The glueline shear strength of *Peronema canescens* and Acacia hybrid

E Enggoh1*, K C Liew 1, M H Sahri1, M O M Khaizir2 and K Masseat2

1 Forestry Complex, Faculty of Science and Natural Resources, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia
2 Timber Engineering Laboratory, Forest Research Institute Malaysia, 52109 Kepong, Selangor, Malaysia

*Corresponding author: enggoh35@gmail.com

**Abstract.** The glueline shear strength is one of the common measures used to estimate potential performance of bonded wood joints. This study was conducted to determine the glueline shear strength of *Peronema canescens* (Sungkai) and Acacia hybrid (A. hybrid). The wood were bonded with polyvinyl acetate (PVAc) and Emulsion Polymer Isocyanate (EPI) and these are for dry use in non-structural timber production. Sungkai and A. hybrid logs were obtained from Telipok and Ulu Kukut, Sabah respectively, were debarked, sawn and air-dried prior to being sawn to 20 mm thick, 60 mm wide and 150 mm long. After reaching the constant moisture content, the gluing process was carried out. 2 types of adhesives were used; EPI and PVAc. The glue was spreaded at a constant spreading rate of 200 g/m². 3 types of assembly combinations were made; Sungkai-Sungkai, A. hybrid-A. hybrid and Sungkai-A. hybrid. The assemblies were clamped for 24 hours, as recommended by the glue manufacturer. The test specimen preparation and the glueline shear strength test was conducted in accordance with the Manual for Testing Methods for Plantation Grown Tropical Timbers (Finger and Laminate Joints in Non-Structural Timber Production). The results showed that, the average glueline shear strength of Sungkai-Sungkai, A. hybrid-A. hybrid and Sungkai-A. hybrid bonded with EPI are 7.48 N/mm², 6.58 N/mm² and 6.87 N/mm² respectively. While the average glueline shear strength of Sungkai-Sungkai, A. hybrid-A. hybrid and Sungkai-A. hybrid bonded with PVAc are 7.61 N/mm², 6.03 N/mm² and 7.60 N/mm² respectively. Based on the results obtained, the glueline shear strength for all assembly combinations exceed the minimum requirement of the shear strength for laminate joints, which is 5.32 N/mm². Thus, Sungkai and A. hybrid wood have the potential to serve as supplemental raw material for the non-structural timber production.

1. **Introduction**

To overcome the challenge related to shortage of raw material for the wood industries, through the NATIP 2009 – 2020, the government recommends to increase the utilisation of small diameter logs from plantation timber species and imported logs [1]. Thus, to increase the utilisation of small diameter logs, additional action such as wood bonding is required and vital. The bonding strength of bonded wood need to be assessed to avoid potential failure during its life service. One of the common measures used to estimates the bonding strength is the shear test [2]. Apart of strength test, percentage of wood failure is also occasionally used to estimate the bonding quality of bonded wood [3], with high percentage of wood failure indicates good adhesives penetration [4].

Both A. hybrid and Sungkai are fast growing tree species that have the prospective to serve as supplemental raw material for the wood industries [5, 6]. Thus, various and continuous research
should be conducted including the study related to their gluing properties to ensure these species can be utilized efficiently and their usage can be expanded.

This study is conducted to determine the glueline shear strength and wood failure of A. hybrid and Sungkai bonded with polyvinyl acetate (PVAc) and Emulsion Polymer Isocyanate (EPI) for dry use in non-structural timber production.

2. Materials and experimental procedures

Two forest plantation tree species were used in this study namely Sungkai and A. hybrid. Sungkai and A. hybrid with diameter breast height ranging from 20 to 25 cm were obtained from Sabahpuri Nursery, Telipok and SAFODA Ulu Kukut, Kota Belud, Sabah respectively. The logs were sawn into a dimension of 50 mm x 100 mm x 120 m, and air-dried for about a month.

Two types of adhesives were used, that is EPI and PVAc. Both adhesives were manufactured by GB Chemical (M) Sdn Bhd, Penang. Table 1 shows the properties of the adhesives used.

| Properties          | EPI           | PVAc          |
|---------------------|---------------|---------------|
| Viscosity (cps at 28°C) | 8,000 – 12,000 | 12,500-15,000 |
| Solid content (%)   | 36.5 – 40.5   | 36 - 40       |
| pH                  | 5.0 – 7.0     | 5.0 – 7.0     |

The air-dried rough sawn timber, were resawn into shorter strips of 20 mm x 60 mm x 150 mm. These shorter strips were air-dried until they reached constant weight and moisture content (MC) of 15±1%. Once these strips reached the constant weight and MC, the gluing process was carried out. The EPI adhesive was mixed according to the manufacturer specification; 100 parts of resin was mixed with 15 parts of hardener (by weight). The type of hardener used was known as polymethylene polyphenyl polyisocyanate.

Single spread adhesive with constant spreading rate of 200 g/m² was applied onto each piece of the strip. Three different types of assembly combination were made for this test; Sungkai-Sungkai, A. hybrid – A. hybrid and Sungkai – A. hybrid. The adhesive spreading process was followed by a close assembly time (CAT) of 40 minutes as recommended by the manufacturer. CAT will allow the adhesive to penetrate into the wood before the pressing process. Later, the assemblies were clamped for 24 hours in a room temperature.

The fabrication of the test piece was in accordance with the Manual for Testing Methods for Plantation Grown Tropical Timbers (Finger and Laminate Joints in Non-Structural Timber Production) [7]. Six test specimen were obtained from each assembly.
The glueline shear test for dry use (dry condition) was conducted in accordance with the Manual for Testing Methods for Plantation Grown Tropical Timbers (Laminate Joints in Non-Structural Timber Production) at the Timber Engineering Laboratory, Forest Research Institute Malaysia, Kepong. The test was carried out by using the Shimadzu Universal Testing Machine with maximum loading capacity of 100 kN.

The basic density of wood samples for both species were also determined in accordance with the ASTM D 2395 – 14e1 [8]. While the percentage of wood failure were estimated accordance to ASTM D 5266 – 13 [9].

3. Results and discussion

The average basic density of Sungkai and A. hybrid are 0.446 g/cm³ and 0.539 g/cm³, respectively. Based on the value obtained, A. hybrid has higher density compare with Sungkai.

The average glueline shear strength and percentage of wood failures for the three types of assembly combinations were shown in Table 2 and presented in Figure 4 and 5.

![Figure 3. Test piece for shear test accordance to the Manual for Testing Methods for Plantation Grown Tropical Timbers [8].](image)

![Figure 4. Glueline shear test carried out using Shimadzu Universal Testing Machine.](image)

Table 2. The average glueline shear strength and wood failure of three types of assembly combinations glued with EPI and PVAc.

| Adhesive / Species combination | EPI Shear strength (N/mm²) | Wood failure (%) | PVAC Shear strength (N/mm²) | Wood failure (%) |
|-------------------------------|----------------------------|-----------------|----------------------------|-----------------|
| Sungkai - Sungkai            | 7.48<sup>a</sup>           | 79.60           | 7.61<sup>a</sup>           | 90.20           |
| A. hybrid – A. hybrid        | 6.58<sup>b</sup>           | 8.80            | 6.03<sup>b</sup>           | 18.80           |
| Sungkai – A. hybrid          | 6.87<sup>ab</sup>          | 28.80           | 7.60<sup>a</sup>           | 57.30           |

*Min. requirement of shear strength (Dry condition) based on Manual for Testing Methods for Plantation Grown Tropical Timbers (Laminate Joints in Non-Structural Timber Production): 5.32 N/mm²

*Min. requirement of wood failure (%) (Dry condition) based on Manual for Testing Methods for Plantation Grown Tropical Timbers (Laminate Joints in Non-Structural Timber Production): 30 %

* P ≤ 0.05 (ANNOVA), <sup>a</sup>, <sup>b</sup> the same letters indicate not significantly different (Tukey pos hoc test)

Based on the results obtained, the glue-line shear strength for all assembly combinations glued with EPI and PVAc exceeded the minimum requirement of 5.32 N/mm². However, for the percentage of wood failure, only Sungkai-Sungkai combination glued with EPI and PVAc and Sungkai – A. hybrid combination glued with PVAc exceeded the minimum requirement of 30 % of wood failure.
In this study, for wood samples glued with EPI showed that, the highest glueline shear strength is from the Sungkai – Sungkai combination (7.48 N/mm²), while the A. hybrid – A. hybrid combination has the lowest glue-line shear strength (6.58 N/mm²). There was statistically significant difference between the groups as determined by one-way ANOVA (p < .05). A pos hoc Tukey test showed that the Sungkai-Sungkai group and A. hybrid-A. hybrid group differed significantly at p < .05, while the Sungkai-A. hybrid group was not significantly different from the two groups.

As for wood samples that was bonded with PVAc, the highest shear strength is obtained from the Sungkai-Sungkai combination (7.61 N/mm²) and Sungkai – A. hybrid (7.60 N/mm²). The lowest glue line shear strength was exhibited in A. hybrid-A. hybrid combination, which is 6.03 N/mm². The one-way ANOVA revealed that there was significant difference between the groups (p < .05). Based on the pos hoc Tukey test, there was no significant difference between Sungkai – Sungkai and Sungkai-A. hybrid group, however, the A. hybrid-A. hybrid group showed significant difference at p < .05 from the two groups.

Based on the average of wood failure, it shows that Sungkai-Sungkai combination has the highest percentage of wood failure, which is 79.60 %, whereas the A. hybrid-A. hybrid has the lowest average of wood failure, which is 8.80 %. This result shows that Sungkai-Sungkai combination bonded with EPI had a very good bonding compare to the other two types of species combination.
Similar to the samples glued by using EPI, the Sungkai-Sungkai combination glued with PVAc has the highest percentage of wood failure, which is 90.20 %, followed by Sungkai-A. hybrid combination with 57.30 % and A. hybrid-A. hybrid combination with 18.80 %.

The wood failure that occurred on the Sungkai-Sungkai assembly combination were deep wood failure, while most of the type of wood failure that occurred on the Sungkai – A. hybrid and A. hybrid- A. hybrid assembly combinations were shallow wood failure. However, for A. hybrid- A. hybrid assembly combination, the failure often occurred on the glueline.

![Figure 7](image)

**Figure 7** The type of wood failure occurred: a) shallow wood failure occurred in A. hyrbrid-A. hybrid b) glueline failure (0 % wood failure) occurred in A. hybrid-A. hybrid c) deep wood failure (100 % wood failure) occurred on Sungkai – Sungkai.

Although the glueline shear strength of A. hybrid-A. hybrid and Sungkai-A. hybrid exceeded the minimum requirement, however these assembly combinations failed to achieved the minimum requirement of the percentage of failure. Such results were also reported by Alamsyah et al, may be due to the presence of extractives on the surface of the A. hybrid wood [4, 10].

In general, the glueline shear strength and wood failure for sample bonded with EPI and PVAc exhibit similar result trend; combination of Sungkai-Sungkai had the highest glueline shear strength, followed by Sungkai-A. hybrid, while the A. hybrid-A. hybrid had the lowest glueline shear strength. The possible explanation for this occurrence could be due to the density of Sungkai and A. hybrid. Based on the basic density of both species, Sungkai had lower basic density compare with A. hybrid. As stated in various literature review and based on previous studies conducted [11-15] density is one of the factors that affected bonding performance of wood, with high-density wood is difficult to be bonded compare with low-density wood for numerous reason, such as; the thicker cell walls of high-density wood, smaller diameter of lumens that presence in high-density wood and the existence of higher extractives in high-density wood compare with low-density wood.

4. **Conclusion**

The glueline shear strength for all types of species combination bonded with EPI and PVAc met the minimum requirement of the referred manual, with the highest strength obtained from the Sungkai-Sungkai combination, while the lowest strength obtained from the A. hybrid-A. hybrid.
As for the percentage of wood failure, for species combination bonded with EPI, only Sungkai-Sungkai combination exceed the minimum value required. Whereas, for sample bonded with PVAc, Sungkai-Sungkai and Sungkai-A. hybrid combination met the requirement stated in the manual referred.

Hence, both Sungkai and Acacia hybrid showed the potential to serve as supplemental raw material for dry use in the non-structural timber production. However, further study is still required to fully understand the bonding performance of both species.

Acknowledgement
The author would like to thank the Forest Research Institute Malaysia, Kepong for the permission to conduct the shear test and allowing the author to use all facilities required for the test at the Timber Engineering Laboratory, Forest Research Institute Malaysia, Kepong, to SAFODA, Ulu Kukut and Sabahpuri Nursery Sdn Bhd for supplying the raw materials utilized in this research.

References
[1] Anon 2009 National Timber Industry Policy 2009 - 2020 Putrajaya
[2] Vick C B 1999, Wood Handbook: Wood As An Engineering Material, “Chapter 9: Adhesive Bonding of Wood Material, pp 463, US Dept. Of Agriculture, Forest Service
[3] River B H and Vick C B Gillespie R H 1991 Wood as an Adherend, Marcel Dekker Inc., New York
[4] Alamsyah E M, Nan, L C, Yamada M, Taki K, and Yoshida H 2007 Bondability of tropical fast-growing tree species I: Indonesian wood species J Wood Sci 53 40-46
[5] Suffian M, Ormondroyd G A, and Hale M D 2010 Comparisons of particleboard produced from Acacia hybrid and a UK commercial particleboard furnish from recycled wood J Trop For Sci 227-236
[6] Ahmad Zuhaidi 2015, National Seminar on Peronema canescens (29th – 30th April 2015), “Peronema canescens Jack: Potential Forest Plantation Species For Commercial Planting”
[7] Tan, Y.E., Lim, N.P.T., Gan, K.S., Wong, T.C., Lim, S.C. and Thilagawathy, M., 2010. Testing Methods For Plantation Grown Tropical Timbers. Forest Research Institute Malaysia, Kepong.
[8] ASTM D2395-14e1, Standard Test Methods For Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials, 2014, ASTM International, West Conshohocken, PA
[9] ASTM D5266-13, Standard Practice for Estimating the Percentage of Wood Failure in Adhesive Bonded Joints, 2013, ASTM International, West Conshohocken, PA
[10] Alamsyah E M, Yamada M, Taki K, Yoshida H, and Inai A 2006. Bondability of Tropical Fast-Growing Tree Species (II)-Malaysian Wood Species Journal-Adhesion Society Of Japan 42 499
[11] Frihart C.R, Hunt C.G 2010, Wood Handbook: Wood As An Engineering Msterial, “Chapter 10: Adhesives With Wood Materials Bond Formation & Performance”10-1 – 10-24
[12] Laiveniece L and Morozovs A 2014 Penetration depth of adhesive depending on applied pressure during gluing process. In International Conference Materials, Methods and Technologies
[13] Dunky M. 2003, Handbook of Adhesive Technology (2nd Edition), Editor: Pizzi.A & Mittal K.L., “Chapter 47: Adhesives In The Wood Industry” 883-951
[14] Scheikl, M., Walinder M. 2002, Cost Action E13: Wood Adhesion & Glued Products 1st Edition (Editor: Dunky, M., Pizzi, T. & Leemput, M.V.), “Chapter 4: Bonding Process-Theory of Bonding; Introduction” 89 – 90
[15] Sahri, M.H., Harun, J. and Jusoh, M.Z., 1986. The glue joint strength of four under-utilized Malaysian hardwood species [Lithocarpus; Pouteria malacensis; Parkia; Irvingia malayana].