna, Sri Lanka. 126-128

Muthumala CK, De Siva Sudhira, Arunakumara KKIU and Alwis PLAG 2018b Investigate the most suitable glue type for finger-joints production in Sri Lanka. Research journal of Agriculture and Forestry Sciences. Res Pap ISCA. India. 6(11) Nov. 2018 p.6-9.

Ruwanpathirana ND & Muthumala CK 2010 Wooden wonders of Sri Lanka. State Timber Corporation, Sri Lanka. 08

Sandika AL, Pathirana GDPS and Muthumala CK 2017 Finger joint timber products for effective utilization of natural resources: An analysis of physical properties. Economic factors and Consumers perception. International Symposium on Agriculture and Environment. University of Ruhuna, Sri Lanka. 109-111.

Vievek S, De Silva S and Muthumala CK 2016 Finger joint and their structural performance in different exposure conditions. 7th International Conference on Sustainable Build Environment. Kandy, Sri Lanka. 207-210.

Winandy JE 1994 Effects of long-term elevated temperature on CCA-treated Southern Pine lumber. Forest Products Journal. 44(6): pp 49–55.

Yavari A, Hemmasi A, Roohnia M and Marusak R 2015 Dynamic Young' s modulus of scarf and finger-jointed beams using longitudinal vibration methods, Wood joints and vibration, BioResources 10(4). pp.6886-6895