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PROPERTIES OF FINGER JOINTED HARDWOOD AND SOFTWOOD TIMBER SPECIES IN SRI LANKA

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Abstract: Finger joint is sustainable, eco-friendly and economically valuable concept for furniture industry. It ensures the sustainable utilization of small wood cut pieces which removed as waste. Finger joints are described as interlocking end joint 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.This study was conducted to determine the effect of flexural strength and compression strength of soft wood species (Pine-*Pinus caribaea*) and Hard wood species (Mahogany-*Swietenia macrophylla*) mainly used two timber species in Sri Lanka. For these test, BS 373: 1957 and BS EN 15497:2014 were used as standards for tests. The test for mechanical properties were performed an 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 level in SPSS. Pine and Mahogany finger jointed sections and comparing them with the clear specimens from the same wood lot. For joining the sections, the Poly Vinyl Acetate was used as a bonding material. Vertical finger joint orientation and 13mm finger joint length were used in this study. It was found that MOR and MOE are affected by the finger jointed specimens and the clear specimens.The values of compression parallel to grain of Mahogany showed no significant difference between the values for the jointed and un-jointed specimens. But the values of compression parallel to grain of Pine showed a significant difference between the values for the jointed and un-jointed specimens. Considering the flexural test, Pine and Mahogany clear specimens are in same strength group and finger jointed Pine and Mahogany specimens are belong to another group which is relatively low strength .However compression strength values of clear Pine specimens are relatively higher than Mahogany clear specimens.

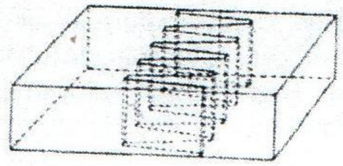
Keywords: Finger joint; Compression; MOR; MOE; Softwood; Hardwood

1. Introduction

Off-cut wood is currently one of the wastes dumped by sawmills as they failed to fully utilize the wood supply. Waste sawn timber material of furniture factories and short length of sawn timber are also considered to be constrains associated with timber industry. Joining system which utilizes the finger jointed techniques is widely employed in minimizing the waste.Finger joint is 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).Finger joints are described as interlocking end joint 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 EN 15497:2014).Two types of finger orientations i.e. Horizontal finger joints and Vertical finger joints are used in Sri Lanka. Mainly two types of finger-joint lengths are used in Sri Lanka (13, 19 mm). Several adhesives are used as wood bonding agents. P-SWR, D3 type adhesive which includes Polyvinyl acetate (PVA) is shown to have the highest tensile capacity. (Sathesrajkumar et al., 2016). In most of the countries, low density timber species (light wood) and softwood species like Rubber wood, Pine wood etc, are used to produce Finger Joint Boards. However, there is little information available concerning the strength properties of finger jointed hard wood species. Mahogany and Pine wood are two timber species widely used in furniture industry in Sri Lanka. The State Timber Corporation also commonly uses Mahogany and Pine wood for making finger joint furniture board and furniture. Comprehensive study initiated in Sri Lanka at State Timber Corporation to examine the relationship between finger-jointed hardwood species and softwood species with nearly similar dry density used in Sri Lanka.

2. Methodology

Samples were cut from Seasoned planks (moisture content varied 10-13 %) of Mahogany (*Swietenia macrophylla*) and Pine (*Pinus caribaea*) wood using a circular saw. The wood sections were selected from visually inspected defects free sawn woods. Ten samples were made for each timber species. The samples of 20 mm x 20 mm x 300mm were used for bending tests while 20 mm x 20 mm x 60 mm were employed in compression tests (BS EN 373:1957). Seasoned ten clear wood samples were cut from the planks and used as the controls.Vertical finger joints samples were made using 13mm finger-joint length cutters. Figure 1 depicted the way as to how vertical oriented finger joints setup was made. Polyvinyl acetate (PVA,P-SWR) adhesive was used for testing the clear samples and finger joint samples. Samples which were placed in normal room temperature conditioned showed good structural performance compared to hot and wet conditioned (Vivek et al 2016). Therefore the control samples and the jointed samples were kept at room temperature for at least seven days.The testing was done under both laboratory and manufactory conditions according to the regulations of the standard on BS



373:1957.The basic density determination was done based on the green volume and oven-dry weight using a water displacement method.

Figure 1 : The Vertical oriented finger joints

The span for the bending measurements was kept at 280 mm. The load was applied continuously by Universal Testing Machine with a loading rate of 2 mm/min for Bending tests and 0.6 mm per minute for Compression tests. Figure 2 shows the loading setup used in bending measurements.

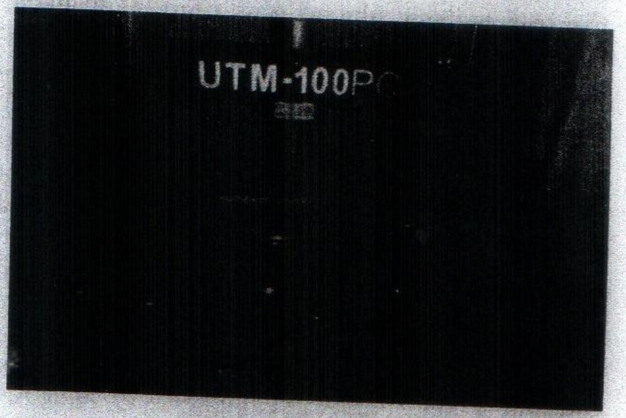


Figure 2 : Loading setup in bending test of finger jointed sections.

The Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) were

$$MOR = \frac{M \times y}{I} \quad (1)$$

calculated for the bending test using the following formula.

Modulus of Rupture (MOR) (ultimate flexural strength) and Modulus of Elasticity (MOE) values were calculated by using Equations 01 and 02 corresponding to test data.

MOR –Modulus of Rupture

M – Maximum Bending moment

y – Maximum distance from neutral axis to edge of the section

I – Second moment of area

$$MOE = \frac{WL^3}{48\delta I} \quad (2)$$

MOE –Modulus of Elasticity

L – Length of timber specimen

W – Maximum Load act in canter of specimen

δ – Maximum deflection of timber beam

I – Modulus of elasticity

2.1 Ultimate compressive strength

Rectangular test piece in measurement of 20 mm x 20 mm x 60 mm was employed in compression tests. Test piece was prepared in smooth and parallel and normal to the axis. The testing machines were of such construction that the plates between which the test piece is placed was parallel to each other and remain so during the whole period of test.

Figure 3. Test piece measurements used in Compression parallel to Grain test.

Maximum load act in timber section before the failure was taken into calculation.

$$\text{Ultimate strength of timber} = \frac{\text{Maximum Load act in specimen}}{\text{Average cross section area of specimen}} \ N/mm^2 \quad (3)$$

Figure 4 shows the loading setup used in Compression parallel to Grain test.

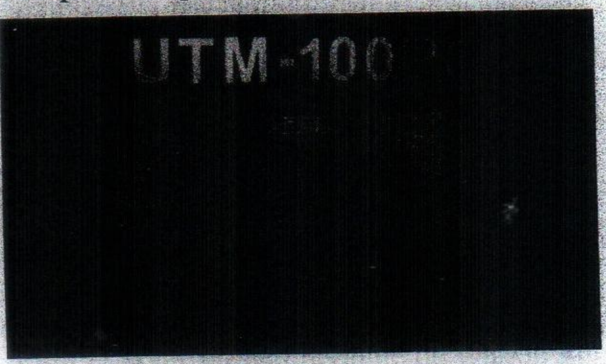


Figure 3: The loading setup used in Compression parallel to Grain test.

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

3Results and Discussion

Calculated average dry density values of Pine (Softwood) and Mahogany (Hard wood) are 511kg/m³ and 570 1kg/m³ respectively. Calculated average moisture content percentage of Pine (Softwood) and Mahogany (Hard wood) are 12%.

Table 1:Analyzed results by ANOVA Procedure

Experiments	Probability value(P)	Level of significance
MOR*	0.000	0.05
MOE*	0.000	0.05
Compression Parallel to Grain*	0.000	0.05

*-significant at 0.05 probability Level

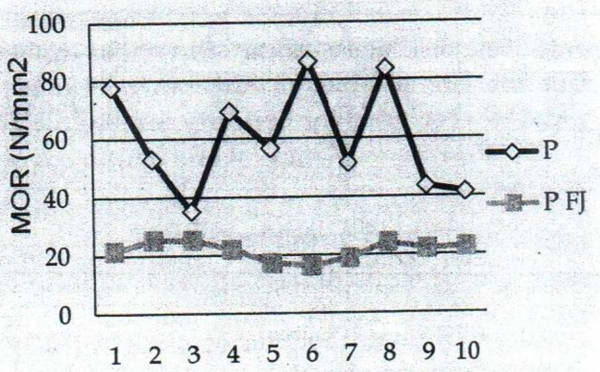


Figure 4: MOR values between Pine clear specimens(P) and Pine finger joint specimens(PFJ)

According to the Figure 4, modulus of rupture showed significant difference between the values for the jointed and un-jointed (clear) Pine specimens. This indicates that MOR is affected by the finger joint. Modulus of rupture ranges between 35.17 N/mm² and 86.62 N/mm² for the control specimen. Modulus of rupture ranges between 16.27 N/mm² and 25.2 N/mm² for the finger jointed specimen.

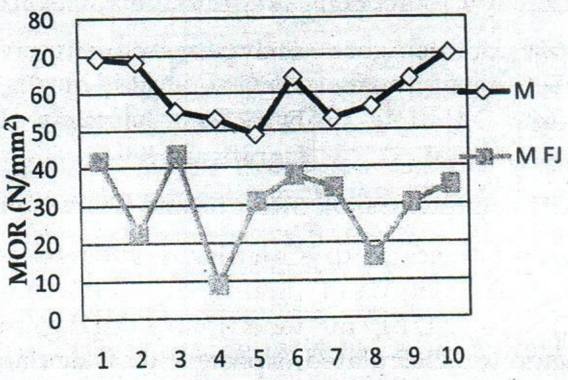


Figure 5: MOR values between Mahogany clear specimens(M) and Mahogany finger joint specimens(MFJ)

Figure 5 shows similar results between jointed and un-jointed (clear) Mahogany specimens as Pine specimens. Modulus of rupture ranges between 48.82 N/mm² and 70.35 N/mm² for the control specimen and8.92 N/mm²ᵇ and 43.57N/mm² for the finger jointed Mahogany specimen.

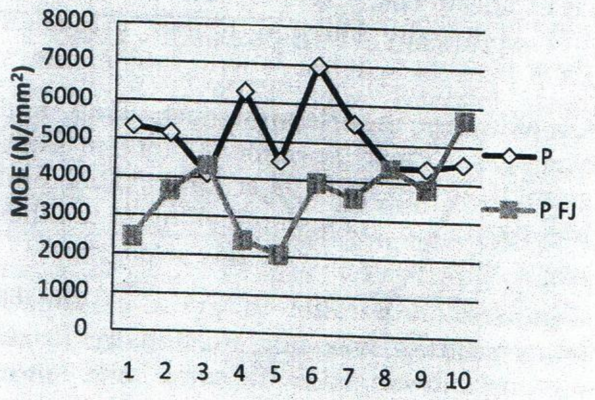


Figure 6:Ultimate modulus of elasticity (MOE) values between pine clear specimens and Pine finger joint specimens(PFJ)

Figure 6 revealed that the, modulus of elasticity values for the jointed and un-jointed (clear) Pine specimens are significant different. This indicates that MOE is affected by the finger joint. Modulus of elasticity ranges between 4103.75 N/mm² and 6987.03 N/mm² for the control specimen and Modulus of rupture ranges between 2058.0 N/mm² and 5672.69 N/mm² for the finger jointed specimen.

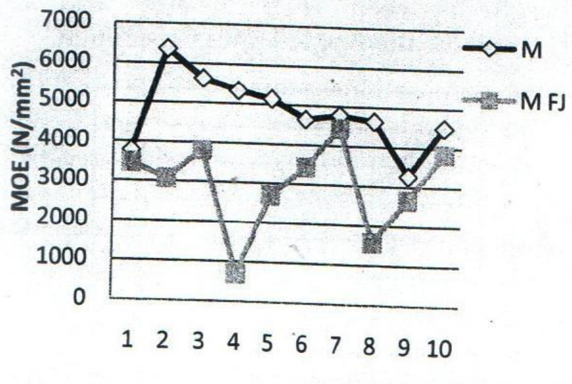


Figure 7: MOE values between Mahogany clear specimens(M) and Mahogany finger joint specimens(MFJ)

Figure 7 shows similar results between jointed and un-jointed (clear) Mahogany specimens as Pine specimens. Modulus of elasticity ranges between 3267.95 N/mm² and 6370.0 N/mm² for the control specimen and 702.53 N/mm² and 4438.82 N/mm² for the finger jointed Mahogany specimen.

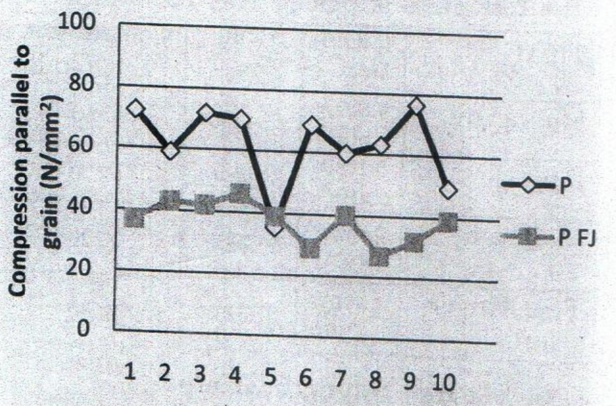


Figure 8: Compression parallel to grain values between Pine clear specimens(P) and Pine finger joint specimens(PFJ)

According to Figure 8, there is a significant difference between jointed and un-jointed specimens was found for the values of compression parallel to grain. Compression parallel to grain values of the clear Pine specimens varied from 35.5 N/mm² up to 76.5 N/mm² and 27 N/mm² up to 46 N/mm² in Finger jointed Pine specimens.

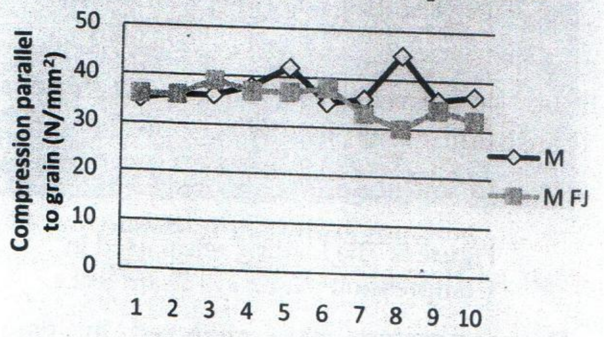


Figure 9: Compression parallel to grain values between Mahogany clear specimens(M) and Mahogany finger joint specimens(MFJ)

Figure 9 revealed that there is no significant difference found between the Mahogany clear specimens and Mahogany Finger jointed specimens. This indicate that compression parallel to grain is not affected by the jointed and non jointed in the Mahogany specimens.

Compressionparallel to grain values of the clear Mahogany specimens varied from 35N/mm² to 45 N/mm² and 30 N/mm² to 39 N/mm² in Finger jointed Mahogany specimens.Duncan Multiple R. test was used to analyze the data.

Table 2. Results of Duncan's Multiple R. Test

Treat.	(MOE) Mean	(MOR) Mean	Compression Pa. to Grain
Mahogany	4.8093^{a} x10^3	60.1650^{a}	37.60^{b}
Pine	5.1180^{a} x10^3	59.9025^{a}	62.70^{a}
Mahogany Finger joint	2.9670^{b} x10^3	30.2400^{b}	35.20^{b}
Pine Finger joint	3.6310^{b} x10^3	21.5250^{b}	37.40^{b}

a , b - Separate Strength Group

According to Table 2, Pine and Mahogany clear specimens are in same group and, finger jointed Pine and Mahogany specimens are belong to another group considering MOR and MOE strengths values.

MOE and MOR in finger jointed Pine and solid Pine are significantly different as similar to Mahogany. But comparing of ultimate compression strength, there is no significant difference found in solid Mahogany and finger jointed Mahogany.

Compression strength values of clear Pine specimens are relatively higher than Mahogany clear specimens.

4. Conclusion

This study was conducted to determine the effect of flexural strength and compression strength of soft wood species and Hard wood species with nearly similar dry density, mainly used in Sri Lanka.

Table 3. Average Strength Results of tests

Ultimate Strength (N/mm²)	Pine		Mahogany	
	Clear	Finger jointed	Clear	Finger jointed
MOR	59.903	21.525	60.165	30.24
MOE	5118.038	3631.039	4809.266	2966.957
Compression Par.to grain	62.725	37.424	37.675	35.263

Based on the experimental investigation reported in this paper, the following conclusions were drawn.

MOR was affected by the finger jointed Pine and Mahogany specimens and the both clear specimens. Clear specimens of Pine and Mahogany showed higher values of MOR than the specimens with finger joint.

MOE was affected by the finger jointed Pine and Mahogany specimens and the both clear specimens. Clear specimens of Pine and Mahogany showed higher values of MOE than the specimens with finger joint.

Considering the flexural test, Pine and Mahogany clear specimens are in same strength group and finger jointed Pine and Mahogany specimens are belong to another group which is relatively low strength .

Compression parallel to grain of all the joints studied was not affected by finger jointing and ranged in the same level values of the control solid wood in Mahogany species. But there is a significant difference between clear Pine and finger jointed Pine considering the compression parallel to grain strength.

However compression strength values of clear Pine specimens are relatively higher than Mahogany clear specimens.

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