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FINGER JOINTS AND THEIR STRUCTURAL PERFORMANCE IN DIFFERENT EXPOSURE CONDITIONS

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Abstract: Timber is widely used as a construction material in Sri Lanka for different application. Finger joint is one of the efficient method to minimize the timber wastages arising in the timber industry. In this study main objectives are to determine the best combination of timber materials for timber joints in different environmental conditions as well as their structural performance. Seven locally available timber species Mahohany, Kumbuk, Grandis, Teak, Jack, Banyan and Pinus were selected for the study. The physical properties (shrinkage and swelling) related to moisture content were investigated in different environment condition by using temperature and humidity chamber to choose best combination of timber materials. In addition different strength tests bending and tension were conducted for those selected combinations. Average moisture contents of timber specimens were around 12%.In wet condition all the samples shows increase in moisture content as well as volume. Modulus of elasticity varies 800 MPa - 2200MPa, modulus of rupture varies 10 MPa – 22 MPa, Similarly other test parameters were investigated and presented in the paper.

Keywords: Finger joint; Moisture content; Timber grains; Shrinkage; Swelling.

1. Introduction

Off-cut wood is currently one of the wastes dumped by sawmills and as they failed to fully utilize the wood supply. Waste sawn timber material of Furniture factory and short length of sawn timber are also big problem in timber industry. However, some of this wasted wood is already being used to fuel kiln dried boiler. To further suggest ways to minimize the waste, by applying a jointing system, this utilizes the finger jointed techniques. Finger joint is that the end to end gluing of short pieces that have several tapered 'fingers' in to long pieces. These are commonly used for making furniture, floors, sidewalls and roof ceilings. In Sri Lanka timber is one of the oldest building materials used in frequently for several purposes. Timber used as a construction material of several hundreds of different types of wood species, some of which are less well known but each species has various wood properties. In Sri Lanka there are more than 400 timber species are available. Timber cooperation of Sri Lanka studied 237 kind of timber. Table 1 shows most commonly used timber species for finger joints. All the timber samples were maintain with the standard moisture content of 10-12 %.

Table 1: Timber species and their classes

Class	Timber Species
Super luxury	Teak
Luxury	Satin, Mahogany, Jack
Special Upper class	Margosa
Special class	Kumbuk
Class 3	Pinus
Class 4	Eucalyptus grandis

(State timber co-operation)

When finger joints expose to different environmental conditions, there properties like shrinkage and swelling varies from each to each timber. This volume change effect the performance of the joints. These finger joints gluing with chemical adhesives, when the environmental conditions changes, the chemical properties change and it cause problems in the joints. So this study was conducted to investigate best combination timber species for finger joints in different environmental conditions and their structural performances.

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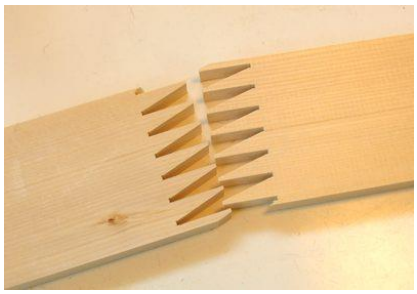

Figure 1: Finger joint sample

2. Methodology

Shrinkage and swelling test was identified to determine the physical properties of the timber. Tension and flexural tests were done to determine the structural properties. Testing methodology was one of the important factors which was considered to obtain more reliable and standards test results. Therefore code of practice BS373:1957 has been referred for testing purpose.

2.1 Shrinkage and swelling properties

For identifying shrinkage and swelling properties of timber species, samples were prepared with 20×20 mm² in cross section and 50 mm long. By using environmental and humidity chamber the exposure conditions can be changed. Temperature 36°C with the humidity of 60% and temperature 15°C with the humidity of 90% used in Chamber as two exposure conditions. By keeping the samples for 24 hours (Kininmonth, J.A., 1976) in these conditions and by measuring the initial and final dimensions, shrinkage, swelling properties can be determined.

Figure 2: Sample preparation using finger cutting machine

Figure 3: Measuring the dimensions of the sample

Figure 4: Temperature and humidity chamber

2.2 Visual on observations

By considering the shrinkage and swelling results suitable timber species (showing high shrinkage value: H, showing low shrinkage value: L) selected for the next experiment.

Arrangement 1:

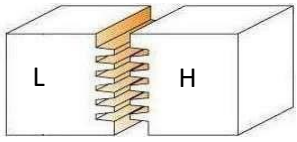

Figure 5: Setup for expansion and shrinkage in finger joints

Figure 5 shows the arrangement -1 of the timber which has low shrinkage value (L) and high shrinkage (H) value respectively. Make this arrangement of finger joints and have to keep in differential environmental conditions. This method is done for identify the problems occurs in finger joint if joint is made in two different properties of timber species.

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Arrangement 2:

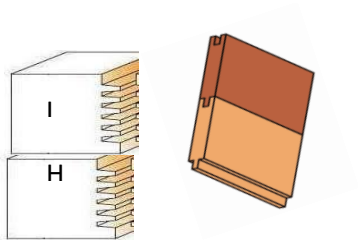

Figure 5: Setup for expansion and shrinkage in finger joints

Figure 6 shows the arrangement-2 to identify the problems related in tongue and groove joining. Because expansion or shrinkage in this joints temp to cause failure in finger joint. By keeping this in different exposure conditions, the problems can be identified.

Arrangement 3:

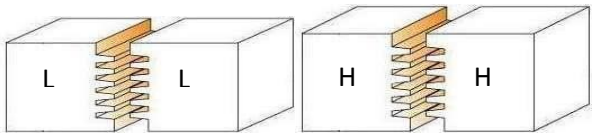

Figure 7: Arrangements of timber species for identify the behaviour of adhesive

Figure 7 shows the arrangement-3 to identify the behaviour of the adhesive in different environmental condition.

Arrangement 04:

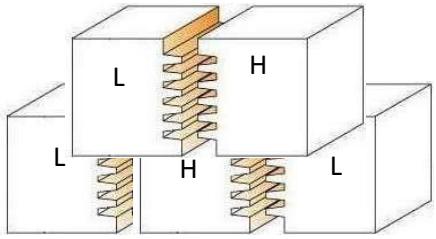

Figure 8: Arrangement of timber species for the combination

Figure 8 shows the arrangement-4 to identify all the problems arising in finger joint boards. By combining the problems in the joints or tongue and groove it's helpful to decide the significance of the problem.

Table 2: Combination of timber properties and their purposes.

Combination	Purpose
High shrinkage – Low shrinkage	To Identify the problem in the finger joint
High shrinkage – Low shrinkage	To Identify the problem in the tongue and groove joint
High shrinkage – Low shrinkage	To Identify the problem in the combination of above joints
High shrinkage – High shrinkage Low shrinkage – Low shrinkage	To Identify the behaviour of the adhesive

High Shrinkage: Kumbuk, Jack and Grandis

Low Shrinkage: Pinus

2.3 Tension test

Timber finger joint section with 50×25 mm² cross section and 300 mm long was used for tension test. Samples were subjected to tension by using Universal Testing Machine (UTM) with 2mm/min loading rate in grain parallel direction.

$$\text{Tension strength} = \frac{\text{Servicebility load in tension}}{\text{Average area}}$$

2.4 Flexural Test

Timber finger joint section with 50×50 mm² cross section and 750 mm long was used for flexural test.

MOR –Modulus of Rupture

M – Maximum Bending moment

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

I – Second moment of area

$$\text{MOE} = \frac{WL^3}{48\delta I}$$

MOE –Modulus of Elasticity

L – Length of timber specimen

W – Maximum Load act in center of specimen

δ – Maximum deflection of timber beam

I – Modulus of elasticity

3.0 Results and Discussion

3.1 High temperature and Low humidity conditions (36°C & 60%).

Table 3: Average values of initial and final moisture content of timber species.

Timber species	Initial Moisture content %	Final Moisture content %
Mahohany	12.8	13.6
Kumbuk	16.9	15.8
Grandis	14.0	15.6
Teak	11.2	12.9
Jack	13.1	13.0
Banyan	13.6	13.7

Table 4: Average volume changes of timber species

Timber species	Ration for initial volume to final volume (Average)
Mahohany	1.01
Kumbuk	0.99
Grandis	1.04
Teak	1.00
Jack	0.98
Banyan	0.98

From the Table 4, the samples which placed in high temperature and low humidity had the average natural moisture content of 12% excluding Kumbuk. Kumbuk having the higher natural moisture content of 17 % which different from other species. After timber species take it from environmental chamber their average moisture content is around 14%. Jack having the lowest moisture content of 12.95 %. Initial volume and the volume after placing in to the chamber was measured. According to the results some of the timber samples are increased in volume. Here jack shows the high shrinkage value of 0.97. By considering this results, Jack and Grandis were selected for further experiments in hot condition.

3.2 Low temperature and High humidity conditions (15°C & 90%).

Table 5: Average Initial and final moisture content of timber species

Timber species	Initial Moisture content %	Final Moisture content %
Mahohany	14.3	15.2
Kumbuk	14.6	15.4
Grandis	17.2	17.8
Teak	12.9	13.9
Jack	14.2	15.2
Banyan	15.7	16.5

Table 6: Average Initial and final moisture content of timber species

Timber species	Ratio for initial volume to final volume (Average)
Mahohany	1.011
Kumbuk	1.006
Grandis	1.012
Teak	1.007
Jack	1.006
Banyan	1.009

The samples which placed in low temperature and high humidity had the average natural moisture content of 14%. Here Grandis had higher natural moisture content of 17.2 % and Teak had less natural moisture content of 12.9%. After timber species take it from the environmental chamber their average moisture content is

15%. Here Grandis had the greatest Moisture content of 17.8%. Initial volume and the volume was measured and the ratio of final volume to initial volume was calculated. All the timber samples shows increase in volume. Here also Grandis shows the high expansion value of 1.01 and Jack shows lower expansion value of 1.005.

By considering this results, Grandis was selected for further experiments in wet condition.

3.3 Tension capacity

Table 7: Average tension capacity at ultimate limit for timber combination

Timber Combination	Average Tension Capacity (MPa)		
	Normal Condition	Hot Condition	Wet Condition
Pinus-Kumbuk	13.96	12.22	10.4
Pinus-Grandis	10.49	7.42	9.97
Pinus-Jack	10.01	8.45	_

3.5 Flexure capacity

Table 8: Average MOE of timber combination.

Timber Combination	Average MOE (MPa)		
	Normal Condition	Hot Condition	Wet Condition
Pinus-Kumbuk	2205.84	2307.1	1993.01
Pinus-Grandis	1679.56	1577.62	1317.03
Pinus-Jack	1167.6	893.084	_

Considering the results listed in Table 7, 8, 9 and 10 the samples which were subjected in normal environment conditions gives higher MOR, MOE and Tension capacity values comparing other two conditions.

Table 9: Average MOR at ultimate limit for timber combination.

Timber Combination	Average Ultimate limit MOR (MPa)		
	Normal Condition	Hot Condition	Wet Condition
Pinus-Kumbuk	20.47	10.86	12.58
Pinus-Grandis	22.03	12.59	18.95
Pinus-Jack	18.04	11.36	_

Table 10: Average MOR at serviceability limit for timber combination.

Timber Combination	Average Serviceability limit MOR (MPa)		
	Normal Condition	Hot Condition	Wet Condition
Pinus-Kumbuk	13.95	11.92	10.91
Pinus-Grandis	14.56	8.64	15.56
Pinus-Jack	12.74	9.5	_

When the samples subjected to high humidity there is a possibility of increase in the moisture content. This causes the cell walls to expand and a dimensional change occurs. Water presence in the sample dramatically softens the cell walls. The hydrogen bonds between different polymer chains in the crystalline can break. This softens the cellulose micro fibrils as they are no longer so strongly bonded to each other, making it easier to untangle and hence stretch the fibers. This leads to a decrease in the stiffness of wood. In the experiment the most of the failure occurs in the softwood side as rather than finger joint. Softwoods are easily intake water and shows increase in moisture level. This is the reason which change the tension and flexure values in different exposure conditions.

When the samples subjected to high temperature and low humidity there is a possibility of change in the glue behaviour. When those samples take it from chamber the glue shows change in physically as it is soften up. This glue behaviour is the reason for the low structural values. This is even support by the failure type as most of the failures occurs in the glue rather than in the finger joints.

3.7 Visual Observations

Figure 9: Observing the crack width using gauge

Arrangement -1: Setup for expansion and shrinkage in finger joints

Considering visual observations all the samples shows expansion in joints and. All the combinations shows similar amount of cracks in joints.

Arrangement -2: Arrangements of timber species for tongue and groove

Considering visual observations on all the samples Pinus-Grandis combination shows much expansion in tongue and groove. Pinus-Kumbuk shows small amount of cracks in joints.

Arrangement -3: Arrangements of timber species for identify the behaviour of adhesive

Considering visual observations on all the samples, there are not much of physical change in the adhesive subjected in low temperature and high humidity. But for high temperature and low humidity there were some physical change in the glue as it is look more soften.

Arrangement -4: Arrangements of timber species for the combination of finger.

Considering visual observations on all the samples, there are too much of change in the Pinus-Kumbuk Combination which subjected in low temperature and high humidity. But comparing tongue and groove with finger joints, there are very less amount of change in the crack width.

3.8 Special consideration on Kumbuk

From the past studies and experiences related that Kumbuk species are behave differently. Their behaviour is unpredictable. So special care was taken to do the experiments with Kumbuk for this study. Considering this anatomical structure, it is coarse texture which means it contains large vessels from other timber species with the diameter of 241 µm and also it is having the higher specific gravity of 0.82. This may be the reason for the unpredictable behaviour of Kumbuk.

4.0 Conclusions

By considering shrinkage variation in different exposure condition, Samples which placed in hot condition show different properties. Some timber samples are increased in volume and some are show reduction in volume. But the samples which placed wet condition show same kind of properties. All samples were got expands. The samples which were seasoned well did not show high increase in moisture level as well as volumetric change but the samples which were got from locally available market that are not seasoned well show high variations in moisture level as well as volume change.. Seasoned timber species have specific moisture content around 12- 14 % which gives more structural benefit and also this will reduce the insect attacks on timber. So seasoning timber samples, is an important activity before the application of timer.

Considering structural performance incorporate with joint characteristics and adhesive characteristic samples which were placed in normal condition shows good structural performance considering other the

two conditions. In hot condition most of the failures occurs due to the failure of the glue not in joints. This may be the reason for the poor structural performance in the hot condition. In wet condition most of the failure occurs in the finger joints at softwood side. Because in that condition softwood intake moisture and weaken the cells which produce low structural performance.

Considering the structural performance of Kumbuk combination, it shows high structural values because the density is very much high. By looking at the results and past experience we can say that the Kumbuk is not good for the products which use for aesthetic purposes. But considering the structural performance Kumbuk can be used at any exposure conditions. Grandis and jack are not preferable to use in different extreme exposure conditions. Especially for hot areas Grandis is not suitable. As in visual observations it shows high increase in crack width and also there were some new cracks forms due to the change of moisture level.

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