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EFFECT OF GLUE LINE THICKNESS ON SHEAR STRENGTH OF WOOD-TO-WOOD JOINTS

Ramazan Kurt, PhD.
KSU Faculty of Forestry, Department of Forest Industry Engineering,
Kahramanmaraş, Turkey

ABSTRACT

The effect of gap-filling phenol resorcinol formaldehyde (GPRF) adhesive on the shear strength of wood joints when thick glue lines present was studied. A number of wood-to-wood joints were manufactured using the press-gluing fastening method with various thicknesses of GPRF adhesive. The results showed that the shear strength was significantly affected by the glue line thickness, so the strength decreased as the glue line thickness increased. The strength decreases by 10.52 % at a glue line thickness of 0.25 mm and by 39.48 % at a glue line thickness of 0.48 mm. The adhesive may be used for bonding up to 0.25 mm glue line thickness that is 43 % more than the normal glue line thickness (0.18 mm). The results indicated that glue line thickness exceeding 0.25 mm may produce inferior bonds. The method may be utilized for wood-to-wood joints i.e. I-beams and structural wood panels.

KEY WORDS: gap-filling adhesive, glue line thickness, thick glue line, block shear, shear strength

INTRODUCTION

The glue line thicknesses for wood joints are generally from 0.13-0.18 mm (0.005-0.007 in.) thick for glued assemblies. Thick glue lines frequently occur in the manufacturing processes due to thickness variation in adherents, poor preparation of gluing surfaces, inaccurate machining, warping or moisture induced dimensional changes (Marra 1992), lack of adequate pressure methods, non-uniform adhesive spreading and the use of adhesive mixes approaching the end of their pot life.

The most common external pressure methods in wood gluing are hydraulic and pneumatic presses, clamps, dead weights, springs, nails, screws, metal gusset plates, lag screws, splices, staples. The methods may also cause thick glue lines in addition to the factors as stated above.

Since lumber surfaces are often not uniform, jointing and planing should provide smooth surfaces for bonding and uniform thickness for intimate contact. The external pressure must be applied uniformly, because the adhesive does not tolerate gaps well. Because of the nature of timber, the adhesive will often have to possess some gap-filling properties (Davis 1997).

There is a strong relationship between glue line thickness and loss of joint strength. The strength of all the glued joints decreases when thick glue lines present. The thickness of a glue line introduces one of the more fractious factors in bond formation because it directly affects how the glue line functions (Marra 1992). A gap-filling adhesive that will bond wood to wood into a structurally-safe building components where thick glue lines occur over large areas can be a feasible solution.

A gap-filling adhesive is an adhesive capable of forming and maintaining a bond between surfaces that are not close fitting (ASTM D-907). The forest products market offers a couple of structural and many non-structural (including semi-structural) gap-filling adhesives.

The synthetic resin-based structural wood adhesives lack gap-filling properties. Construction adhesives (especially elastomeric types) were introduced to the industry as a solution to the problem. They have gap-filling properties, but their use is limited to semi-structural and non-structural applications, because they do not have the required strength and resistance moisture, heat and other chemicals and are not rigid enough to support high and long term loads without deforming. Many modified synthetic resins using different fillers and chemical materials have been tested (Vick 1973, Elbez 1989) for their gap-filling properties.

Wood joints that are fabricated using a press-gluing method with the GPRF adhesive can help advance the use of wooden panel products as well as gap-filling adhesives. However, information is needed for the expanded use of this method. Thus, this study investigated the effect glue line thickness on the strength of wood-to-wood joints.

MATERIAL AND METHODS

The lumber species was spruce-fine-fir (SPF), kiln-dried, number 1 or better grade. The lumber was free from defects including knots, knotholes, bark, resin pockets, short grain, decay and any unusual discolorations within the shearing area. Block shear assemblies consisted of two blocks (approximately 16 by 63 by 356 mm).

They were conditioned in relative humidity of 50±5 % and 23±2 °C until they reached the equilibrium moisture content of 11%. The adhesive was commercial GPRF adhesive that cures at room temperature. The hardener was mixed with the resin in a 3:10 ratio by weight. The spreading rate was changed with different glue line thicknesses. The specification of the adhesive is given in Table 1.

Tab. 1: Specification of the GPRF adhesive

pH at 25°C	7.00
Viscosity at 25°C	790 cps
Specific Gravity at 25°C	1.18
Open Assembly Time at 21.11°C	20 min
Closed Assembly Time at 21.11°C	90 min
Spreading Rate for each 0.4 mm	48.83 kg per 100 m^2

Specimens were prepared and tested according to ASTM D3931. This test method covers the determination of comparative shear properties of gap-filling adhesives in wood-to-wood joints at specified thicknesses of bond line in the dry condition when tested on standard specimens under specified conditions of preparation, conditioning and loading in compression, and also it is intended as an evaluation of gap filling adhesives such as those used to bond plywood to lumber, lumber to lumber, and other similar materials in building construction.

Five glue line thicknesses were used, i. e., 0.18, 0.25, 0.33, 0.40 and 0.48 mm. For each thickness, three assemblies were manufactured yielding 12 block shear specimens. A general view of the assembly is illustrated in Figure 1. The grain direction was parallel to the longest dimension of the block. Special attention was given for choosing the adhesive spreading tool, shim placement and gluing rate.

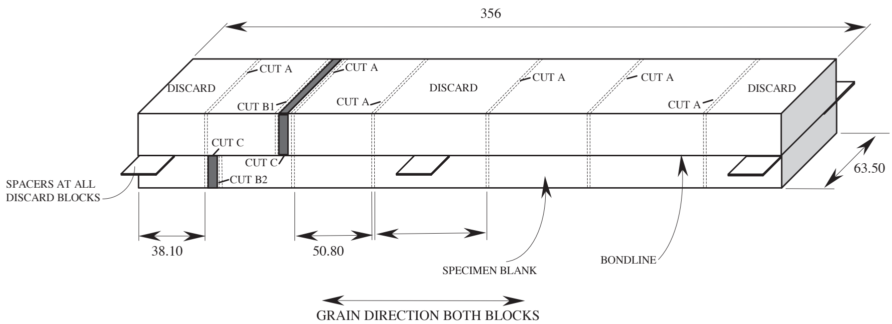

Fig. 1: Bonded assembly showing method of cutting four test specimen blanks

To control the glue lines to specified thickness between blocks, spacer strips made of steel shims in various multiples were used, the exception was the glue line thickness group of 0.18 mm that represents a normal (control) glue line thickness. The shim dimensions were 13 by 89 mm. They were placed crosswise at the ends and center of the lower test joint block. Shim placement is shown in Figure 1. To avoid air entrapment in the glue line, the adhesive was not spread closer than 13 mm to any spacer that could affect the glue line thickness. Precautions were taken to control glue line thickness to specified thicknesses between blocks. Also, the factors such as thickness variation in adherents, uniformity of external pressure, preparation of gluing surfaces, assembly times and pot life of the adhesive were checked in advance to prevent any gap filling error.

After gluing, the assemblies were placed on the Baldwin Emery universal testing machine for 24 hours to provide the uniform required pressure of 0.7 MPa over the entire bond area.

The test specimens were cut in accordance to ASTM D3931. Bonded assembly showing method of cutting four test specimen blanks is illustrated in Figure 1. Special care was taken that the loading surfaces are smooth, parallel to each other, and perpendicular to the edges and the glue line.

After cutting, glue line thickness was measured for each block shear specimen. Form and dimension of test specimen is illustrated in Figure 2. The glue line test area was 50.80 by 38.10 mm. Glue line thicknesses were measured using image analysis technique using a stereo microscope (Nikon SMZ800) and a reflected light (MR2, fiber optic light) and by operating the computer program of MetaMorph (Universal Imaging Corporation 2000). Values were recorded to the nearest 0.0254 mm level. Six measurements were made (three from each side) and averaged for each specimen. The thickness tolerance accepted for each group was $\pm$0.08 mm except for the first group which was the normal glue line thickness.

They were conditioned in relative humidity of 50$\pm$5 % and 23$\pm$2 °C until they reached the equilibrium moisture content of 9.5% before testing. The specimens were tested for shear strength in the dry condition using the Baldwin Emery SR-4 (model FGT) testing machine equipped with a standard shearing tool containing a self aligning seat to ensure uniform lateral distribution of the load. The rate of loading was 5.0 mm/min.

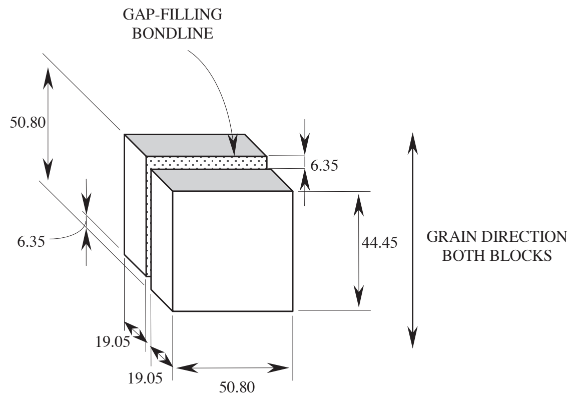

Fig. 2: A general view of the component is illustrated in Figure 2 after gluing

The load measurements were made using a computer-controlled data acquisition system operating the Lab-view Program (National Instruments Corporation 2000). The block shear strength at failure in MPa was calculated. Statistical procedures were performed using the Statistical Analysis System (SAS) program (SAS INSTITUTE 2001).

RESULTS AND DISCUSSION

60 block shear specimens were tested. Their descriptive statistics values are summarized in Table 2 each value represents the average of 12 replications.

The block shear strength all joints decreased with increased glue line thickness. Mean shear strengths for the five glue line thicknesses fell within a wide range, between 4.20 and 6.94 MPa. Specimens made with a glue line 0.18 mm thick showed the highest block shear followed by the glue line 0.25 mm thick specimens. An examination of test results showed that the strength decreased by 10.52 % at a glue line thickness of 0.25 mm and by 39.48 % at a glue line thickness of 0.48 mm compare to control joints. Glue line thicknesses in excess of 0.25 mm resulted in a very sharp decrease of strength up to 0.48 mm (Table 2). The glue line thickness of 0.48 mm had a drastic effect on the strength. Figure 3 shows average block shear values for the five different glue line thicknesses.

Visual examination of glue lines revealed that the adhesive form a continuous film. The failure was found either in wood, in the glue film or at wood-glue-wood interface. Different glue line thicknesses caused only a small difference among values of average wood failures that ranged between 90-100%.

The analysis of variance (ANOVA) was used to determine the effect of glue line thickness on the shear strength. The results indicated that the glue line thickness effect was significant at 0.05 level of probability (Table 3). This suggests that the difference in average strength values was observed as the glue line thickness changed.

Tab. 2: Descriptive Statistics Values of Specimens

GLT (mm)	N	Mean (MPa)	Reduction (%)	Min. (MPa)	Max. (MPa)	SD	COV (%)
0.18	12	6.94	-	5.50	8.86	1.17	16.83
0.25	12	6.21	10.52	3.63	7.57	1.01	16.31
0.33	12	4.65	33.00	4.00	5.64	0.47	10.05
0.40	12	4.37	37.03	3.52	5.47	0.63	14.40
0.48	12	4.20	39.48	2.84	5.30	0.76	18.01

GLT: Glue line thickness, N: Sample size, Min.: Minimum, Max.: Maximum, SD: Standard deviation and CV: Coefficient of variation

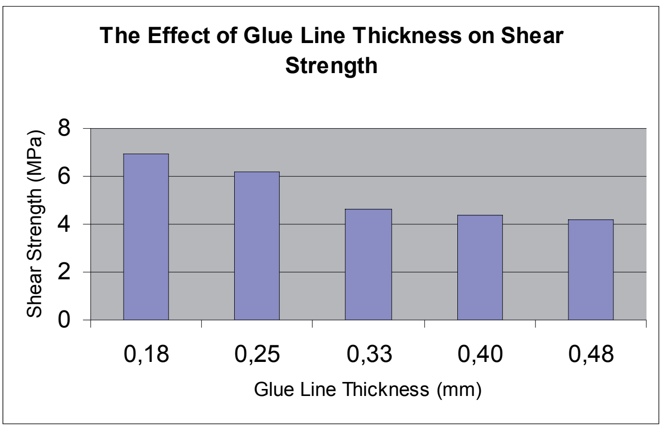

Fig. 3: The effect of glue line thickness on shear strength

Comparisons of mean block shear strengths as they were affected by the glue line thickness were made by the Bonferroni (Dunn) t-test (Table 4). When the differences exceeded α=0.05 level of probability, the differences between means were considered significant. There were no significant differences between mean shear strengths in glue line thickness of 0.18 mm and 0.25 mm. The results showed that the glue line thicknesses as high as 0.25 mm resulted in little strength reduction. This was not the case between other glue line thicknesses and control joints (0.18 mm). This indicates that the adhesive can be safely used up to 0.25 mm glue line thickness under dry conditions. On the other hand, the glue line thickness of 0.33 mm, 0.40 mm and 0.48 mm had similar effects on strength reduction. The strength decreased approximately 33-39 % at a glue line thickness of 0.33 to 0.48 mm.

Tab. 3: ANOVA Table for Shear Strength Values

Source	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
Model	4	72.20	18.05	25.25	<0.0001
Error	55	39.32	0.71		
Corrected Total	59	111.52			
	R-square	64%	Root MSE	0.85	
	COV	16.04	Mean	5.27	

Pr>F: Probability > F value

Tab. 4: Mean shear value of the different glue line thicknesses

Glue Line Thickness (mm)	Shear[a] (MPa)
0.18	6.94 a
0.25	6.21 a
0.33	4.65 b
0.40	4.37 b
0.48	4.20 b

[a] Means with same letters are not statistically different.

CONCLUSIONS

Sixty block shear specimens were tested in shear to determine the suitability of the GPRF adhesive when thick glue lines are present. The block shear strength of glued specimens glued with the GPRF adhesive was affected by the glue line thickness. The block shear strength decreased with increased glue line thickness due to the differences in glue line thickness. The critical glue line thickness would appear to be 0.25 mm where strength decreased by 10.52 %. Within, a glue line thickness range of 0.18 to 0.25 mm, strength decrease was not significant. The adhesive could be used to bond wood to wood into a structurally sound and efficient product up to 0.25 mm glue line thickness. The bond quality may be adversely affected at a glue line thickness in excess of 0.25 mm. The results are not applicable to thick glue lines resulting from improperly formulated mixture, excessive assembly times or adhesive's end use is expired. The experimental result related to the adhesive is a positive step for the production of wood-to-wood joints for building components. The method appears to be positive step for panel-based building components, i.e., stressed skin and sandwich panels especially when the gaps exist. To expand the use of GPRF adhesive, more research, promotion and marketing forecasts are necessary.

REFERENCES

1. Davis, G., 1997: The performance of adhesive system for structural timbers. International Journal of Adhesion and Adhesives 17(13): 247-255
2. Elbez, G., 1989: Expanding resorcinol cold sets fir gap-filling adhesives for wood. In: Wood adhesives (ed. A. Pizzi A). Pp 389-408, Marcel Dekker Inc. New York
3. Marra, A. A., 1992: Technology of wood bonding, principles in practice. Van Nostrand Reinhold. New York, 454 pp.
4. National Instruments Corporation: The lab-view computer program. Downingtown
5. SAS Institute, 2001: SAS/Sat Release 8.2. Cary
6. Vick, C. B., 1973: Gap-filling phenol-resorcinolic adhesives for construction. Forest Products Journal 23(11): 33-41
7. Universal Imaging Corporation 2000: The MetaMorph Imaging System 2000. Downingtown
8. ASTM D-907 (1994): Standard terminology of adhesives, ASTM D-907. American Society for Testing Materials (ASTM). Philadelphia
9. ASTM D-3931 (1993): Standard test method for determining strength of gap-filling adhesive bonds in shear by compression loading, ASTM D-3931. American Society for Testing Materials (ASTM). Philadelphia

Ramazan Kurt, PhD.
KSU Faculty of Forestry
Department of Forest Industry Engineering
46100-Kahramanmaraş
Turkey
Tel: +90 344 2237666 (Ext:361)
Fax: +90 344 2217244
E-mail: ramazankurt@yahoo.com