Finger-joint technique to mitigate climate change

C.K. Muthumala[1*], Sudhira De Silva[2], K.K.I.U. Arunakumara[3] and P.L.A.G. Alwis[4]

[1]Research, Development and Training Division, State Timber Corporation, Sri Lanka
[2]Department of Civil and Environmental Engineering, Faculty of Engineering, University of Ruhuna, Sri Lanka
[3]Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Sri Lanka
[4]Department of Agric. Engineering, Faculty of Agriculture, University of Ruhuna, Sri Lanka
*ck_muthumala@yahoo.com

- **Finger joint is a recognized technique connecting two small pieces of timber together**
- **This technique is used in Sri Lanka for non-structural purposes such as making timber boards and furniture**
- **Issues related with the strength of the joints are still not fully investigated under Sri Lankan conditions**
- **With higher tensile strength, finger -joint technique can be used to manufacture furniture and minimize the use of small sawn timber planks in boilers**
- **This technique will enhance the mitigation of greenhouse gases and assist in carbon sequestration**

Introduction

Human induced climate change is one of the most pressing and complex issues facing society in the 21st century. Increased use of forests and wood products, does make an important contribution towards tackling the problem of climate change although it does not necessarily reduce greenhouse gas emissions at source (Hannah *et al*, 2004). Trees sequester carbon during their lifetime, absorbing carbon dioxide (CO_2) from the atmosphere and storing it in their mass. For every kilogram of wood grown, 1.5 kg of CO_2 is removed from the atmosphere (ASCE, 2010). Storing CO_2 in wood could therefore be considered as an effective means of mitigating climate change, though wood also releases CO_2 when it is used as fuel (Philippe, 2013).

When comparing the various heat sources: wood, coal, fuel oil, gas or electricity, in respect of climatic impacts, the pertinent characteristic is the emission factor, which is the amount of carbon (or carbon dioxide) emitted per unit to released energy. Substitution of wood for fossil fuels does not reduce emissions of carbon dioxide because the emission factor of wood shows a higher value than that of other fuels in common use. Thus, giving the primacy to carbon sequestration is vital to increase the carbon stock in forests, wood products or in some kind of long-term wood storage, (Philippe, 2013).

While using timber in construction and furniture manufacturing industry, waste timber materials and short-length sections of timbers which are dumped by sawmills is considered to be a matter of concern. However, some of this discarded timber planks are already being used to fuel kiln dried boilers. Finger joint is a sustainable, eco-friendly and economically valuable concept in furniture industry (Sandika *et al.*, 2017). Finger joint is a recognized technique connecting two small pieces of waste timber together to ensure 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 are still not fully investigated under Sri Lankan conditions. Consumers are paying their attention to the strength of finger joint productions. This study was undertaken to determine the tensile strength performance of both un-jointed (clear) and finger-jointed four species of timber with 13 mm finger lengths and 4 mm finger pitch.

Materials and methods

Un-jointed and jointed finger joint samples were cut from seasoned defect-free sawn wood timber to calculate tensile strength properties. Finger joint specimens were made at finger joint factory of the State Timber Corporation (STC) at Boossa using 13 mm finger joint length cutters, and an assembling pressure of 6 Nmm^{-2} was used in this study. Clear timber specimens taken as control specimens and finger jointed timber specimens with same dimensions were made with constant finger geometry such as 13 mm Finger Length, 1 mm Tip width and 4 mm finger pitch. A recent research reported that no significant difference in the tensile strength of finger-jointed lumber was found between horizontal and vertical finger formation (Min-Chyuan *et al.* 2011). Finger joint geometry is shown in figure 1. Polyvinyl acetate (PVA) SWR adhesive was used as bonding agent (Glue type) for finger jointed wood (Muthumala, 2018).

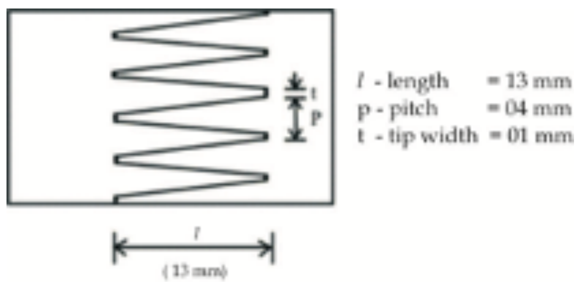

Figure 1: Finger joint geometry

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

Table 1: Four timber species mainly used for furniture manufacturing industries in Sri Lanka.

Timber Species	Botanical Name	Timber Class (STC)
Grandis	*Eucalyptus grandis*	Class –II
Mahogany	*Swietenia macrophylla*	Luxury
Pine	*Pinus caribaea*	Class-III
Teak	*Tectona grandis*	Supper Luxury

The specimens were prepared from defect-free sawn woods, and dimensions of the sample prepared for above test are shown in figure 2.

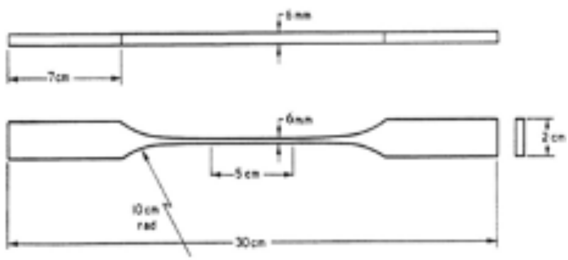

Figure 2: The dimensions of the samples prepared for tension test.

The density values were calculated for seven timber species using the following equation (Eq 01). Dry weight of the timber samples was taken by placing in the electric oven at 105°C for a period of 48 hours (BS EN 373:1957).

$$\text{Density} = \frac{\text{Weight of oven dried wood (kg)}}{\text{Volume of wood (m}^3\text{)}} \quad (\text{Eq} - 01)$$

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 conditions (Vievek *et al*,2016).

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

Determination of the Tensile strength

Maximum load act in timber section was taken into calculation. Equation 2 was used to calculate the Tensile strength (BSI, 1957).

Tensile strength of timber =(Maximum Load)/(Average cross section area of specimen)(Average cross section area of specimen)

$$\text{Tensile strength of timber} = \frac{\text{(Maximum Load)}}{\text{(Average cross section area of specimen)}} \ N/mm^2 (\text{Eq-02})$$

Results and discussion

Dry density values and moisture content of the timber species are shown in table 2. Dry Density values varied between 460 (kg/m^3) to 720 (kg/m^3) in 12 % moisture content.

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

Timber species	Density (kg/m3)	Moisture content %
Grandis	570 ± 5	11 ± 2
Mahogany	570 ± 3	12 ± 1
Pine	460 ± 2	12 ± 2
Teak	720 ± 5	12 ± 2

Table 3: Finger joint efficiencies of four 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
Mahogany	47.64	35.77	11.87	75.08
Pine	83.23	17.04	66.19	20.47
Teak	124.25	36.47	87.78	29.35

Table 4: Mean C stock (t ha-1)

Timber species	Mean Carbon stock (t ha^{-1}) of monoculture forest plantations of Sri Lanka in 2008 (De Costa & Suranga, 2012)
Grandis	132.72
Mahogany	97.57
Pine	130.19
Teak	42.70

According to Table 03, the highest mean finger-joint efficiency percentage (75.08%) was obtained from Mahogany timber species and the second highest mean finger-joint efficiency percentage (48.70%) was recorded in Grandis timber species. The least mean finger- joint efficiency percentage (20.47%) was recorded in Pine timber species. Mean finger- joint efficiency percentage varied as:Mahogany>Grandis>Teak >Pine.

Table 4 shows the mean Carbon stock (t ha^{-1}) of commonly used timber species of monoculture forest plantations of Sri Lanka in 2008 (De Costa & Suranga, 2012). The lowest amount of mean C stock was showed in the timber species of Teak (42.7t ha-1) and the highest amount of mean Carbon stock was showin the timber forest species of Grandis (132.72t ha^{-1}). However, fast grown species generally consume higher amount of resources, which are more sensitive to resource availability (Amarasinghe, 2018). Pine is a fast-growing species, which shows the second highest Carbon stock (130.19t ha^{-1}). Therefore, use of short- length sawn timber pieces for finger- jointed furniture production could contribute to carbon storage.

Conclusion

The following conclusions can be drawn from this study:

The highest tensile strength was recorded in Teak clear specimens and the lowest was recorded from finger- jointed Pine timber specimens.The highest mean finger- joint efficiency percentage (75.08%) was obtained from Mahogany timber species and the lowest (20.47%) was recorded in Pine timber species.

This study illustrates the joint efficiency of finger- jointed four timber species. The present findings could be effectively used in finger- joint manufacture.

Furniture is the portable equipment used in various human activities such as seating, working and relaxing. This end can be considered as a form of decorative art. Finger- joint techniques can be used to manufacture furniture and minimize the use of small sawn timber planks in boilers through which sequestration of the carbon stock in wood products could be enhanced.Hence, investigating the tensile strength of finger jointed products is important.

References

Amarasinghe, T. W.V., Terada, T and Yamamoto, H. (2018). ''Forest management options to increase carbon sequestration in Eucalyptus plantations of Sri Lanka," Sustainable Forest Ecosystem Management, IUFRO, Taiwan.Pp 113- 118 https://www.researchgate.net/.../330214337(Accessed: 6June 2019).

ASCE.(2010). Sustainability Guidelines for the Structural Engineer. D. Kestner, P.E.; J. Goupil, P.E.; and Emily Lorenz, P.E. https://materialspalette.org/wood/ (Accessed: 30 ,May 2019).

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

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

De Costa, W.A.J.M and Suranga H.R.(2012). Estimation of carbon stock in the forest plantations of Sri lanka, J.Natn.Sci. Foundation Sri Lanka, 40(1) 9-41

Min-ChyuanY,Yu-Li,L and Yung-Chin H.(2011). Evaluation of the Tensile Strength of structural Finger-Jointed Lumber, Taiwan J forSci 26(1): 59-70 www.airtilibrary.com(Accessed: 3 August 2018).

Muthumala C.K., De Siva S, Alwis PLAG and Arunakumara K.K.I.U.(2018a). Factors affecting the glue strength of finger-joints in commonly used timber species in Sri Lanka. International symposium on Agriculture and Environment.Faculty of Agriculture. University of Ruhuna, Sri Lanka. Pp. 126-128.

Muthumala C.K., De Siva S, Alwis PLAG and Arunakumara K.K.I.U.(2018b). Investigate the most suitable glue type for finger-joints production in Sri Lanka, Research journal of Agriculture and Forestry Sciences, ISCA, India, Vol. 6(11), 6-9, November, Pp. 6-9

Philippe L.(2013). Wood preservation (carbon sequestration) or wood burning (fossil-fuel substitution), which is better for mitigating climate change? , Annals of Forest Science (2014) 71:117–124, https://hal.archives-ouvertes.fr/hal-01098394/document (Accessed: 30May 2019).

Sandika, A.L., Pathirana G.D.P.S. and Muthumala C.K. (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. Pp. 109-111.

Vievek, S., De Silva S., De Silva, S and Muthumala, C.K. (2016).Finger joint and their structural performance in different exposure conditions, 7thInternational Conference on Sustainable Build Environment, Kandy, Sri Lanka.Pp. 207-210