THE PERFORMANCE OF KEMPAS AND KERUING IN STRUCTURAL FINGER JOINTING

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ABSTRACT

Structural finger jointing were made from Kempas (Koompassia malaccensis), and Keruing (Dipterocarpus spp.) using three finger length profiles (11, 12, 13 mm) and were tested in bending and tension to assess and compare their finger joint strength. The adhesive used was cold setting resorcinol formaldehyde (RF). The results showed that finger jointed Kempas has strength properties superior to Keruing and met the requirement as specified in the Malayan Grading Rules stress grade for solid timber only when finger length of greater than 11 mm was used, while Keruing failed to meet the requirement.

INTRODUCTION

In recent years, there has been more attention towards the effective utilization of timber resources. As a result, many efforts were focused and aimed at achieving better and more complete utilization of timber resources hoping to improve the supply of raw materials and the profitability of the timber industry. One such effort that has great potential and viable economic value is the use of finger joints to obtain long pieces of timber.

Although most wood end jointing processes were done by scarf joint, this type of joint was not economical due to the large wastage of wood (Madsen and Littleford, 1962; Strickler, 1980). Hence, finger joints for non-structural application came into use, followed by the development of the structural finger-jointing technology more than 20 years ago. However, in Malaysia, the use of finger-jointed timbers have been limited to only non-structural application such as table tops, door cores, staircases, balustrades, and so forth. Very few researches were undertaken in this area. For example, Chu (1967), Brock and Chu (1973) and Sim (1987) have recorded results of finger joints for three Malaysian timbers. Since very little data is available, the suitability of Malaysian timbers for finger jointing has to be further examined and established before encouraging the industry to explore the potential usage of this jointing system for structural purposes in the form of glued laminated timber. This careful attention has to be made since load-bearing strength is the primary criteria in determining its suitability (Strickler 1980).

It was the objective of this study to assess and compare the strength of finger joints in Kempas and Keruing timbers of different finger length profiles using resorcinol formaldehyde (RF) resin as binder. Kempas has strength comparable to some heavy hardwoods and Keruing has been used very extensively for heavy and general structural construction.

MATERIALS AND METHODS

Raw Materials

Kempas (*Koompassia malaccensis*) and Keruing (*Dipterocarpus gracilis*) used in this study were purchased from a few sawmills located in the Klang Valley, Selangor. The Select Structural graded timbers of approximate dimensions of 50 mm x 100 mm x 2 mm were then kiln-dried to moisture content down below 19%.

Preparation of specimens

Finger jointed specimens with finger lengths of 11, 12 and 13 mm respectively, as well as unjointed specimens were prepared from each of the timber species according to BS 5291(Anon. 1984a). The timbers were first planed on all four sides to facilitate clear viewing for selecting defect free test specimens. The timbers were then crosscut to the length required for bending and tension tests. The specimens to be jointed were further crosscut into equal halves prior to finger cutting and assembly.

The profiles of the finger were cut on a finger shaper machine. The geometric parameters of a finger joint are shown in Table 1. The joints were assembled immediately after finger cutting using resorcinol formaldehyde (RF) resin, which was applied manually to the fingers of both members to be jointed. Sufficient glue was applied to ensure some squeeze-out along the whole profiles when the end pressure was applied. The joints were assembled by means of a finger composer with an end pressure of 7.0 MPa. The assembled joints were left for about 24 hours before undertaking further planing, ripping and crosscutting to final dimensions which are required for bending and tension tests.

Table 1. Geometric parameters of the finger joints

L(mm)	P(mm)	t(mm)	t/P	L/P
13	4.1	0.6	0.146	3.17
12	4.1	0.8	0.195	2.93
11	4.1	1.2	0.293	2.68

P = pitch; L = length of finger; t = tip thickness.

Bending test

Bending tests of jointed and unjointed specimens were carried out according to British Standards BS 5291 (Anon. 1984a). The test specimens had dimensions of 41 x 92 x 700 mm. The tests were conducted on a Shimadzu testing machine, in which the specimens were freely supported on edges as beams over a span equal to twelve times the depth. The finger-jointed specimens were positioned at midspan with their profiles visible on the specimen depth. Load was applied continuously at the midspan until failure occurred, with the loading head moving at a constant rate of 35 x 10^{-3} mm/sec.

Tension test

Tension tests were conducted according to British Standards BS 383 (Anon. 1967). The test specimens had dimensions of 4 x 41 x 410 mm. No neck was made on the test specimens as the strength of the finger joints was anticipated far too low to create slippage at the grip and failure at any other points far from the joints. Both ends of the specimens were held in the toothed grip of the Shimadzu testing machine. A tensile load parallel to grain of the timber was applied continuously until failure occurs, with the loading head moving at a constant rate of 13 x 10^{-3} mm/sec.

RESULTS AND DISCUSSION

The results of the standard bending and tension tests are given in Tables 2 and 3. Both tables give the mean values of bending and tensile strength for jointed and unjointed (control) kempas and keruing specimens of different finger lengths. Standard deviations (SD) and coefficient of variations (COV) of the MOR values are also presented in these tables. The COV in Tables 2 and 3 show that the spread of results for the bending and tensile strength of keruing are greater for the jointed specimens. The reverse generally occurs with the results for bending and tensile strength of kempas, except for bending of 11 mm finger length. In such a case, it is appropriate enough to assess the joint efficiency using the ratio of the mean MOR value of jointed specimens to that of unjointed control specimens. Brock and Chu (1973) used the estimates of the probable lower limit values of the strength to assess the joints against the unjointed controls because of greater variation in bending strength for the jointed specimens. However, adjustment to the bending and tension values of keruing for the jointed specimens was not made.

Table 2. Mean bending modulus of rupture (MOR) and joint efficiency for Kempas and Keruing.

SPECIES	Modulus of Rupture (MPa)				Joint efficiency based on MOR (%)[a]		
		Finger length (mm)					
	Control	11	12	13	11	12	13
KEMPAS	143.86	49.89b	59.83a	62.86a			
	(27.68)	(10.64)	(10.10)	(10.55)	34.68	41.59	43.69
	((19.24))	((21.32))	((16.88))	((16.78))			
KERUING	79.34	28.51b	30.91b	38.58a			
	(14.78)	(10.47)	(10.34)	(10.91)	35.94	38.96	48.63
	((18.63))	((36.72))	((33.44))	((28.28))			

Means were obtained from 30 test specimens in each case.

Means in the same row followed by the same letter are not significantly different according to LSD test.

( ) denotes standard deviation

(( )) denotes coefficient of variation

[a] Joint efficiency = (finger joint strength / solid wood strength) x 100

Table 3. Mean tensile strength and joint efficiency for Kempas and Keruing.

SPECIES	Modulus of Rupture (MPa)				Joint eff. based on MOR (%)		
		Finger length (mm)					
	Control	11	12	13	11	12	13
KEMPAS	80.33 (40.48) ((50.39))	37.86c (5.15) ((13.60))	43.19b (7.87) ((18.222))	56.15a (13.05) ((23.24))	47.14	53.77	69.91
KERUING	62.98 (10.77) ((17.10))	19.01b (3.56) ((18.66))	17.96b (3.52) ((19.60))	22.28a (4.01) ((18.02))	34.45	32.41	40.21

Means in the same row followed by the same letter are not significantly different according to LSD test.

( ) denotes standard deviation

(( )) denotes coefficient of variation

Results of the mean bending and tension MOR for the jointed specimens show that mean tension MOR values for almost all joints. As for the variation in the results, greater variation was found to occur in bending than in tension, except for Kempas specimens bearing 12 and 13 mm finger lengths. The results for control specimens indicate a mean tension MOR of 56% and 79% of the mean bending MOR for Kempas and Keruing respectively. Great variation for control specimens results were also found to occur in tension except for Keruing which was the reverse. The modulus of elasticity (MOE) was not determined in this study as it was indicated in the literature that joints have no significant effect on the MOE (Brock & Chu 1973, Sim 1985).

The mean bending and tension MOR values for the jointed specimens in Tables 2 and 3 also indicated that the 13 mm profile gave the best results. In general, increase in MOR is associated with the increase in finger length being employed. According to Selbo (1963), increase in tensile strength was proportional to the increase in the length to pitch (L/P) ratio until the ratio reaches about 4, after which the stress remains more or less constant. In this study, the L/P ratios for the three different finger lengths were less than 4, and the results for both bending and tension MOR seemed to agree with Selbo`s conclusion. Strickler (1980), on the other hand, stated that finger length affects joint strength significantly only when it is reduced to approximately the length of a single fiber.

In order to establish that an increase in finger length will contribute to the cause of significant changes in the strength properties of the jointed specimens, the data was subjected to an Analysis of Variance (ANOVA) test. The analysis apparently indicate that the bending and tension MOR of different finger lengths differed significantly for the three species of Kempas ($F_b = 13.81$; $F_t = 33.56$), and Keruing ($F_b = 7.13$; $F_t = 11.59$) at $P \leq 0.01$. Result of least-significant-difference (LSD) means comparison tests was presented in Tables 1 and 2. Finger length 13 mm employed to joint the Kempas and Keruing specimens gave significantly better strength in bending and tension than timbers jointed using 12 and 11 mm finger lengths. In case of Kempas, the bending MOR of timbers jointed using 13 and 12 mm finger lengths did not differ significantly from one another. However, it was significantly stronger than that of 11 mm finger length.

Strength comparison of jointed specimens with that of unjointed control specimens which was expressed as joint efficiency was also presented in Tables 2 and 3 for the different finger length profiles. In comparison with the performance of joints recorded by Brock and Chu`s (1973), the percentage joint efficiencies in bending determined by the present study was rather low, except for bending strength of Meranti bearing 12 and 13 mm finger lengths. However, for tensile strength, only keruing joint efficiency was exceptionally low for the three finger lengths, while the rest were fairly high compared to Brock and Chu`s (1973) results. However, it should be noted here that their values could be regarded as not valid for comparison due to few differences in the methods of fabricating the finger joints and also the modes of testing employed in the determination of these different sets of results. Among the different were the horizontal finger joints being used compared to the vertical finger joints used in the present study, and the use of a 4-point loading bending test as compared to a 3-point loading bending test employed in the present study.

In comparison with Sim`s study (1985), the present study gave better results. With the same joints configuration and method of testing, except for longer finger length of 32 and 37 mm being used. As claimed by Sim (1985), the joints in his study were fabricated using simple clamps, in which pressure were being manually applied. But we used a finger composer to apply the pressure, resulting in better joint efficiencies.

The results in Tables 2 and 3 also revealed that there is a trend of increasing joint efficiency as longer finger lengths are being used. Timber specimens jointed with 13 mm finger length apparently had the best joint efficiency for

Kempas and Keruing, followed by 12 and 11 mm finger lengths.

ANOVA test indicated that a highly significant difference existed in bending ($P \leq 0.01$; $F= 169.97$) and tension ($P \leq 0.01$; $F = 351.06$) joint efficiency when different species of wood were used. Results of LSD means comparison tests presented in Table 4 confirmed Kempas joint efficiency in tension was significantly better than Keruing. However, Kempas and Keruing joint efficiency in bending were found not significantly different from one another. The low joint efficiency in Keruing as compared to Kempas could be due to the resinous nature of the species, which impart the penetration of the adhesive. As for Kempas its broad open pores could cause over penetration of the adhesive in which at the time of pressing, starve joint could have happened.

Table 4. The mean joint efficiency of Kempas and Keruing in bending and tension

Species	Mean Joint Efficiency (%)	
	Bending	Tension
Kempas	40.98a	56.80a
Keruing	39.93a	31.42b

Means in the same column followed by the same letter are not significantly different at $p < 0.05$

The test also shows that all of the jointed specimens tested for bending and tension failed at the joints. Based on this observation, it is believed that a better performance of the finger joints could be obtained if different gluing procedure is used in this experiment. The use of a different end-pressure, different pressing time, different finger geometry, and/or different glue mixture or content to suit the individual species of timbers would contribute to a better finger joint performance. As such, Keruing joint performance could be improved if the glue content is altered or the wood surface to be finger jointed is pre-treated with reactive chemicals to overcome the effect of resin or oil contained in them.

CONCLUSION

The present study exhibited that glued finger joints of Kempas and Keruing with finger profiles ranging between 11 - 13 mm could achieve a minimum mean strength equal to 35% and 36% in bending, and 47% and 32% in tension respectively (based on MOR) of the unjointed timber. Based on the stress grade included in Malayan Grading Rules for Sawn Hardwood Timber (Anon. 1984b), Keruing failed to met even the requirement of Common Building Grade which requires at least a 50% of the strength of clear timber. Kempas only satisfy the requirements in tension when finger lengths of greater than 11 mm is used. The fact that all of the finger joints showed an extensive glueline failure would indicate that the poor performance of the joints in the current study in Kempas and Keruing could be improved. Further investigation should be carried out into the physical parameters of Kempas and Keruing finger jointing to overcome this poor joint performance.

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