Identification of Joint Efficiencies in 13 mm Finger Jointed Timber Species Used in Sri Lanka

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Abstract. When using timber in construction and the furniture manufacturing industry, waste timber materials and short length sections of timbers which are dumped by sawmills are considered to be matter of concern. 'Finger joint' is a recognized technique connecting two small pieces of waste timber together to ensure their sustainable utilization. Currently, the technique is used in Sri Lanka for non-structural purposes such as making timber boards and furniture. However, issues related with the strength of the joints have not fully investigated in Sri Lanka. This study was undertaken to determine the tensile strength performance of seven timber species in both unjointed (clear) and finger-jointed methods with 13 mm finger lengths and 4 mm finger pitch. An SWR adhesive (PVA) type was used as bonding material at normal exposure conditions. Well-seasoned Grandis, Jack, Kumbuk, Mahogany, Pine, Satin and Teak timber materials were used for the study.

BS 373: 1957 and BS EN 15497:2014 were used as standards for tests. The tests for tensile properties were performed using the Universal Testing Machine (UTM 100 PC) with a loading plate moving speed of 01 mm/min. Maximum load was read on graph to calculate the ultimate tensile strength.

The highest ultimate average tensile strength values were recorded in control specimens and different joint efficiencies were recorded in different finger jointed species. The highest mean finger joint efficiency percentage was obtained from Mahogany timber species and the least mean finger joint efficiency percentage was recorded in Kumbuk timber species.

Keywords: Finger joint · Tensile strength · SWR glue type · Joint efficiencies

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1 Introduction

The history of wood architecture of Sri Lanka has revealed that architects and craftsman with the natural creative skills have existed since the beginning of the country's long history and civilization. As a result of low quality and low strength of the local wood used by some of these ancestral architects and craftsmen, most wood creations have not lasted for long and have perished with time (Ruwanpathirana and Muthumala 2010).

The forests of Sri Lanka have nearly 450 types of hardwood timber species which are used for structural and non-structural purposes. The wood is excellent material for roofing and other construction works, furniture, interior decorations, doors and window frames, panelling, partition borders, floorings, wood carvings, musical instruments etc.

Physical and mechanical properties are very important in structural and non-structural purposes of timber. The properties not only vary with the species but also with factors such as the moisture content and defects of wood.

Finger joint is a sustainable, eco-friendly and economically viable concept for the furniture industry. It ensures the sustainable utilization of small wood cut pieces which are removed as waste (Sandika 2017). Finger joint timber manufacturing is considered to be a viable solution for minimizing the waste production in furniture manufacturing activities. Types of glue applied for the joining process of finger joint is one of the key factors which determines the strength of the product. The highest tensile strength of finger jointed timber solids was recorded in the SWR glue type in Sri Lanka (Muthumala et al. 2018a, b).

However, issues related with the strength of the joints have still not been fully investigated in Sri Lanka. This study was undertaken to determine the tensile strength performance of both unjointed (solid) and finger-jointed in seven species of timber with 13 mm finger lengths, which is the commonly used finger type in Sri Lankan furniture manufacturing.

2 Materials and Methods

Unjointed and jointed finger joint samples were cut from seasoned, defect-free wood timber to calculate tensile strength properties. Finger joint specimens were made at the finger joint factory at Boossa in the State Timber Corporation (STC) using 13 mm finger joint length cutters and an assembling pressure of 6 MPa was used in this study. Clear timber specimens were taken as control specimens and finger jointed timber specimens with the same dimensions were made with constant finger geometry such as 13 mm Finger Length, 1 mm Tip width and 4 mm finger pitch. Finger joint geometry is shown in Fig. 1. Polyvinyl acetate (PVA) SWR adhesive was used as a bonding agent (Glue type) for finger jointed wood.

Table 1 shows that timber species mainly used in furniture industries in Sri Lanka. In this study those timber species were used to calculate tensile strength properties.

The specimens were prepared from defect – free, sawn woods and dimensions of the sample prepared for above test is shown in Fig. 2.

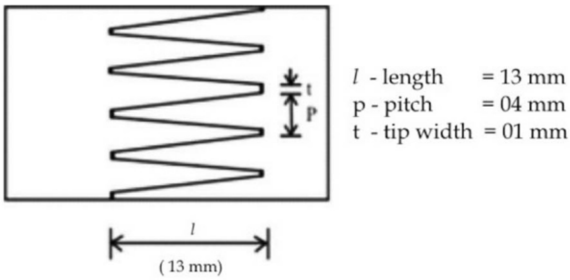

Fig. 1. Finger joint geometry

Table 1. Timber species mainly used in the furniture manufacturing industry in Sri Lanka.

Timber species	Botanical name	Timber class (STC)
Grandis	*Eucalyptus grandis*	Class-II
Jack	*Artocarpas heteroplyllus*	Luxury
Kumbuk	*Terminalia arjuna*	Special
Mahogany	*Swietenia macrophylla*	*Luxury*
Pine	*Pinus caribaea*	*Class-III*
Satin	*Chloroxylon swietenia*	*Luxury*
Teak	*Tectona grandis*	*Supper Luxury*

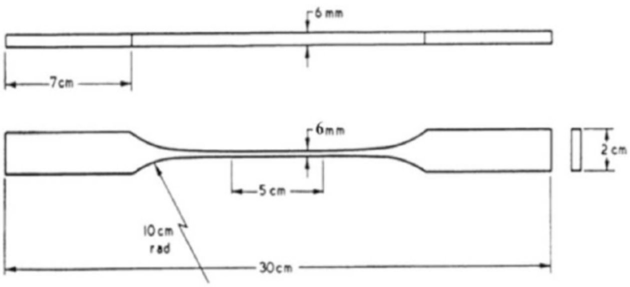

Fig. 2. The dimensions of the samples prepared for tension test.

The density values were calculated for seven timber species using following equation (Eq. 1). Dry weight of the timber samples was taken by placing them in the electric oven for a period of 48 h at 105 °C (BS EN 373:1957).

$$\text{Density} = \frac{\text{Weight of oven dry wood (kg)}}{\text{Volume of wood } (\text{m}^3)} \tag{1}$$

Determination of basic density was done based on the green volume and oven-dry weight using a water displacement method. Moisture contents were measured using a moisture meter.

Ten replicates were made for each timber species. Samples which were placed in normal room temperature conditions showed good structural performance compared to hot and wet conditioned ones (Vievek et al. 2016).

BS 373: 1957 and BS EN 15497:2014 were used as standards for tests. The test for tensile strength were performed by the Universal Testing Machine (UTM 100 PC) (Figs. 3 and 4).

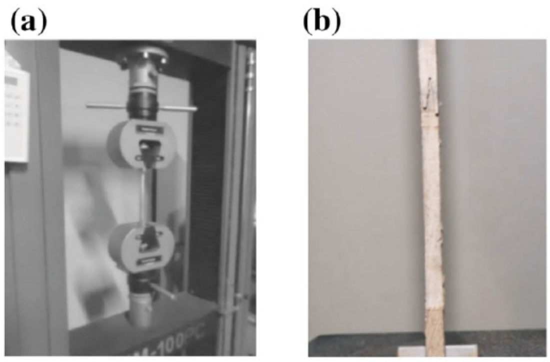

Fig. 3. a. The loading setup b. Finger joint specimen

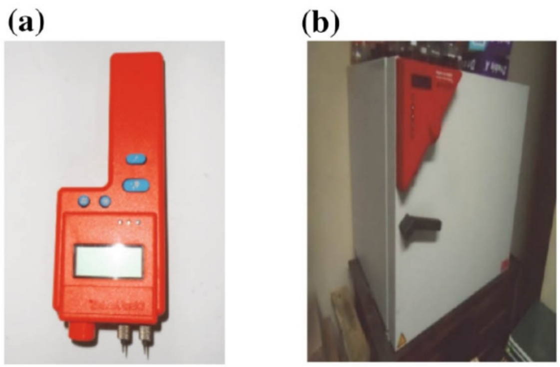

Fig. 4. a. Moisture meter b. Elec. Oven

Determination of the Tensile Strength

Maximum load act in timber section was taken into calculation. The following equation was used to calculate the Tensile strength (Eq. 2).

$$\text{Tensile strength of timber} = \frac{\text{Maximum Load}}{\text{Average cross section area of specimen}} \text{N/mm}^2 \quad (2)$$

3 Results and Discussion

Dry density values and moisture content of the timber species are shown in Table 2 (Fig. 5).

Table 2. Dry density values and moisture content of timber species.

Timber species	Density (kg/m^3)	Moisture content %
Grandis	570 ± 5	11 ± 2
Jack	645 ± 3	12 ± 2
Kumbuk	750 ± 4	11 ± 2
Mahogany	570 ± 3	12 ± 1
Pine	460 ± 2	12 ± 2
Satin	975 ± 5	12 ± 1
Teak	720 ± 5	12 ± 2

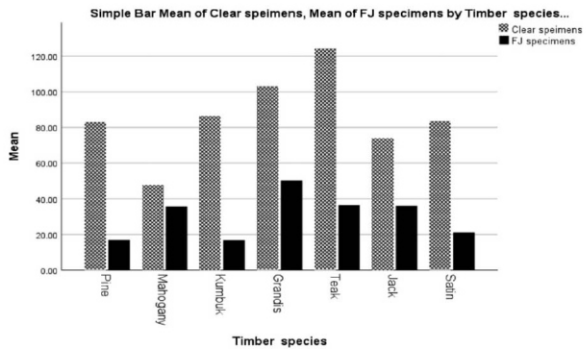

Fig. 5. Tensile strengths of clear and finger jointed specimens

According to Table 3, clear specimens and finger jointed specimens have statistically significant effect. $P < 0.0005$

Table 3. Statistical data from SPSS for tensile strength in both c lear and finger-jointed specimens

ANOVA						
		Sum of squares	df	Mean square	F	Sig.
Clear specimens	Between groups	33890.571	6	5648.429	7.372	0.000
	Within groups	48272.864	63	766.236		
	Total	82163.435	69			
FJ specimens	Between groups	9385.919	6	1564.320	14.253	0.000
	Within groups	6914.491	63	109.754		
	Total	16300.410	69			

According to the overall results of the tests, control (unjointed) samples gave significantly ($p < 0.005$) higher tensile strength than 13 mm finger jointed specimens. The highest tensile strength was recorded in clear specimens of Teak and the least tensile strength was showed by finger jointed Kumbuk.

Clear specimen of Teak showed the highest tensile strength followed by Grandis, Kumbuk, Satin, Pine, Jack, while the lowest recorded was Mahogany. Finger joint specimen of Grandis showed the highest tensile strength followed by Teak, Jack, Mahogany, Satin, Pine, while the lowest was Kumbuk.

According to Table 4, the highest mean efficiency percentage (75.08%) for finger joint was obtained from Mahogany and the least mean efficiency percentage for finger joint (19.60%) was recorded in Kumbuk. Mean finger joint efficiency percentage varied as, Mahogany > Jack > Grandis > Teak > Satin > Pine > Kumbuk.

Table 4. Finger joint efficiencies of seven timber species

Timber species	Mean tensile strength of clear specimens (N/mm^2)	Mean tensile strength of finger-joint specimens (N/mm^2)	Strength difference (Clear - joint) (N/mm^2)	Joint efficiency %
Grandis	103.16	50.24	52.92	48.70
Jack	73.88	36.06	37.82	48.80
Kumbuk	86.13	16.88	69.25	19.60
Mahogany	47.64	35.77	11.87	75.08
Pine	83.23	17.04	66.19	20.47
Satin	83.57	21.13	62.44	25.28
Teak	124.25	36.47	87.78	29.35

Yeh et al. (2011) reported that no significant difference in the tensile strength of finger-jointed lumber was found between horizontal and vertical finger formation.

4 Summary and Conclusion

The following conclusions can be drawn from this study.

Control (unjointed) samples gave higher tensile strength than 13 mm finger jointed specimens.

(1) The highest tensile strength was recorded in clear specimens of Teak and the least tensile strength was showed by finger jointed Kumbuk.
(2) The highest mean efficiency percentage (75.08%) in finger joint was obtained from Mahogany and the least mean efficiency percentage (19.60%) in finger joint was recorded in Kumbuk.
(3) The study illustrates the joint efficiency of seven finger jointed timber species. Finger joint manufacturers can use these results in increasing their production efficiency.

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