Identification of Strength Parameters in Finger Jointed Timber Sections

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Abstract

Timber is widely used as a building material in the construction industry. As it is in short supply, there is now a high demand for timber in the construction industry. This has made waste timber utilization for construction important. Finger jointing can be used to connect two small pieces of waste timber. Machinery is now available in Sri Lanka to fasten, using finger jointing, the timber pieces that are used for the manufacture of furniture. As it is important to determine the structural properties of finger jointed (FJ) timber, three-point bending and compression tests using a universal testing machine (UTM) were conducted on samples of selected timber species commercially available in Sri Lanka, in accordance with BS 373:1957 to determine these properties. Samples were finger jointed with a finger length of 19 mm using the adhesive, Fevicol SWR. Satin with its high resistance to bending is found to be the most suitable species for finger jointing. The tests carried out indicated that when finger jointed, the bending strength of Satin gets reduced by only 9.5%. In the compression parallel to grain test, Jak displayed the minimum reduction of 1.53% in its compressive strength. In the timber species tested, finger jointing was found to be 100% effective in resisting compression perpendicular to grain. The compressive strength of Pine is found to be increased by 27.39% when it is under compression perpendicular to grain. Strength classes of the timber species selected were identified from BS 5268-2:2002. The compressive strength of finger jointed Grandis and Pine are found to be too poor for use as structural elements. Finger jointing of Teak is found to be cost effective. Finally, it is recommended that further studies be done on using finger jointed local timber waste.

***Keywords**:* *Economic analysis;Finger joint; Local timber species; Strength properties; Timber utilization, Waste timber*

Introduction

Timber is used as a building material in building construction. Waste timber material and short sections of timber dumped by sawn mills are creating many problems in the construction industry. It is therefore necessary to effectively use the timber residues produced in building construction. Timber wastage can be minimized by using proper machines and adopting new technologies (Ruwanpathirana 2007).

Joining of timber pieces longitudinally using fingered end joints as shown in Figure 1 has been recognized as a qualitative and profitable method for producing high quality timber sections of required length and for reducing timber waste. Through finger jointing, undesirable timber sections can be removed to improve the strength and appearance of the timber product. Therefore, finger jointing is an ideal way for improving the efficiency of sawn mills as it minimizes waste of timber (Ayarkawa et al. 2000).

Most of the locally available timber species are hardwood. Although there have been several studies done in the past on the strength of finger jointed sections of softwood, only few such studies have been done on hardwood. Finger jointing is already being used in Sri Lanka to produce non-structural timber products such as furniture. The mechanisms and machinery required to perform this finger jointing on hardwood are already available in the country. Because of its good structural performance, finger jointed hardwood can be recommended for use as structural elements by the construction industry in Sri Lanka.

Past studies have identified the structural performance of finger joints (FJs) used in the manufacture of finger jointed timber products such as stunts, trusses, columns, beams etc.

Figure 1: A finger jointed timber section

Since British Standard (BS) Design Codes do not refer to timber connections done using finger jointing, this study focused on determining the bending properties, compressive strength and Modulus of Elasticity (MOE) of finger jointed sections. The study used timber species commonly available in Sri Lanka to determine their strengths and strength grades for use in structural applications. To understand the behavior of finger connected joints when they are under actual loading conditions, structural scale specimens were tested for compression.

Methodology

Sample Collection

State Timber Corporation (STC) has graded Teak, Jak, Mahogany, Grandis, Satin and Kumbuk as the most used hardwood in Sri Lanka. Similarly, Pine has been graded as the most used softwood in the country. Thus, samples made from sections of Teak, Jak, Mahogany, Grandis, Satin, Kumbuk and Pine that were discarded as waste at the Sawn Mill of STC in Galle were used for the tests. The long sections of timber identified from the waste timber at STC for making the samples were visually inspected to ensure that they were defect free and strong enough for jointing.

Specimen Preparation

Specimens for the bending and compression (parallel and perpendicular to grain) tests conducted as Test Series 1 were prepared in accordance with BS 373:1957. Each finger jointed timber specimen had a finger length of 19 mm, tip width of 1.0 mm, tip gap of 0.2 mm and a pitch of 4.5 mm. The control specimens used for the tests were made of clear timber species and had the same dimensions as the finger jointed specimens.

The specimens were finger jointed at mid span under normal exposure conditions using Fevicol SWR water resistive adhesive.

For the compression tests in Test Series 2, specimens of clear finger jointed and normal glue jointed sections of non-standard timber were prepared at STC, Galle. Finger cutting machinery of the STC were used to machine the specimens (Figure 2).

Figure 2: Finger cutting machines

Experiment Procedure is shown by below flow chart 1.

Experiment Proceudre

Test Series 1

Test on standard finger jointed & clear timber specimen as per BS373:1957 by Universal Testing Machine

1. Three point bending test
2. Compression parallel to grain test
3. Compression perpendicular to grain test

Test Series 2

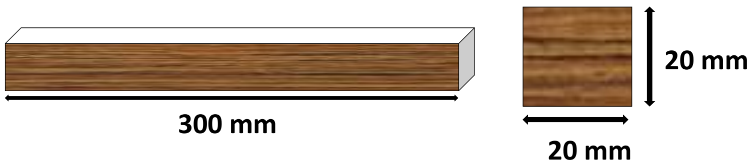
Test on standard finger jointed & clear timber By using Compression Testing Machine

Compression testing on 1000 mm× 100 mm×100 mm column of Pine & Grandis timber

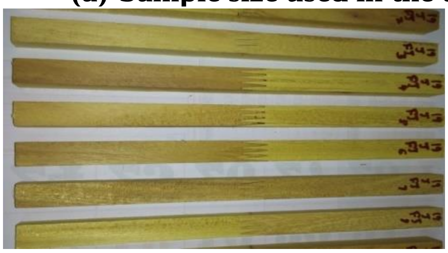
Chart 1 : Experiment Procedure

Specimens used in the Three Point Bending Test

Finger jointed and clear timber specimens used in the three-point bending test were 20 mm × 20 mm in cross section and 300 mm in length according to test method describes in BS 373:1957. (Refer Figure 3 and dimensions are not in scale).



(a) Sample size used in the test

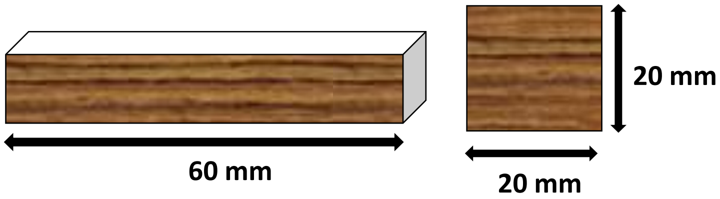


(b) Finger jointed timber specimen

Figure 3: Specimen used in the three-point bending test

Specimen used in the Compression Parallel to Grain Test

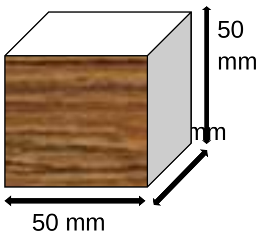
Finger jointed and clear timber specimens used in the compression parallel to grain test were 20 mm× 20 mm in cross section and 60 mm in length according to test method describes in BS 373:1957. (Refer Figure 4 and dimensions are not in scale).



(a) Sample size used in the test

(b) Finger jointed timber specimen

Figure 4: Specimen used in the compression parallel to grain test



(a) Sample size used in the test

(b) Finger jointed timber specimen

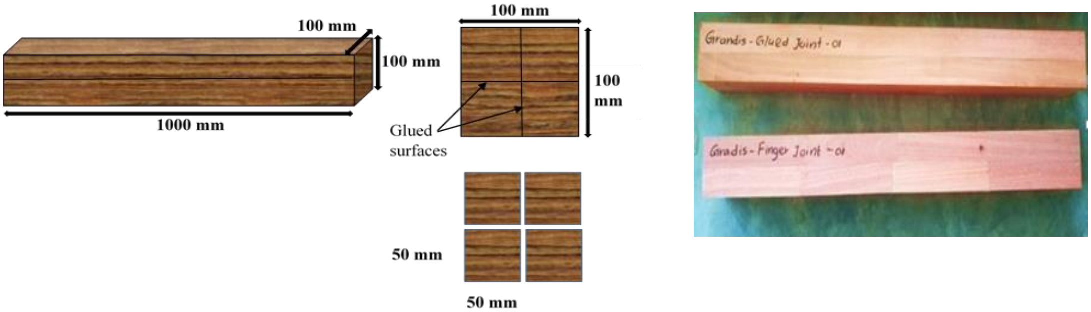
Figure 5: Specimen used in the compression perpendicular to grain test

Specimen used in the Compression Perpendicular to Grain Test

The length, width and depth of the specimens of both clear and finger jointed timber used in the compression perpendicular to grain test were each 50 mm according to test method describes in BS 373:1957. (Refer Figure 5 and dimensions are not in scale).

Specimens of Structural Scale

For the Test Series 2, 1000 mm × 100 mm ×100 mm finger jointed and glue jointed specimens of structural scale, made of Grandis and Pine were prepared as shown in Figure 6. Clear timber specimens of the same dimensions made of same species of timber were used as the control samples.



(a) Sample size **(b)** Finger jointed timber specimen

Figure 6: Structural scale specimen

Experimental Procedure

The three-point bending and uniaxial compression tests of Test Series 1 were conducted on the specimens in accordance with BS 373:1957 Code of Practice, using a universal testing machine (UTM). A compression testing machine was used in Test Series 2 to determine the ultimate axial compression capacity of the large non-standard specimens. Before applying the load through the UTM, the average density and natural moisture content of the specimens of each species were measured.

Figure 7: Universal Testing Machine

Three Point Bending Test

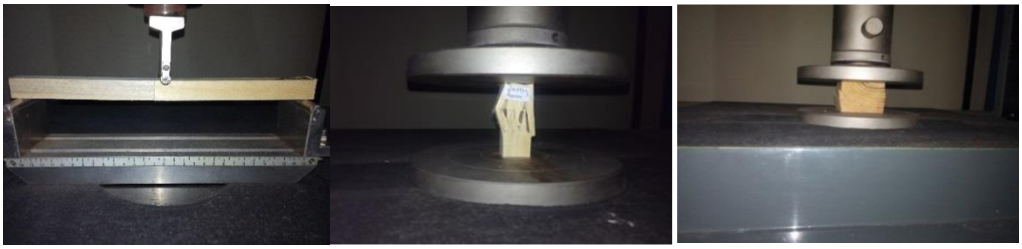
Specimens having a span length of 280 mm were tested for their bending strength using the three-point bending test. As shown in Figure 8(a), the load was applied on the specimens at their mid spans with a loading speed of 0.0066 m/min. The displacements of the specimens were recorded to obtain their load - displacement curves. Bending strength was calculated at the elastic limit assuming it as the serviceability limit state. The maximum load possible in the elastic region represents the serviceability limit state load.

Compression Parallel to Grain Test

Compression parallel to grain test with the loading plate moving at a speed of 0.000635 m/min was carried out on the specimens as shown in Figure 8(b) to see how their displacements varied with the load. The maximum possible load at the elastic limit was used to obtain the serviceability limit state compressive strength.

Compression Perpendicular to Grain Test

The specimens were loaded perpendicular to grain as shown in Figure 8(c) with the loading plate moving at a speed of 0.000635 m/min to obtain their displacements. The maximum possible load in the elastic region was used to obtain the serviceability limit state compressive strength.



(a)Three-point bending (b) Compression parallel to grain c) Compression perpendicular to grain

Figure 8: Standard specimen testing using a UTM

Compression Test on Specimens of Structural Scale

The specimens were tested for compression parallel to grain by using a compression testing machine and their lateral deflections were recorded as the load varied. The lateral deflections were measured by manual observations using deflection gauges attached to the specimens in two sides.

Results and Discussion

Bending Strength

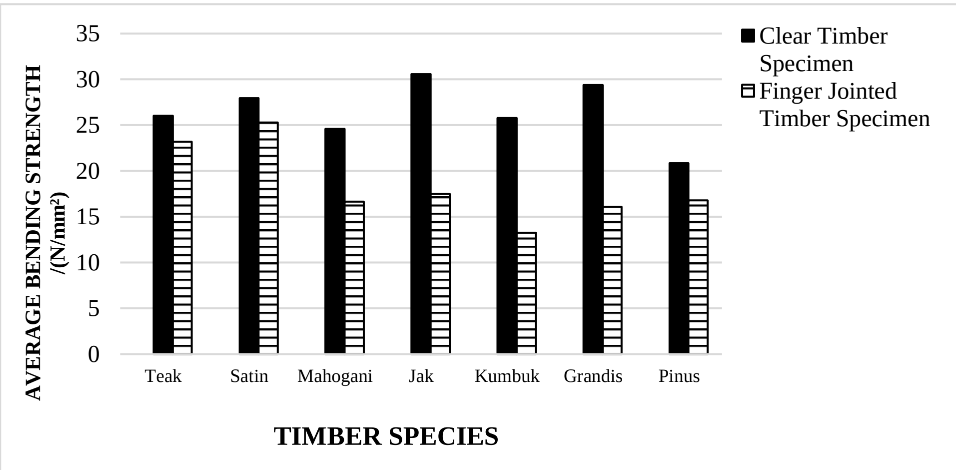
Table 1 presents the three-point bending test results and Figure 9 presents the bending strength variation of clear and finger jointed timber species. Four clear timber specimen and four finger jointed specimen were tested for each species. The bending strength of Teak, Satin and Pine got reduced by less than 20% under this test. These results reveal that finger jointed Satin is the timber species that can withstand the bending most.

Characteristic bending strength should be reduced by modification factors to derive the grade bending stresses (Department of Communities and Local Government 2008). According to BS 5268-2, the modification factor for sections less than 72 mm in depth and for short term loads are 0.856 and 0.571 respectively. Table 1 shows the grade bending stresses calculated for clear and finger jointed timber specimens.

Table 1: Bending test results.

Species	Bending strength			Grade stress	
	Clear (N/mm^2)	**Finger Jointed (N/mm^2)**	**Strength Reduction %**	**Clear (N/mm^2)**	**Finger Jointed (N/mm^2)**
Teak	26.02	23.20	10.84	13.97	10.4
Satin	27.94	25.28	9.5	24.12	20.93
Mahogany	24.59	16.64	32.34	8.93	7.72
Jak	30.58	17.49	42.82	8.53	8.4
Kumbuk	25.77	13.26	48.54	16.87	11.53
Grandis	29.39	16.09	45.25	8.92	7.74
Pine	20.86	16.8	19.43	9.08	8.8

Source: Author compiled



Source: Author compiled

Figure 9: Comparison of the average bending strength of different timber species

Compressive Strength Parallel to Grain

Table 2 presents the results of the compression parallel to grain test. Figure 10 compares the compressive strength variations of clear and timber jointed species. The strength reduction of Satin, Mahogani, Jak and Pinus is less than 20%. Jak is found to be the most suitable species for finger jointing being able to withstand the compression most. The compressive strength obtained has to be multiplied by 0.571, modification factor for very short-term loads given in BS 5268-2 to obtain the corresponding grade compressive stress. Table 2 summarizes the grade stresses of the specimens when under compression parallel to grain.

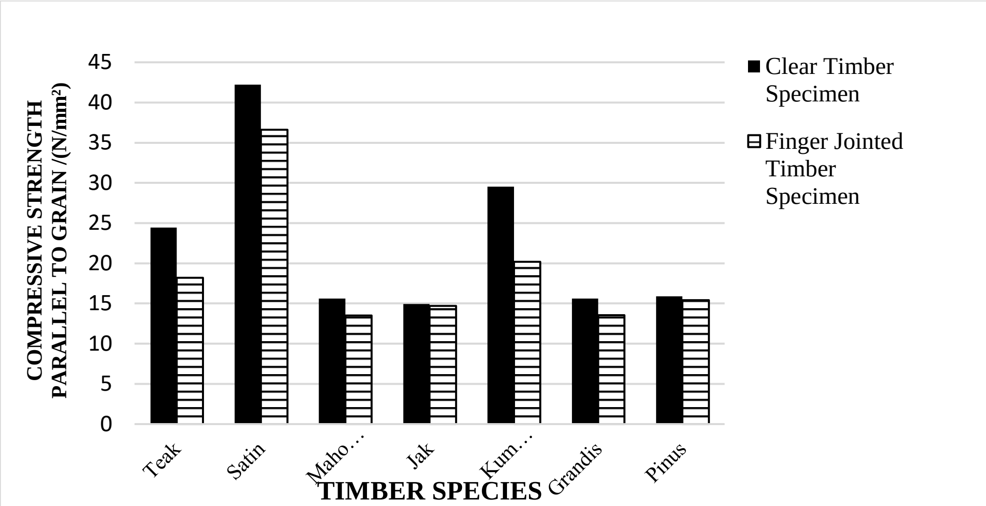
Table 2: Compression parallel to grain test results

Species	Compressive strength parallel to grain			Grade stresses	
	Clear (N/mm^2)	Finger jointed (N/mm^2)	Strength reduction %	Clear (N/mm^2)	Finger jointed (N/mm^2)
Teak	24.45	18.2	25.54	12.71	11.33
Satin	42.21	36.62	13.24	13.64	12.35
Mahogany	15.62	13.51	13.51	12.01	8.13
Jak	14.93	14.7	1.53	14.94	8.54
Kumbuk	29.53	20.17	31.68	12.59	6.48
Grandis	15.61	13.55	13.22	14.35	7.86
Pine	15.89	15.40	3.04	10.19	8.21

Source: Author compiled

Compressive Strength Perpendicular to Grain

Table 3 presents the results of the compression perpendicular to grain test. Figure 11 compares the compressive strength variations of clear and finger jointed species. Strength of all finger jointed species except Jak is higher than that of clear timber. Therefore, finger jointed sections of most timber species can withstand compression perpendicular to grain better. Based on the modification factor given in BS 5268-2 for very short-term loads, the strength has to be multiplied by 0.571 to obtain the grade compressive stress. Table 3 summarizes compression perpendicular to grain grade stresses.



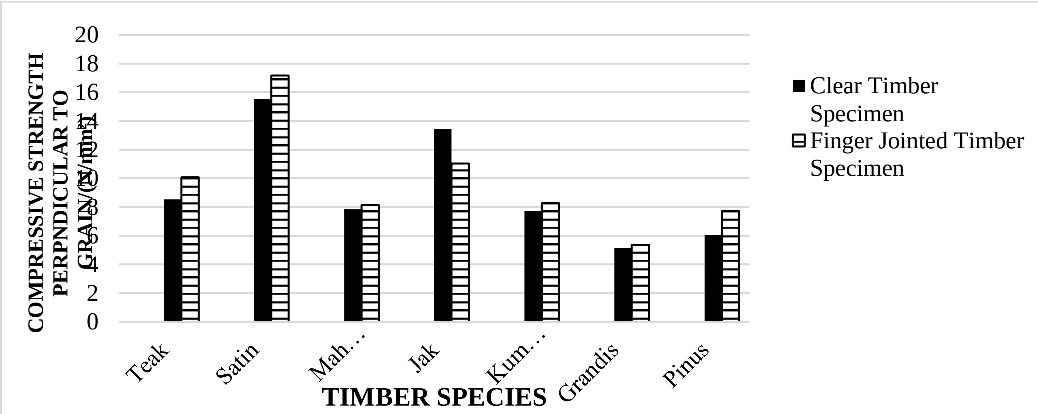
Source: Author compiled

Figure 10: Comparison of the average compressive strength parallel to grain of different timber species

Table 3. Compression perpendicular to grain test results

Species	Compressive strength perpendicular to grain			Grade stresses	
	Clear (N/mm^2)	Finger jointed (N/mm^2)	Strength reduction %	Clear (N/mm^2)	Finger jointed (N/mm^2)
Teak	8.53	10.08	-18.13	4.88	5.76
Satin	15.51	17.16	-10.66	8.86	9.8
Mahogany	7.85	8.13	-3.66	4.48	4.65
Jak	13.43	11.03	17.90	7.67	6.3
Kumbuk	7.71	8.28	-7.31	4.41	4.73
Grandis	5.14	5.38	-4.72	2.94	3.07
Pine	6.06	7.72	-27.39	3.46	4.41

Source: Author compiled



Source: Author compiled

Figure 11: Comparison of the average compressive strength perpendicular to grain of different timber species

Compression of Specimens of Structural Scale

The compressive strengths of finger jointed specimens of Pine and Grandis, which were of structural scale, got values of 80.29% and 72.58%, compared to clear timber section, respectively. The test was also carried out on sections jointed with glue. The test results reveal that the compression capacities of normal glue jointed Pine and Grandis species are got values of 70.89% and 72.16%, compared to clear timber section, respectively. Both test results indicate that there is no significant variation in the ultimate capacity of both glued and finger jointed timber species. However, it is recommended to carry out further tests on these species.

Conclusions

The study demonstrates the usefulness of finger jointed timber to utilize the timber waste focusing structural applications. Therefore, mainly the strength capacities under static bending and compression were analyzed for finger jointed timber with the commercially available finger joint profile and adhesive in Sri Lanka and the discussion is led to below conclusions.

Reliability testing on finger jointed timber according to the standard experimental procedures reveal that,

- Satin, Teak and Pine timber which have minimum bending strength reduction as 9.5%, 10.84% and 19.43 % respectively compared to clear timber are effective to manufacture finger jointed timber element to withstand bending. Bending strength was varied as; Satin>Teak>Pine>Mahogany>Grandis>Jak>Kumbuk
- Compressive strength parallel to grain reduction was found to be only 1.53% of that of clear specimens for Jak and therefore it is the most suitable species to use for finger joining. Satin, Grandis and Pine also have 13.24%, 13.22% and 3.04% strength reduction which are also suitable for withstand compression parallel to grain after Jak. Compressive strength parallel to grain was varied as was varied as; Jak>Pine>Grandis>Satin>Mahogany>Teak>Kumbuk
- Compressive strength perpendicular to grain values were found to be higher than clear timber other than Jak. Higher increment is shown by Teak and Pine as 18.13% and 27.39% that of clear timber. Compressive strength perpendicular to grain was varied as was varied as; Pine>Teak>Satin>Kumbuk>Grandis> Mahogany>Jak.
- Reliability testing of finger jointed large scale timber which was done by using 1000 mm×100mm×100mm structural scale members of Grandis and Pine resulted 72.58% and 80.29% reduction of ultimate compression capacity compared to clear timber. It was led to think that finger joint large scale timber members are poor to withstand axial compression and several number of finger joints are not effective for compression member.

The primary goal of this research is to utilize the timber waste considering the applications in construction industry. For that, below recommendations are done and it could increase the use of finger joint on waste timber.

- Bending and compressive strengths of finger jointed timber have been established for commercially available timber species in Sri Lanka by using larger number of standard specimens for experiment and they can be used for finger jointed timber designing.
- Finger joint can be used to manufacture shorter length of timber member such as beams, strut to withstand both bending and compression.
- Finger jointed element of Teak timber is structurally and economically effective for the construction industry.
- Finger jointed timber element which is manufactured by using waste of Satin, Grandis and Pine wood are structurally effective.

Further, it is revealed that there is a need for future research to understand the performance of finger jointed timber species made with metal connectors, mechanical improvements etc. These future studies could be used to determine the mechanical properties of timber species of different sectional dimensions, limitations of the dimensions that can be used for finger jointing and the durability of the joints bonded using epoxy adhesives under higher load bearing capacities.

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