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The Durability of Phenol-Resorcinol Formaldehyde Glue Joints on Three Malaysian Hardwood Species

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ABSTRAK

Kekuatan dan ketahanan rekatan perekat fenol-resorsinol formaldehid ke atas tiga spesies kayu keras Malaysia telah dinilai. Pelapisan spesies tunggal dan pelapisan spesies campuran di hasilkan menggunakan perekat di atas dan diuji pada suhu bilik. Kekuatan rekatan terhadap pelekangan di uji berdasarkan spesifikasi ASTM D 1101-59. Semua kombinasi perekatan telah menghasilkan tahap peratus pelekangan yang amat rendah dan memenuhi keperluan seperti yang diperuntukan dalam spesifikasi AITC. Peratus pelekangan yang paling tinggi terhasil daripada kombinasi Kempas-Kempas dengan nilai 4.7% dan yang paling rendah daripada kombinasi Seraya-Seraya yang tidak menunjukkan sebarang pelekangan rekatan. Kombinasi spesies campuran pada umumnya memberikan peratus pelekangan yang lebik baik berbanding kombinasi spesies tunggal.

ABSTRACT

The integrity and durability of phenol-resorcinol formaldehyde glue joints on three Malaysian hardwood species were evaluated. Single and mixed-species laminations were produced using phenol-resorcinol formaldehyde adhesive at room temperature. The integrity of the glue bond to delamination was tested according to the ASTM D 1101-59 specification. All combinations, produced very low delamination percentage levels and met the requirement specified by AITC. The highest delamination percentage was shown by Kempas-Kempas combination with only 4.7% and the lowest was Seraya-Seraya combination with 0.0% delamination. Mixed-species combinations offered lower percentage of delaminaton that their single-species counterparts.

INTRODUCTION

The suitability of glues and gluing techniques for the production of joint adequate for exterior service need to be evaluated regularly. The choice of wood species and wood adhesives is governed by many factors, but the most important one is the strength and integrity of the glue joint. For structural laminated members such as laminated beams and decking boards, the integrity of the glue joints should be at least equal to that of the wood.

Few studies have been conducted to check the strength and integrity of the glue joint of tropical hardwood using phenol-resorcinol formaldehyde and urea formaldehyde. Selbo (1967), found that more delamination occurred in specimens bonded with urea formaldehyde compared to phenol-resorcinol bonded specimens. Nishihara *et al.* (1967) used Meranti to compare the reliability and intergrity of these glue bonds. He also found that phenol and phenol-resorcinol formaldehyde adhesive offered better delamination resistance and delaminated only 2% and 8% respectively in contrast to urea formaldehyde adhesive with 51% delamination. Wan Sardini (1979) agreed with the previous researchers on the performance of phenol-resorcinol formal delyde adhesive on five Malaysian hardwood species and on average all species offered encouraging results with only 1% delamination. Bohlen (1972) indicated there was severe bond

degradation in the specimens during the second cycle of delamination test resulting in the failure of these glue lines meeting the standard requirement.

The present study was conducted with one main objective i.e. to evaluate the integrity of phenol-resorcinol adhesive glue joints on three Malaysian hardwood species, namely Seraya, Nemesu and Kempas.

MATERIALS AND METHODS

Three Malaysian hardwood species namely Nemesu (*Shorea pauciflora*), Kempas (*Koompassia malaccensis*) and Seraya (*Shorea curtisii*) were used in this study. All selected species were obtained from Mantega Forest Products (M) Sdn. Bhd., Pahang. The sawn lumber were taken from three different logs (one from each species). Average sizes of the rough lumber were 150 mm x 30 mm x 2 m.

A phenol-resorcinol formaldehyde, PRF a synthetic thermo-setting adhesive was used in this study. This is the most common adhesive used for the production of laminated decking board in Malaysia. The sample specimens were made by bonding wood strips with this adhesive into specimen sizes sufficient to conduct the test in the laboratory.

Laboratory Sample Fabrication

After being air dried, the rough sawntimber was resawn into shorter strips of 30 mm x 30 mm x 350 mm using a multiple rip saw. Each wood strip was planed just prior to edge-gluing.

Adhesive was mixed according to the manufacturers' specifications. For PRF, 10 parts of Norres 45 with 53% solid content was mixed with 2 parts of hardener H-10. The well mixed adhesive was then hand spread onto the piece of wood with a metal spatula at a rate of between 320 to 370 g/m^2 followed by a close assembly time of 15 to 30 minutes.

Seven different types of assemblies were made for the glue joint integrity test. Three types consisted of single species combination namely Seraya-Seraya, Nemesu-Nemesu and Kempas-Kempas; three types consisted of a combination of two species i.e. Seraya-Nemesu, Seraya-Kempas and Nemesu-Kempas; and the last type consisted of all species, Seraya-Nemesu-Kempas. A total of 30 replicates were made for each of these seven types.

The assemblies were pressed in a cold press for one hour with a panel pressure of 10 kg/cm^2. Each press contained 10 assemblies of the same combination. The temperature and the relative humidity of the pressing are were 28°C and 75% respectively. The assemblies were stored for a week at room temperature for proper conditioning.

Integrity of Glue Joint (Delamination) Test

This test covers an accelerated means of measuring the resistance to delamination of structural laminated wood members intended for exterior service and exposure.

Each test specimen consisted of a full cross section of sample board and 75 mm in length along the grain *(Fig. 1)*. The test was performed in accordance to ASTM* D 1101-59. The following sequence was followed in performing the test.

i. The specimens were placed in a small pressure vessel (3.0 m long x 380 mm diameter). Sufficient water was admitted to submerge the specimens.

ii. 500 mm - 635 mm Hg of vacuum was drawn and held for 15 minutes. The vacuum was then released and 1.03 x 10^3KPa (kilopascal) of pressure was applied for a period of 2 hours.

iii. The sequence was repeated to complete 2 cycles (a total of 4.5 hours).

iv. The specimens were then removed from the pressure vessel and dried for a period of 91.5 hours in a forced draft oven at a temperature of 27 - 29°C and relative humidity of 25 - 30%. During drying, the specimens were placed at least 50 mm apart to allow for sufficient air movement.

v. The soaking and drying cycles were then repeated at once to complete a total period of 8 days.

* American Society for Testing and Materials

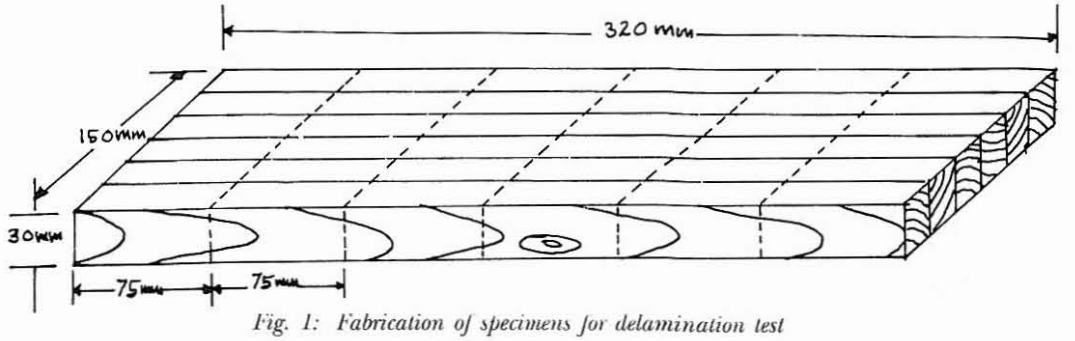

Fig. 1: Fabrication of specimens for delamination test

At the end of the final drying period, the delamination if any, was measured by inserting a feeler gauge with a blade thickness of 0.08 mm to 0.10 mm into the delaminated gluelines. Measurements were made to the nearest 1.3 mm from the end grain surfaces.

RESULTS AND DISCUSSION

The integrity of glue bonds to delamination was tested, on 210 different gluelines, representing seven combinations with 30 replicates each. The delamination from the end grain was measured and expressed as percentage of total lengths of the glue line. The minimum, maximum and average lengths of delamination in each combination are presented in Table 1 and illustrated in Figure 2.

Single Species Combination

The Seraya-Seraya combination produced the best result as no apparent glueline failures were observed. The Nemesu-Nemesu combination produced the second best result since 15 out of 30 specimens did not delaminate. The average delamination length and percentage were 2.8 mm and 3.7% respectively. Kempas-Kempas combination exhibited the highest delamination percentage of 4.7% and all of the tested gluelines were delaminated to some degree. All single species combination demonstrated delamination percentages of less

TABLE 1
Average values of delamination percentage of phenol-resorcinol glue joints

Combination	No. of gluelines tested	No. of glue-lines delaminated		Average length delamination (mm)		Percentage of delamination	
		No.	%	Max.	Min.	Ave.	%
Single-species							
Seraya-Seraya	30	0	0	-	-	-	-
Nemesu-Nemesu	30	15	50	6.5	1.3	2.8	3.7
Kempas-Kempas	30	30	100	7.8	1.3	3.6	4.7
Two species							
Seraya-Nemesu	30	72	3.3	3.9	1.3	2.3	3.0
Seraya-Kempas	30	11	36.7	3.6	1.3	2.0	2.6
Nemesu-Kempas	30	25	83.3	5.2	1.3	2.6	3.4
Three species							
Seraya-Nemesu-Kempas	30	17	56.7	6.5	1.3	2.4	3.1

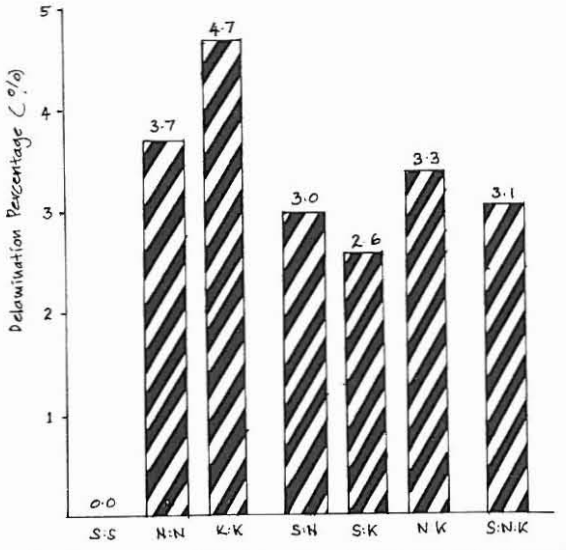

Fig. 2: Average delamination percentage of phenol-resorcinol glue joints

than 8% and met the requirements specified by AITC* for wet use adhesives. Results from this study compared favourably with previous works. Moriya *et al.* (1970) using Keruing (*Dipterocarpus spp*) to compare the reliability and integirty of phenol-resorcinol and phenol formaldehyde glues found the phenol-resorcinol glue joints offered better delamination resistance than straight phenol. The phenol-resorcinol gluelines delaminated by only 8-26% compared to 79-88% for the phenol formaldehyde glue. Hoshi (1977) also found that phenol-resorcinol glue joints performed better than straight phenol on 13 hardwood species from Kalimantan, Indonesia.

Excellent resistance to delamination after soaking and drying cycles was shown by the glue joints especially with Seraya-Seraya combination. This shows that phenol-resorcinol formaldehyde can produce very durable glue joints with these wood species.

Mixed-Species Combinations

The average values of delamination percentage of all gluejoints in each mixed-species combination were generally below 3.5%. Nemesu-Kempas combination gave the highest delamination percentage with 3.4%, followed by three species combination of Seraya-Nemesu-Kempas with 3.1%, Seraya-Nemesu with 3.0% and Seraya-Kempas with 2.6%. The mixed-species combination produced rather low delamination percentages and meet the requirements as specified by AITC. This also confirmed that the gluejoints are likely to be suitable for exterior exposure.

Mixed-species combinations showed a lower delamination percentage as compared to the single species counterparts, except for Seraya-Seraya combination. Kempas, being the most dense species, under soaking and drying cycles swelled and shrank in greater magnitude than the other two species. Combination of Kempas and Seraya showed a lower average delamination percentage. Seraya and Nemesu has lower density value, thus lower coefficient of expansion. Combining two or more species of different wood densities, in this case was slightly advantageous. Therefore, gluing various species into a single board products, may result in better resistance to delamination and improve other properties as well.

CONCLUSION

The integrity test of the phenol-resorcinol glue joints on three Malaysian hardwood species gave good results. All combinations produced very low delamination percentage levels and met the requirements specified by AITC. The highest delamination percentage was shows by Kempas-Kempas combination with only 4.7%. Excellent delamination resistance after soaking and drying cycles showed that the glue joints produced are adequate for exterior exposure services.

Mixed-species combination offered lower percentage of delamination compared to the single-species counterparts, except for Seraya-Seraya combination which showed no apparent delamination.

The results are considered preliminary evidence and by no means complete in depicting the absolute integrity of the glue joints. However, it provides information for the evaluation of adhesives for production of products intended for exterior uses.

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AITC: American Institute of Timber Construction

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