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Bonding Performance of CCA Treated Glulam Timber under Different Environmental Exposure

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Abstract: This study reports the bonding performance of CCA treated glued laminated timber (glulam) made from two Malaysian tropical timber species namely bintangor *(Calophyllum sp.)* from Strength Grouping (SG) 5 and Sesenduk *(Endospermum sp.)* from SG 7. All the glulam beams were exposed to three different service conditions namely room condition, covered condition and uncovered condition for six month period prior to the test. The bonding properties of the beams were obtained by block shear test and delamination test accordance to malaysian standard MS758. Results showed that the delamination for untreated glulam were higher than the delamination of treated glulam. The wood failure percentage for all glulam in all exposure conditions were higher than the acceptance criteria for good glue line performance as stated in MS758. This indicates that the glulam untreated and treated with CCA have good bonding performance.

Key words: Bonding performance, CCA preservative, environmental exposures, glued laminated timber, Malaysian tropical timber, Malaysia

INTRODUCTION

Glued laminated timber (glulam) technology represents one of the timber construction technique where a low grade of sawn timber jointed together by an adhesive bonding process to produce a high-quality timber of any width and length. Efficient utilization of lower grade and lower density timber for engineered wood products has become one of the possible ways to overcome the limited supply of large section timber logs and the high cost of higher grade timber. In fact, previous research had proven that by converting to glulam, the strength properties have improved significantly and some has improved to two grades higher from the original strength grade (Bhkari *et al*., 2016). Realizing the true potential of glulam timber products in 2012, Malaysian government had built the first glulam building in Johor, Malaysia. Internationally, glued laminated (glulam) timber is an engineered wood product that has been accepted and used for heavy structures and light structures.

However, there is an issue concerning the strength properties of glulam using tropical hardwood in lower grade timber. Lower grade and not naturally durable timbers are very prone to fungal degradation and insect damage especially at outdoor environments particularly in a tropical climate. Therefore, these timbers need to be treated with preservative before used for glulam structures at outdoor conditions. Once the timbers treated with chemicals, it creates envelope of protection around the wood. Chromate Copper Arsenate (CCA) is a common waterborne preservative that contains chromium, copper and arsenic salts that has been used as treatment chemical by the wood preservation industry.

To evaluate the potential utilization of CCA treated glulam timber it requires assessment of adhesive bondability. Better performance of adhesive bond of glulam depends on the proper combination of adhesive, preservative treatment, wood species (Vick, 1999; Lee *et al*., 2006; Lorenz and Frihart, 2006) clamping pressure and cure temperature during production (Gaspar *et al*., 2010). Lower density timber species is known to have a better bonding performance as these timber are easy to glue compared to higher density timber species. Research on the adhesive performance of treated wood has been explored by several researchers. Yang *et al*. (2012) evaluate the mechanical and bonding properties of ACQ-treated glulam made from hardwood timber and found that there was no signficance difference in the delamination values of glulam between treated and

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untreated group and less delaminating was found in all glulam after delamination tests. This finding was also supported by Podgorski and Legrand where they carried out experimental work using Scots pine wood treated with CCA preservative. Result showed that the shear strength and delamination percentage met the requirement. Similiar results were also obtained by Li *et al*. (2004).

Peservative treatment could also interfere the bonding quality of the glued laminated timber. Preservative treatment generally decrease the ability of the adhesive to wet the wood. According to Lorenz and Frihart (2006), poor bondability of treated wood is due to reduction of wettability of wood, physical blockage between adhesive and wood surface and the chemical can influence the curing of adhesive. Many studies have shown that the treatment has interfered negatively with the adhesive and reduced the mechanical and physical properties (Li *et al*., 2004; Clausen *et al*., 2001; Mengeloglu and Gardner, 2000; Munson and Kamdem, 1998; Sellers and Miller, 1997; Vick and Christiansen, 2007; Vick, 1995). Vick (1995) used Scanning Electron Microscopy (SEM) and elemental analysis to explore the penetration of adhesive into CCA treated wood. The researchers found that the lumen surfaces of wood were covered by insoluble mixture of chrome, copper and arsenic of CCA preservative which physically blocked the molecular forces between wood and adhesive. In other words, the presence of CCA on the wood surface has attributed to the limited access of the adhesive to the wood. It was believed that the precipitation of chemically fixed of CCA preservative on the cell wall interfering the bond formation between adhesive and wood may reduced the durability and significance loss of the internal bond.

Most of the wood preservation literature focuses only on wood and wood products from European or American wood. Hence, there is a need to establish data on the performance of glulam manufactured using treated Malaysian hardwood timber. Studies have shown that CCA treatment can have positive and negative effect on the bondability of timbers. As CCA treatment is commonly used as preservative in Malaysia, this study explored the bond durability performance of treated glulam timber made from lower density tropical hardwood timber after being exposed to room condition, covered condition and uncovered condition.

MATERIALS AND METHODS

Raw material and sample preparation: Timber species from Strength Group (SG), SG5, Bintangor *(Calophyllum sp.)* from Guttiferae family and SG 7, sesendok *(Endospermum sp.)* belongs to euphorbiaceous family were selected. The selection of timber species of this study is according to the availability and material cost. These timber logs were sourced from reserved forest in UiTM Jengka, Temerloh Pahang. The timbers were firstly dried in the kiln drying until 12±2% moisture content was achieved. Then, the dried timbers were planned into 33 mm in thickness, 105 mm in width and 1200 mm in length. All the sawn timbers were graded using visual strength grading rule for Hardwood Structural Grade (HSG) to select the quality timbers for making glulam beams. Once sawn timbers have been graded they were divided into untreated group and treated group of sawn timbers. Prior to vacuum pressure treatment they were weighted on the weighing machine and measured by using digital venire caliper before transported them to the treatment plant. The procedures for the treatment process are as recommended in Malaysian Standard MS544: Part 10. In this research study, bethell full cell process was selected for the preservative treatment process. CCA Tanalith preservative solution was prepared at 3% concentration based on weight over volume. Then, the treatment solution was pumped into the cylinder. After the cylinder was filled, the samples were kept in the treatment solution for further 60 min. Then, the vacuum was released with 1.38 N/mm^2 pressure for 2 h. Preservative solution was pumped out from the cylinder. Once all the solution was removed, the final vacuum was applied for 15 min. The timber samples were taken out from the cylinder and wiped lightly to remove any solution left on the timber surface. Once the treatment process have been completed, timbers were weighted again to determine the Dry Salt Retention (DSR) value. The DSR was calculated by the following Eq. 1:

$$\text{DSR} = \frac{G \times C}{V} \text{kg/m}^3 \quad (1)$$

Where:

G = The gram of treating solution absorbs by the wood (weight after treatment, T_2-weight before treatment, T_1)
C = The concentration based on weight over volume
V = The volume of the wood

After treatment, the process begins with the finger jointing profiling process of sawn timbers through the finger sharper to form ends joint profile of 25mm length. Then, both ends of finger-shaped timber coated with prefere™ 4001-2 and prefere 5837 Phenol Resorcinol Formaldehyde (PRF) adhesive with 2:5:1 mixing ratio before composed to a pressure of 0.49 N/mm^2 by the finger composer. This process was done within 24 h after

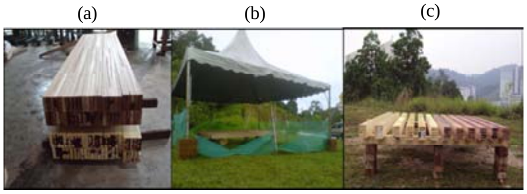

Fig. 1: Environmental conditions: a) room condition; b) outside covered condition and c) outside uncovered condition

the profiling process. After 48 h of curing process, finger jointed timbers were assembled into 5-ply or layers of laminations to form 150 mm in thickness, 100 mm in width and 3000 mm in length of glued laminated timber beams. Once all the glulam beams were assembled at the cramping bed, hydraulic cramp pressure of 6.8 N/mm^2 was applied. After a week of cramping periods at cramping bed, finally, all glulam beams were exposed to three service conditions namely room, outside covered and uncovered conditions for six months period as shown in Fig. 1.

Test methods: The bonding performance was determined by performing the block shear test and delamination test. Block shear test is the standard test to check for the bonding strength of the bonded timber. The block specimens with dimension of 50 mm in width, 50 mm in thickness and 50 mm in length were cut from the exposed beam after bending test. The bending test was not reported here. Total of 180 specimens were prepared for the test. It was conducted as describes in ASTM 198 by using Universal Testing Machine (UTM) model UTS 348 equipped with a 100 kN load cell at Laboratory of Concrete, Faculty of Civil Engineering, Universiti Teknologi MARA, Shah Alam. The specimen was loaded in a shear jig with an average loading speed of 0.5 mm/min. The shear bond strength and the Wood Failure percentage (WF%) from each test result from the block shear tests of each cross-sectional specimen were evaluated and compared against the minimum requirement as stipulated in MS758. The shear bond strength is to be at least 6 N/mm^2 and WF% of 70%. The WF% was estimated by the percentage of total glued area in the specimen. The greater the percentage of wood failure the better the joint. The shear bond strength was calculated based on Eq. 2:

$$\text{Shear bond strength, } f_v = F/A, \text{ N/mm}^2 \qquad (2)$$

Where:

F = The ultimate load (N)
A = The sheared area (mm^2)

Delamination test method, method A was employed accordance to MS 758 since the PRF adhesive was used. The delamination samples were prepared by cutting a block specimen with dimension; 100 mm in width, 150 mm in thickness and 75 mm in length. The delamination of each test specimen was calculated in percentage based on Eq. 3:

$$\text{Delamination percentage (\%)} = \frac{l_{\text{tot, glue line}}}{l_{\text{tot, delam}}} \times 100\% \qquad (3)$$

Where:

$l_{\text{tot,glue line}}$ = The delamination length of all glue lines in test specimen (mm)
$l_{\text{tot,delam}}$ = The entire length of glue lines on the two end grain surfaces of test specimen (mm)

According to MS758, for Type 1 Adhesive and Method A, the maximum delamination % after Cycle No.2 must be less or equal to 5%

RESULTS AND DISCUSSION

In order to identify the beam, the notation for bintangor glulam beam was, i.e., UBR (untreated glulam made of bintangor exposed to room) and USR (untreated glulam beam made of Sesenduk exposed to room) for sesenduk glulam beam. The notation for covered and uncovered environmental conditions were, i.e., UBC (untreated glulam beam made of Bintangor exposed to covered) and UBU (untreated glulam beam made of bintangor exposed to uncovered), respectively.

Dry salt retention: Table 1 shows the DSR value for all the sawn timber used to prepare the glulam. It can be seen that the DSR for sesenduk (SG 7) is higher than bintangor (SG 5). This indicates that the higher density timber has lower DSR value compared to lower density timber which implies the lower density timber can absorb the treatment better than higher density timber.

Glue line delamination percentage: Figure 2 shows the delamination values for sesenduk and bintangor glulam. Since, the delamination obtained in the study was <5%, therefore the delamination criteria for the glulam produced in the study is satisfied. In general, the delamination increases as the environmental become extreme. At the same time, the delamination percentage for untreated glulam were higher than the delamination of treated glulam. Since, delamination process was conducted after exposing the specimen into much adverse environment, the lower delamination of treated glulam is evidence that the treatment helps in preventing the delamination of glue line. To show further that treatment helps in preventing the delamination of glueline, comparison was made in the delamination value of the control specimen. The delamination of TSR and TBR were 83 and 70% lower than USR and UBR, respectively. This indicates that the

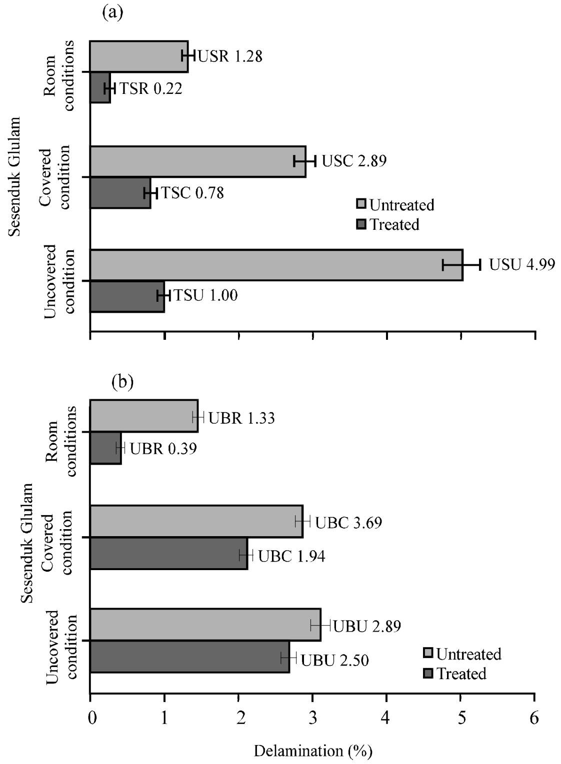

Fig. 2: Histogram of delamination percentage for: a) Sesenduk and b) Bintangor Glulam Timber after exposed to different environments

Table 1: Dry salt retention of treated timber

Timber Species	Weight before treatment, T_1 (kg)	Weight after treatment T_2 (kg)	Dry salt retention, DSR (kg/m^3)
Sesenduk	1.81	3.47	12.01
Bintangor	2.90	4.34	10.36

application of treatment reduced delamination, thereby improving the integrity of bonding of the laminated beams. The present of CCA solution blocked some of the hydroxyl of the wood fibers thus, reduced the potential of swelling, cracking and delaminating of laminated timber. This result similar to other result conducted by Yang *et al*. (2012) and Podgorski and Legrand.

Shear bond strength and wood failure percentage: Figure 3a shows that the shear bond strength for treated sesenduk glulam was reduced in all conditions. The reduction in shear bond strength become higher as the environment exposure become extreme. Nevertheless, it shows a slowly improvement in shear strength value when exposed at covered and uncovered conditions by comparing the shear strength among treated sesenduk glulam. TSU and TSC had improved by 9 and 6% compared to TSR, respectively. It indicates that CCA treatment protect Sesenduk glulam timber eventhough the shear bond strength was lower than untreated at all conditions. By comparing among the different timber species, the shear bond strength for Bintangor Glulam was found to be higher than Sesenduk in all conditions as shown in Fig. 3b. This could be due to the density of Bintangor timber is higher than Sesenduk timber. However, it is quiet surprisingly to see that the shear bond strength for untreated glulam in all conditions either Bintangor or Sesenduk are higher than shear bond strength for treated glulam. This phenomena could be explained by the absorption of the glue into the timber.

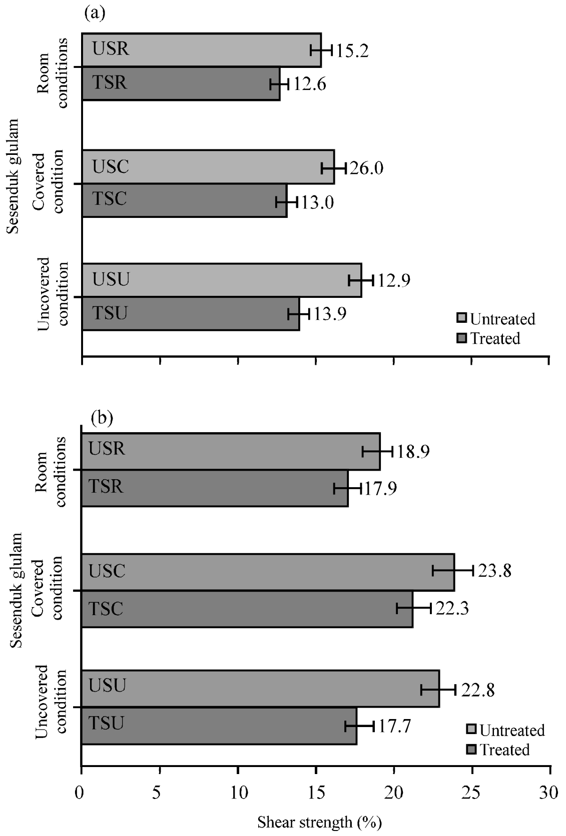

Fig. 3: Shear bond strength for: a) Sesenduk and b) Binatangor gluam under different exposures

From Fig. 4a and b, the WF% for treated glulam are higher than untreated glulam for all conditions. However, the WF% for Sesenduk glulam are not much different than WF% for Bintangor. The trend for WF% is opposite with the trend for shear bond strength, the shear bond strength for treated glulam are lower than shear bond strength for untreated glulam. This study also shows that when the value of WF% increases, the value for shear bond strength decreases. This finding contradicts the statement made by Vick (1995) which is the higher

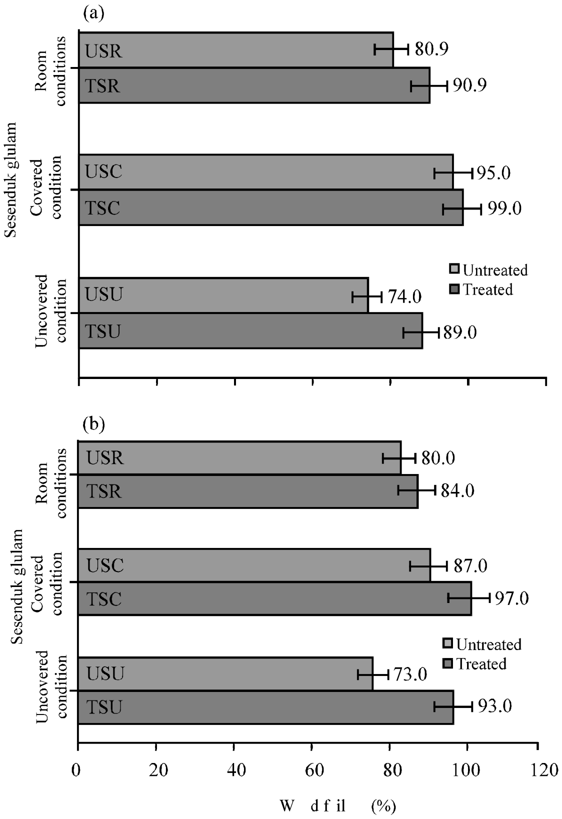

Fig. 4: Wood failure percentage for: a) Sesenduk and b) Bintangor under different exposures

proportional of wood failure and deeper the fracture surface into the grain of wood the stronger the bond is. However, Brandy and Kamke (Brady and Kamke, 1988) make a conclusion that the type of failure is an important indicator of bond strength and its often more importance than measured shear strength of the bond. Anyway, in this study the value of WF% and shear bond strength satisfied the requirement stated in MS758.

Glue line delamination percentage: To observe the penetration of adhesive into timber surface, the block shear specimen for sesenduk and bintangor were sectioned to reveal the adhesive to adherend interface. The aim was to evaluate adhesive penetration into the timber. Adhesive penetration, defined by Sernek *et al.* (2007) is the spatial distance into the timber from the interface of the adjoining substrate. From observations, it can be seen that the bond integrity in sesenduk (Fig. 4a) and Bintangor (Fig. 5b) appears to be good where an intimate bond line can be seen at the timber to adhesive interface.

The similarity in the intimate contact of SSG and BTG is reflected by the same amount of WF% which is 80%.

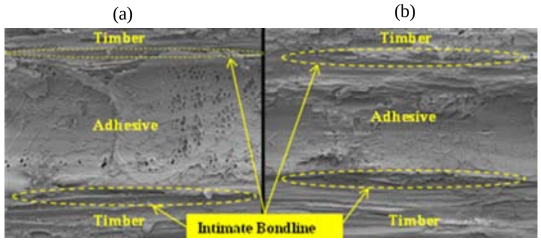

Fig. 5: SEM micrographs of the sectioned surface of block shear specimens of untreated glulam: a) Sesenduk, at magnification of 500x, b) Bintangor at Magnification of 500x, the marked circle shows smooth bond-line

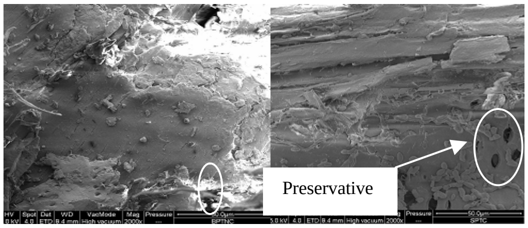

Fig. 6: SEM micrographs

Since, the high WF% was not correlate well with shear bond strength, further analysis were conducted by observing the microstructure of the bonding interface. From the Scanning Electron Microscopy (SEM) test of treated glulam as shown in Fig. 6, it can be seen that the surface area of the cell lumen of both sesenduk and bintangor were covered by CCA concentration of hemispherically shaped deposits at a magnification of 2000x.

It was found that the lumen surfaces of wood were covered by insoluble mixture of chrome, copper and arsenic of CCA preservative which physically blocked the molecular forces between wood and adhesive which definitely influenced and reduced the shear strength values of timber after treatment especially for the lower density timber. In fact, this phenomena similar to study conducted by Vick (1995) and Vick and Kuster (2007). Besides that, it was reported that the copper present in CCA preservative had an influence in retarding the cure of adhesive which resulted in low adhesive strength (Munson and Kamdem, 1998; Vick and Christiansen 2007). Lorenz and Firhart (2006) and Vick (19995) also reported that CCA preservative can cause adhesion problems.

CONCLUSION

As a conclusion, CCA treatment improves the bondability of Sesenduk glulam which evidenced by the low low delamination and high WF%. The delamination% of treated sesenduk glulam was lower than treated bintangor glulam . This indicates that treatment could reduce the rate of delamination of the lower density timber which implies good bonding performance. The shear bond strength and wood failure percentage for all glulam in all exposure conditions were higher than the acceptance criteria for good glue line performance as stated in MS758. This indicates that the glulam produced from this research is satisfactory. The shear bond strength values for bintangor were higher than the shear bond strength values for sesenduk for treated and untreated glulam under all conditions. This also indicates that higher density timber has higher shear bond strength than lower density timber.

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REFERENCES

Bhkari, N.M., Z. Ahmad, A.A. Bakar and P.M. Tahir, 2016. Assessment in bending and shear strength of glued laminated timber using selected Malaysian tropical hardwood as alternative to timber railway sleepers. J. Technol., 78: 111-117.

Brady, D.E. and F.A. Kamke, 1988. Effects of hot-pressing parameters on resin penetration. For. Prod. J., 38: 63-68.

Clausen, C.A., S.N. Kartal and J. Muehl, 2001. Particleboard made from remediated CCA-treated wood: Evaluation of panel properties. For. Prod. J., 51: 61-64.

Gaspar, F., H. Cruz, A. Gomes and L. Nunes, 2010. Production of glued laminated timber with copper azole treated maritime pine. Eur. J. Wood Wood Prod., 68: 207-218.

Lee, D.H., M.J. Lee, D.W. Son and B.D. Park, 2006. Adhesive performance of woods treated with alternative preservatives. Wood Sci. Technol., 40: 228-236.

Li, W., T.F. Shupe and C.Y. Hse, 2004. Physical and mechanical properties of flakeboard produced from recycled CCA-treated wood. For. Prod. J., 54: 89-94.

Lorenz, L.F. and C. Frihart, 2006. Adhesive bonding of wood treated with ACQ and copper azole preservatives. For. Prod. J., 56: 90-93.

Mengeloglu, F. and D.J. Gardner, 2000. Recycled CCA-treated lumber in flakeboards: Evaluation of adhesives and flakes. For. Prod. J., 50: 41-45.

Munson, J.M. and D.P. Kamdem, 1998. Reconstituted particleboards from CCA-treated red pine utility poles. For. Prod. J., 48: 55-62.

Sellers, J.T. and J.G.D. Miller, 1997. Evaluations of three adhesive systems for CCA-treated lumber. For. Prod. J., 47: 73-76.

Sernek, M., J. Resnik and F.A. Kamke, 2007. Penetration of liquid urea-formaldehyde adhesive into beech wood. Wood Fiber Sci., 31: 41-48.

Vick, C., 1999. Adhesive Bonding of Wood Materials. In: Wood Handbook: Wood as an Engineering Material, USDA (Eds.). Forest Products Research, USA., ISBN-13: 978-1892529022.

Vick, C.B. and A.W. Christiansen, 2007. Cure of phenol-formaldehyde adhesive in the presence of CCA-treated wood by differential scanning calorimetry. Wood Fiber Sci., 25: 77-86.

Vick, C.B. and T.A. Kuster, 2007. Mechanical interlocking of adhesive bonds to CCA-treated Southern pine a scanning electron microscopic study. Wood Fiber Sci., 24: 36-46.

Vick, C.B., 1995. Coupling agent improves durability of PRF bonds to CCA-treated southern pine. For. Prod. J., 45: 78-84.

Yang, T.H., C.H. Lin, S.Y. Wang and F.C. Lin, 2012. Effects of ACQ preservative treatment on the mechanical properties of hardwood glulam. Eur. J. Wood Wood Prod., 70: 557-564.