VARIATION OF DENSITY, FLEXURAL STRENGTH AND ANATOMICAL FEATURES OF FINGER JOINTED WOOD PRODUCTS IN SRI LANKA

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Abstract

Timber is considered to be an ecological friendly building material with less construction energy requirements (Muthumala et. al, 2019). Finger jointed technique is used to eliminate wood defects which weaken the strength of sawn wood plank. Surface properties are not considered to be the only factors affecting bonding in wood. Bond quality is also affected by density, porosity, moisture content and shrinking properties. Variations in flexural strength and anatomical features of six common timber species used in furniture industry in Sri Lanka were studied. Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) were measured with and without finger joint specimens of 13 mm and 19 mm finger lengths of six timber species. The 3-point bending tests were performed by using Universal Testing Machine (UTM 100 PC). Transverse, radial and tangential section at the range of 10-15 micrometer thickness were taken using a sledge microtome (Model Leica SM2000 R). Measurements were obtained using Micrometrics SE Premium 4 software available at Wood laboratory, Research division of the State Timber Corporation, Sri Lanka. Quantitative wood anatomical features such as mean vessel diameter, vessels per square millimeter and ray heights were measured. The relationship between wood density, mechanical properties and anatomical features of finger jointed and clear timber species were analyzed by regression models. There was a positive correlation between total vessel area and flexural strength of 13 mm finger joint specimens. Mean ray height and flexural strength are not found to be affected significantly in finger jointing works and clear specimens.

Key words: *Finger joint; density; flexural strength; total vessel area; ray height.*

INTRODUCTION

Adhesive bonding of wood plays an increasing role in the forest products industry and it is the key factor for efficiently utilizing timber resources. The main use of adhesives is in the manufacture of the building material, engineered wood products and assembly of the furniture products. Surface properties are not considered to be the only factors control bonding in wood. Bond quality is affected by density, porosity, moisture content and shrinking properties also. The porosity and adhesive flow of wood varies greatly. In hardwoods, the thin walled, relatively large longitudinal vessels have porous end walls, so adhesive can penetrate deeply along the end grain (Charles and Christopher 2010).

Polyvinyl acetate adhesive type is mostly used in nonstructural designs. Polyvinyl Acetate (PVA) resin emulsions are thermoplastic. In emulsified form, the PVAs are dispersed in water and have a consistency and nonvolatile content generally comparable to thermosetting resin adhesives. PVAs are marketed as milky-white fluids in order to use at room temperature in the form supplied by manufacturers, normally without additives or separate hardeners. SWR, SH and Speedx are the mostly used three bonding materials in Sri Lanka and the highest tensile strength was recorded in PVA SWR glue type (Muthumala 2018).

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 EN 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). Physical and mechanical properties are very important factors of structural and nonstructural uses of timber. The properties not only vary with species but also with the moisture content, density, porosity and other anatomical features etc.

OBJECTIVES

The main objective of the present research was assessing the relationship between density and anatomical features (Total vessel area and Ray height) and bonding Flexural strength of Finger Jointed hardwood timber species in Sri Lanka.

MATERIAL, METHOD, EQUIPMENT

Preparation of the samples

Timber samples were cut from seasoned (Moisture content up to 10-12 %) defects free sawn wood timber to calculate flexural strength properties. The vertical finger jointed samples were made at finger joint factory at Boossa in the State Timber Corporation (STC) using 13 mm and 19 mm finger-joint length cutters at assembling pressure of 6 MPa. Seasoned ten clear wood samples were cut from the planks and used as the controls. Polyvinyl Acetate (PVA) adhesive was used as bonding materials (Glue type).

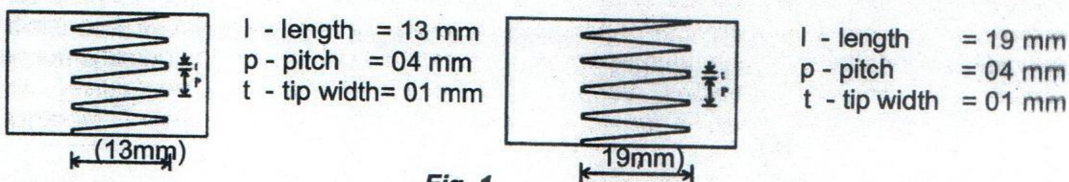


Fig. 1.
Geometric parameters of Finger joint.

Finger joint specimens' preparation

The specimens with moisture content of 12% and size of 314 mm × 20 mm × 20 mm were cross cut using a circular saw machine. Similar two pieces for joining with adhesive after making 13mm finger joint (measurement of one joining piece is 157 mm in their length). The size of 320 mm × 20 mm × 20 mm were cross cut using a circular saw machine into two pieces for joining 19 mm finger jointed samples (measurement of one joining piece is 160 mm in their length). All the samples were made in finger joint factory in State Timber Corporation, Galle, Sri Lanka. BS 373: 1957 and BS EN 15497:2014 were used as standards for tests. The test for mechanical properties were performed by using Universal Testing Machine (UTM 100 PC). Following hard wood timber species were used for this study.

Table 1

Wood species studies in the research

Common name	Botanical name	Timber Class (STC)
Grandis	*Eucalyptus grandis*	*Class II*
Jack	*Artocarpas heterophyllus*	*Luxury*
Kumbuk	*Terminalia arjuna*	*Special*
Mahogany	*Swietenia macrophylla*	*Luxury*
Satin	*Chloroxylon swietenia*	*Luxury*
Teak	*Techtona grandis*	*Super Luxury*

The density values were calculated using following equation (1):
Dry weight of the timber samples was taken by placing in 105^{0}C oven for 48 hours (BS EN 373:1957).

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

Calculation of the Flexural Strength

Ten replicates were made for each timber species. The samples of 20 mm x 20 mm x 300 mm were used for flexural tests (BS EN 373:1957). Samples which were placed in normal room temperature (27^{0}C) conditioned showed good structural performance compared to hot and wet conditioned (Vivek et al 2016). Fig. 2 shows the loading setup for flexural strength.

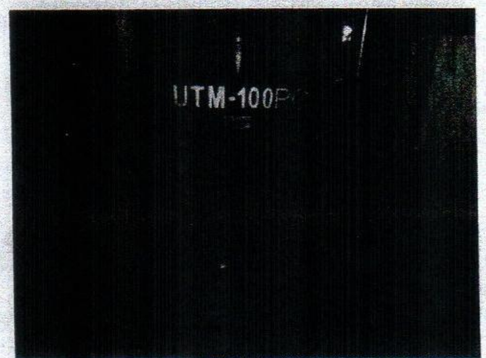


Fig. 2.
The loading setup for flexural strength.

The Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) were calculated using the formula mentioned below. Modulus of Rupture (MOR) (Ultimate flexural strength) and Modulus of Elasticity (MOE) values were calculated by using equations (2) and (3):

$$MOR = \frac{M \times y}{I} \quad (2)$$

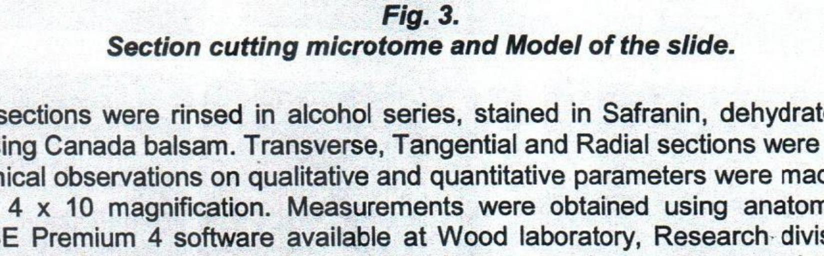
MOR –Modulus of Rupture
M – Maximum Bending moment
y – Maximum distance from neutral axis to edge of the section
I – Second moment of area

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

MOE –Modulus of Elasticity
L – Length of timber specimen
W – Load act in center of specimen
δ – Deflection of timber beam

Preparation of Wood for microscopic examination

Wood samples were boiled in water periodically for three days until air space of wood were filled with water. Each species was shaped and sized into wood block of 2 cm x 2 cm x 3 cm. Transverse, radial and tangential section at the range of 10-15 micrometer thickness were taken using a sledge Microtome (Model Leica SM2000 R). The piece of wood sample and the knife were flooded with 30 % ethanol, during the section cutting to facilitate fine sectioning.



Leica SM 2000 R
Fig. 3.
Section cutting microtome and Model of the slide.

Wood sections were rinsed in alcohol series, stained in Safranin, dehydrated and mounted permanently using Canada balsam. Transverse, Tangential and Radial sections were placed as Fig. 3.

Anatomical observations on qualitative and quantitative parameters were made under the light microscope at 4 x 10 magnification. Measurements were obtained using anatomical photos and Micrometrics SE Premium 4 software available at Wood laboratory, Research division of the State Timber Corporation. Quantitative wood anatomical features such as mean vessel diameter, vessels per square millimeter and mean ray heights were measured according to IAWA (1989). Total vessel area per square millimeter of each timber species were taken from the following method.

Total Vessel area per Square mm = πr^2 x No. of Vessels per sq.mm

= 22/7 x (Mean tangential vessel diameter/2) x (Mean tangential vessel diameter/2) x No. of Vessels per sq.mm (4)

RESULTS AND DISCUSSION

Table 2

Statistical summary of the research study.

Timber Species	Density Kg/m^3	MOR(N/mm^2) Clear	FJ-13mm	FJ-9mm	MOE(N/mm^2) Clear	FJ-13mm	FJ-9mm	Vessels per sq.mm	Mean tangential Vessel Diameter (μm)	Total Vessel area per sq. mm (μm^2)	Ray Height (μm)
Grandis	570	71.1	25.78	42.4	8203	5146.66	10643	9	161	183298.5	294.3
Jack	645	64.5	20.33	41.3	5765	3158	6845	2	215	72639.3	666.4
Kumbuk	756	52.9	27.3	40.6	4651	5437.01	5355	4	257	207582.6	277.8
Mahogany	570	60.2	30.24	36.8	5775	2966.96	4874	11	128	141604.6	344.8
Satin	980	106.7	16.7	54.5	10819	3155.47	10036	22	74	94656.6	258.2
Teak	720	84.4	28.87	52.5	8538	6157.99	8666	10	185	268910.7	555

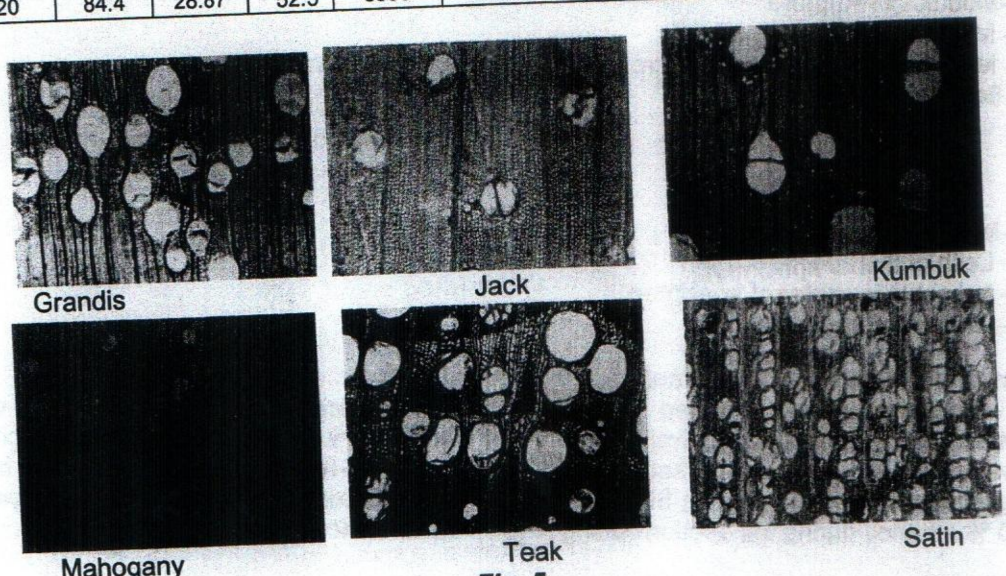


Fig. 5.

Cross section views of timber species (mag: 4x10).

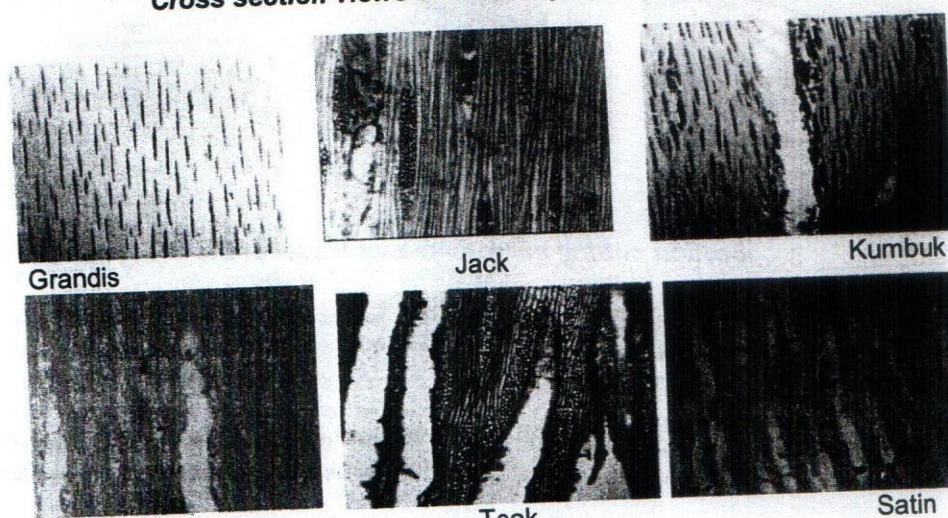


Fig. 6.

Tangential section views of timber species (mag: 4x10).

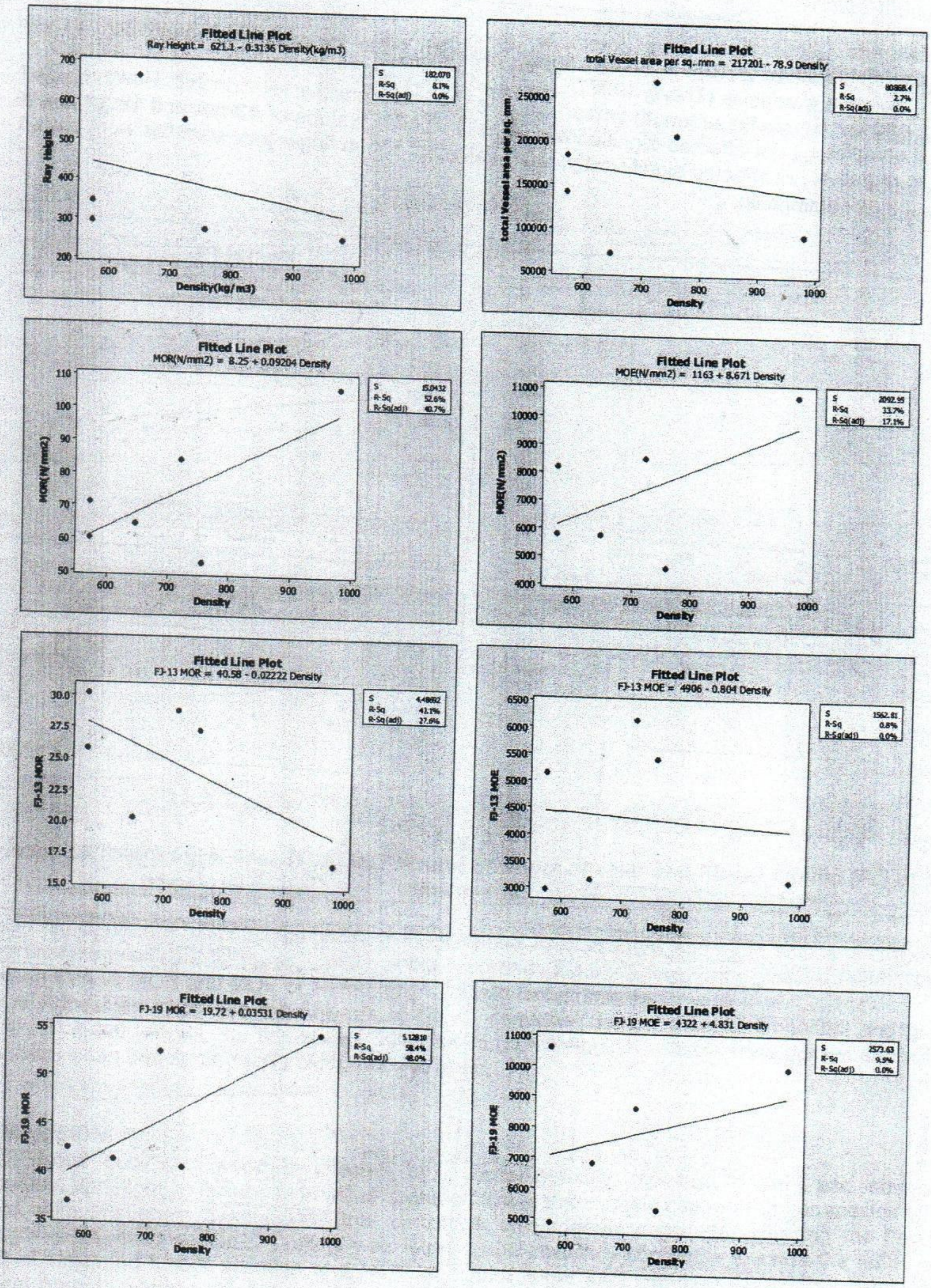


Fig. 7.
Variation of density vs Anatomical and mechanical properties of clear and Finger jointed (FJ) specimens.

As shown in Fig. 7, relationships between density and MOR, MOE, Mean Ray height and Total Vessel Area per square millimeter of Finger jointed and unjointed six timber species could be identified. A positive correlation was obtained between density vs MOR and MOE of unjointed timber species. Higher density wood contains more material per unit of volume and can carry more load

(Charles and Christopher 2010). A similar trend has also been reported previously by several researchers for various species (Zhang 1997).

Density and 19mm finger length timber samples showed a positive relationship. However, Ray height and density was not affected significantly. Density vs MOE values of 13mm and 19mm finger jointed samples were not affected significantly. MOR values of 13mm finger joint samples were shown to have negative relationship.

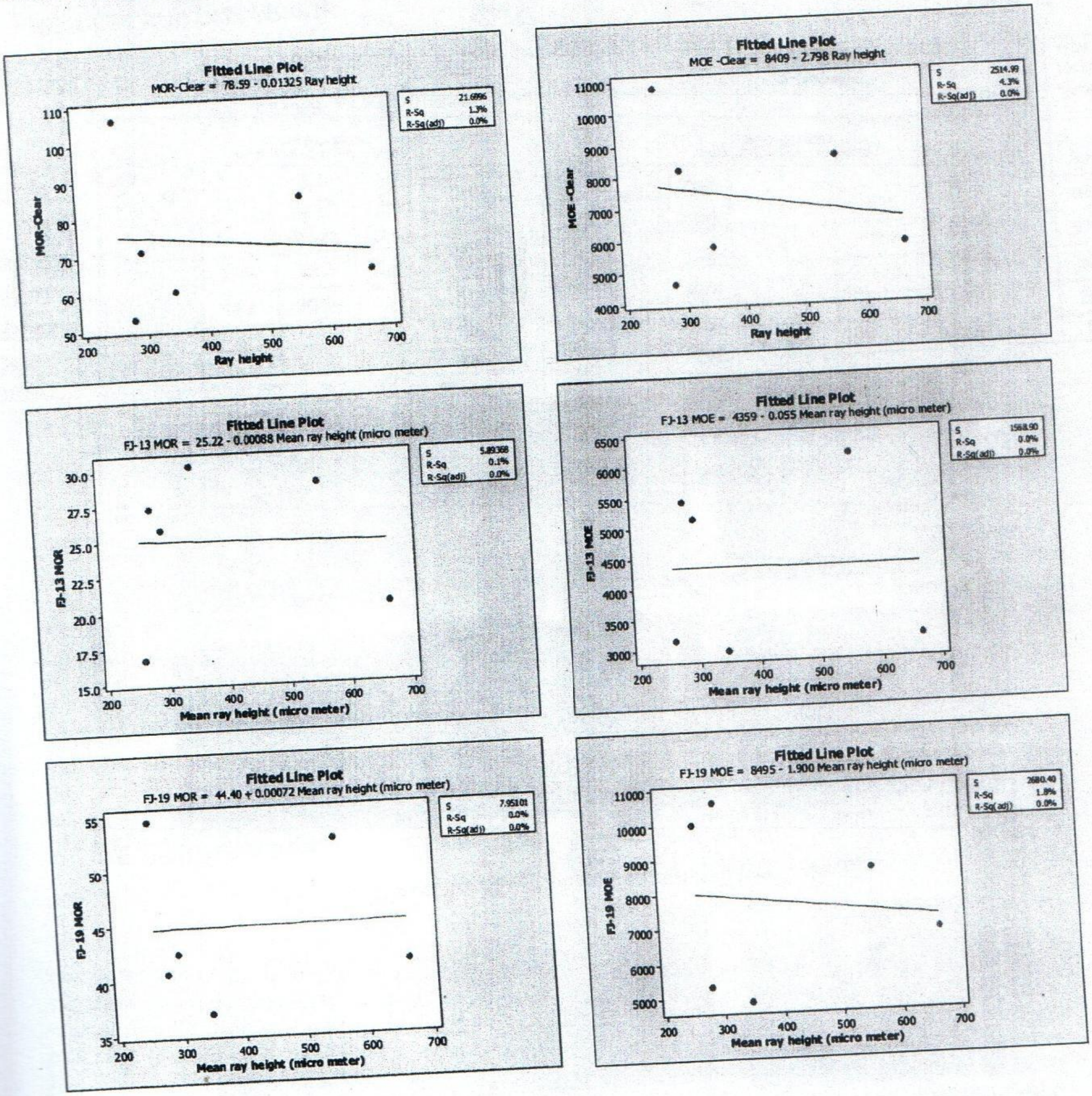


Fig. 8.

Variation of Mean Ray Height vs Flexural Strength of Finger jointed and Unjointed timber species.

As depicted in Fig. 8, no significant relationships between Mean Ray Height vs MOR and MOE values of Finger jointed and Unjointed timber species were observed.

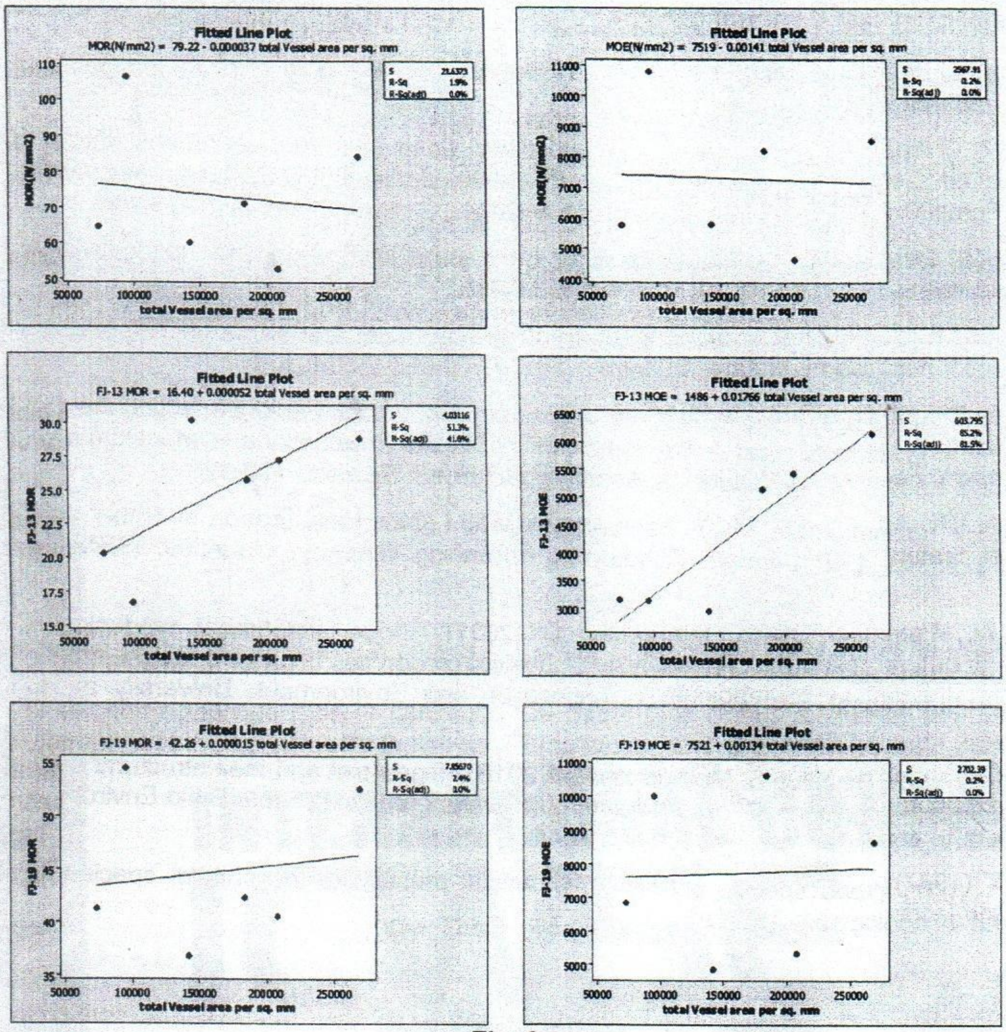


Fig. 9.

Variation of Total Vessel Area (TVA) vs Flexural Strength of clear and Finger jointed (FJ) timber specimens.

No significant relationships between Total Vessel Area vs MOR and MOE values of Unjointed and 19mm Finger jointed timber species were recorded (Fig.9). There were positive relationships between TVA vs MOR and MOE of 13 mm finger jointed timber species.

Adhesives might use the network of pits to penetrate deeply, even in tangential and radial directions. In hardwoods, the thin-walled, relatively large longitudinal vessels have porous end walls, so adhesive can penetrate deeply along the end grain.

CONCLUSION

Bond quality of wood is affected by density, porosity, moisture content and shrinking properties. Variations in flexural strength and anatomical features of six common timber species in Sri Lanka were studied. It is concluded that density is an important parameter affecting the flexural strength of unjointed samples. Density was found to be positively contribute towards the MOR and MOE of Unjointed timber samples and MOR of 19mm finger joint samples. Mean Ray height and flexural strength was not affected significantly in finger jointed and clear specimens. Total Vessel Area per square millimeter was positively affect in 13mm finger jointed specimens.

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