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DELAMINATION AND ADHESION STRENGTH OF SELECTED MALAYSIAN TIMBER FOR GLUE LAMINATION: PULAI (*ALSTONIA SPP.*)

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INTRODUCTION

Pulai (*Alstonia spp.*) is classified as lesser known species that can be widely found in lowland, highly-elevated dryland and swampy areas. The colour of the wood is creamy-white and the colour is indistinctive between sapwood and heartwood. Due to its light colour in nature, pulai has gained much popularity as an alternative timber resource to countries such as Japan (ITTO 1990) and Korea.

The species is grouped in the Malaysian Strength Group SG7 (Anon. 1984). It has light air-dry density (210–500 kg/m^3) which classifies it as light hardwood under the Malaysian Grading Rules (Lim 2016). The average Modulus of Elasticity (MOE) of the air-dried small clear specimens is 7100 MPa, with moderately low air-dried bending Modulus of Rupture (MOR) of 43MPa - i.e. slightly stronger than its counterparts such as *Pinus caribeae* (36 MPa) and *Pinus merkusii* (41 MPa) (Lee et al. 1979).

However, the species is less popular for its poor durability and susceptibility to insects and fungi attacks. Due to having low density and poor durability attributes, the species has often being marked as inferior for structural application and somewhat has limited its potential for greater use. On the flip side, the species is easy to work with and can be easily treated using suitable chemicals and treatment method (Sim 1982). This suggests durability issue that occurs in pulai can be overcomed using proper preservative treatment. Furthermore, enhancement on the mechanical performance of the species by means of reengineering, such as glue lamination could value-add the species. One of the prerequisites in glue lamination is the understanding of glueability of the species. An interesting observation in pulai is that the tree is naturally producing milky latex (Pratap et al. 2013). This justifies the need of research to assess whether the occurrence of latex in the wood would impede its glueability. The objective of this paper is to assess the bonding performance of pulai laminated using phenol resorcinol formaldehyde (PRF), and to suggest its suitability for lamination.

METHODS & MATERIALS

Sample preparation

Pulai timber were dried and conditioned to approximately 12% moisture content in a conditioning chamber at 27 °C and 55%RH. The specimens were sent for planing to nominal dimensions of 75 mm × 95 mm × 20 mm. Two pulai lamellae were laminated using PRF at a double-sided glue spread of 400 g/m^2. The glulam samples were clamped at 10 kgf/cm^2. The closed assembly time for preparation on all glulam samples were less than 20 minutes and each sample was left for further curing under closed assembly for at least 48 hours. All samples were cut to testing dimensions according to the respective testing methods.

Delamination tests

i. *Cyclic Delamination Tests: VP Method A (MS758:2001)*
Test pieces of 75mm length were placed in the vessel and vacuum pressure of between 75 and 85 kPa was applied; it was held for 5 minutes. Later, the vacuum was released and a pressure between 500 and 600 kPa was applied for 1 hour. The same process was repeated for the second cycle. Subsequently, all test pieces were removed from the vessel and dried in a conditioning chamber at 60–70 °C and relative humidity of less than 15%. The percentages of delaminations were computed. If delamination occurs for more than 5% after the second cycle, the above process was repeated for the 3rd cycle for determination of the final delamination.

ii. *Boiling water soak test: JAS1152:2007 Appendix 3(2)*
Test pieces of 75 mm length were immersed in boiling water for 4 hours and transferred to water at room temperature (10–25 °C) for 1 hour. Later, test pieces were dried in an oven at 70±3 °C until the mass reached between 100–110% of the pretest mass.

Total percentage of delamination can be computed as follows:

$$Total\ delamination, \% = \frac{Total\ delamination\ length\ (mm)}{Total\ glue\ line\ (mm)}\ x\ 100\%$$

… Equation 1

Glue line shear test

Test pieces at nominal dimensions 25 mm × 25 mm (Figure 1) were prepared. Test method was based on JAS1152:2007 with slight modification on testing speed based on ASTM D905-03. Test pieces were placed under shear loading at a constant rate of deformation at 6.16 cm/min (ASTM D905-03) and failure occurred not less than 20 seconds. Testing procedures of JAS1152:2007 and MS758:2001 resemble one another. Results in accordance with the respective standards' criteria in performance acceptance are discussed in Table 3.

The calculation of shear strength was obtained using Equation 2:

$$Shear\ strength, MPa\ or\ N/mm^2 = \frac{Maximum\ load\ for\ shear\ failure\ (N)}{Area\ of\ adhesion\ (mm^2)}$$

… Equation 2

RESULTS AND DISCUSSION

A total of 20 replicates had been allocated for vacuum pressure delamination test and boiling water soak test, respectively. The percentage of delamination in each specimen was computed using Equation 1 and the mean of the percentage was reported according to the rating described in Table 1. Summary of the test results are presented in Table 2.

Similarly, 20 replicates were used in the glue line shear test. The summary of the shear strength performance and the percentage of wood failure are shown in Table 3.

In general, pulai has performed exceptionally well in meeting all test requirements for glue line integrity, particularly on bonding performance under cyclic delaminations for outdoor structural glulam applications. This is a positive indicator for Pulai to be value-added as engineered products, desirably for outdoor and structural uses.

Table 1 Rating indicator for Delamination Test

Percentage of delamination	Rating indicator
0.00%–0.99%	Excellent
1.00%–1.99%	Very good
2.00%–3.99%	Moderately good
4.00%–5.00%	Requirement met

Table 2 Delamination performance for vacuum pressure test and boiling water soak test, the average moisture content and average density of pulai

Vacuum pressure delamination, %		Boiling water soak delamination, %		Moisture content, %		Density, kg/m^3	
Mean	MS758:2001	Mean	JAS 1152:2007	Mean	COV	Mean	COV
Excellent	< 5% in the first cycle	Excellent	≤5% from both butt ends and total length of delamination not more than ¼ of the glue line length	11.81	0.0415	250.70	0.0359

Table 3 Performance on glue line shear and percentage of wood failure

Average shear strength values, N/mm^2				Average percentage of wood failure, %		Percentage of wood failure, %	
MS758:2001	Requirement Met?	JAS 1152:2007	Requirement Met?	MS758:2001	Requirement Met?	JAS 1152:2007	Requirement Met?
≥ 6.0	Yes	≥ 6.0	100% fulfilled	≥ 90%	Yes	65%	90% fulfilled

CONCLUSION

Pulai has passed exceptionally well in adhesive delamination tests. It has also met the minimum shear strength requirement supported by evidences of observation on the percentage of wood failure. Each of the listed test results essentially substantiated one another in confirming that pulai has very good glueability and glue line integrity in response to PRF adhesive. In addition, the natural occurrence of latex in pulai tree has not impeded its glueability performance.

Further research on evaluation of its mechanical performances, i.e. comparison between before and after glue lamination will enable the final justification on its suitability as glulam feedstock. Despite that the above results are insufficiently comprehensive in predicting pulai for structural glulam use, the above information on its glue line integrity is regarded crucial as the basis for further development of any timber engineering products.

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This paper discusses the gluing performance of Pulai in terms of its glue line integrity and strength. The gluing performance of Pulai was found to be exceptionally well. The potential of the species as glulam feedstock is encouraging. Further assessment on its mechanical performance would conclude its suitability for structural glulam feedstocks. Nevertheless, information on gluing performance of Pulai plays a vital role for future development of engineered timber products.

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