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SHORT NOTES

BENDING STRENGTH OF STRESSED SKIN COMPONENTS WITH SCREWS AND ADHESIVE

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ABSTRACT

In this study, the effect of adhesive on the flexural properties of stressed skin components (SSCs) with a gap-filling phenol resorcinol adhesive (GPRF) was investigated. For this purpose, SSCs that were manufactured using different fastening methods (press-gluing, screw-gluing, screw-only and no-connection) from Douglas fir plywood skin and spruce-pine-fir lumber stringer were tested at two-point loading in bending. The experimental results showed that the introduction of the adhesive makes stressed skin panels much stronger than conventional screwed-only components. The study determined that the modulus of rupture and slope of load-deflection curve were increased with addition of the adhesive. The results showed that the required strength could be achieved using press-gluing as well as screw-gluing fastening methods. Also, the methods may be used for the sound and economical interior and exterior applications i.e. panel based building components manufacturing.

KEY WORDS: stressed skin components, gap-filling adhesive, press-gluing, screw-gluing, screwing-only, screw

INTRODUCTION

The glue line thicknesses stressed skin panel (SSP) can be defined as a panel consists of a plywood sheet or several sheets attached to a stringer (web) or stringers either by glue (usually in combination with fasteners) or mechanical means. Its technology was developed by the Forest Products Laboratory in the early 1930's (Heyer and Blomquist 1964). SSP are now produced in many areas, including North America, Europe (especially Scandinavia) and the Far East and becoming more popular. It has proved its usefulness and efficiency in commercial, residential, agricultural, and recreational construction. It is often used as a building component for roof, floor, ceilings, and walls. They can be fabricated in different shapes and sizes to suit architectural and structural aims. This is especially important for the prefabricated house industry.

In wooden prefabricated construction and wood frame construction, plywood is generally applied to floor, wall and roof. Jointing of plywood to the wood stringers like floor joists, studs and rafters results in the composition of the stressed skin panel and consequently contributes to the increase of strength and flexural rigidity of floor, wall and roof (Ando and Sugiyama 1980).

Recent developments of adhesives, wood-based composites, engineered products, insulation materials, and treatment process raised the acceptance and use of SSPs. It has high strength, good nail/screw bearing capabilities, large panel size, lightweight, and dimensional stability. Since the skin-stringer joint must transfer stresses between the skin and stringer, the performance of the SSP is greatly dependent on individual component characteristics and the completeness of the joint. The development of this industry is strongly related to adhesives and external pressure methods (Kurt 2002).

Maximum utilization of materials in structural components can be realized by rational design of composites wherein materials or portions of the cross sections of composites are held together rigidly (Kuenzi and Wilkinson 1971). For that reason, the selection of most suitable adhesive is very important. Structural adhesives can be used to bond two or more components together in a way that they transfer load between the components. The purpose of the adhesive is to increase the stiffness and strength of the structural system (floor, shear wall, or diaphragm) by composite action (Filiatrault and Foschi 1991). Usually, the choice of the type, quality, and quantity of adhesives depend on the end use, exposure and manufacturing conditions, present technology, equipment, dimensions, treatment and design requirements of SSPs.

The use of wood and wood based materials in many structural and other applications often involves the use mechanical fasteners such as nails, screws, bolts, lag screws and connectors (ASTM D-1761, 1994). They are the most common external pressure methods among others. They can be used in conjunction with an adhesive to bring surfaces into as close contact as possible, produce a thin glue line, squeeze out glue, and increase penetration to undamaged portion of the adherent, transfer glue to the opposite unspread surface of a component as well as to position (Marian 1967) the components of SSPs.

SSPs that are manufactured using methods that involve adhesive addition can be a feasible option to advance their use. It is expected that information needed for the improvement of SSPs' structural applications may be provided from such an investigation. Stressed skin components (SSCs) were used instead of full size panels due to their size.

This paper presents the results from an experimental evaluation of a structural wood adhesive, as an effective bonding provider between skin and stringer of SSCs subjected to bending tests. The primary objective of this research was to gain a more complete understanding of how the addition of adhesive affects the flexural properties of SSCs.

MATERIALS AND METHODS

The skins were made of Douglas fir plywood (4-ply veneer, A to C sheathing grade, with exterior glue). The dimensions of each skin were 1.19x39.37x111.76 cm. The stringers were made of spruce-pine-fir (SPF) lumber, already kiln dried, number 1 or better grade. The dimensions of each stringer were 7.62x3.81x111.76 cm.

The skins and stringers were conditioned in an environmentally controlled room in relative humidity of 50±5 % and temperature of 23±2 °C until they reached the equilibrium moisture content of 11%.

A commercial gap-filling phenol resorcinol formaldehyde (GPRF) adhesive that cures at

Tab. 3: Descriptive statistical values of slope of load-deflection curve (N.mm)

FM	N	Mean	Minimum	Maximum	SD	CV (%)
Press-glued	10	1777.82	1526.63	2151.10	164.60	9.26
Screw-glued	10	1931.23	1725.37	2630.78	265.68	13.76
Screw-only	10	1010.42	906.38	1065.29	50.08	4.96
No-connection	10	1001.09	902.18	1080.25	60.28	6.02

FM: Fastening method, N: Sample size, SD: Standard deviation and CV: Coefficient of variation.

All of the components failed near the mid-span. The strength of four different fastening methods varied considerably. Adding adhesive significantly increased both MOR and slope of the components. The strength of PG and SG components was almost equal. The PG/SG to SO/NC mean MOR ratio was 1.76 and mean slope ratio was 1.84 for the components used in this study. The fastening method of PG/SG yield considerably higher strength values than SO/NC methods. These methods would be more suitable for structural applications where higher levels of prolonged stress are present. There was no relationship between the MOR and slope of components with (PG and SG components) and without (SO and NC components) adhesive.

Screws were found suitable to bring plywood skin and lumber stringer into close contact and component form and to force out excess adhesive and also provide necessary initial glue line pressure during the curing period of SG components. The number and spacing of screws were shown to provide the required pressure for the curing. They did not cause any of the SG and SO components failures. Fig. 2 and 3 illustrates a summary of the test results.

Statistical procedures were performed using the Statistical Analysis System (SAS Institute 2001) program. The analysis of variance (ANOVA) was used for statistical analyses to determine the effect adhesive on MOR and slope (Tab. 4 and 5). The resulting F value was compared to the tabular F value at the 95% probability level. The results showed mean MOR and slope values were changed with different fastening methods. There was a significant difference between MOR and slope values due to adhesive addition at 0.05 level of probability among the components. This suggests that the difference in average MOR and slope values were observed when the adhesive was used.

Tab. 4: ANOVA table for MOR (MPa) values

Source	**Degree of Freedom**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr>F**
Model	3	198136387.30	66045462.40	72.06	<.0001
Error	36	32993691.70	916491.40		
Corrected Total	39	231130079.00			
	R-square	0.86	Root MSE	957.34	
	CV	11.97	Mean	7998.04	

Pr>F: Probability > F value and CV: Coefficient of variation, and Root MSE: Root mean square error

Tab. 5: ANOVA table for slope (N.mm) values

Source	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
Model	3	7322274.28	2440758.09	94.04	<.0001
Error	36	934389.83	25955.27		
Corrected Total	39	8256664.10			
	R-square	0.89	Root MSE	161.11	
	CV	11.27	Mean	1430.14	

Pr>F: Probability > F value and CV: Coefficient of variation, and Root MSE: Root mean square error

Tab. 6: Mean MOR value of the different glue line thicknesses

Fastening Method	MOR (MPa)	
Press-glued	10212.69	A
Screw-glued	10189.53	A
Screw-only	6241.72	B
No-connection	5348.20	B

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

Tab. 7: Mean slope value of the different glue line thicknesses

Fastening Method	Slope (N.mm)	
Press-glued	1777.82	A
Screw-glued	1931.23	A
Screw-only	1010.42	B
No-connection	1001.09	B

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

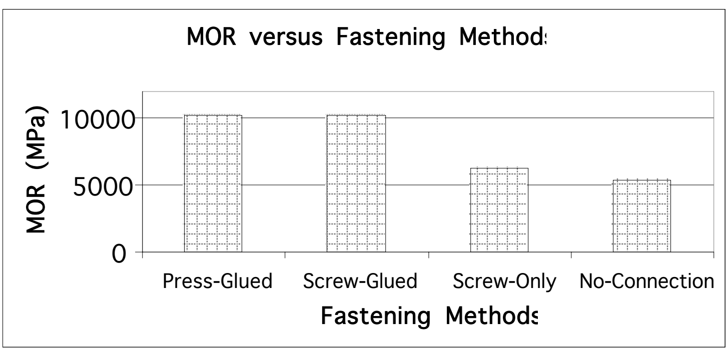

Fig. 3: MOR of different fastening methods.

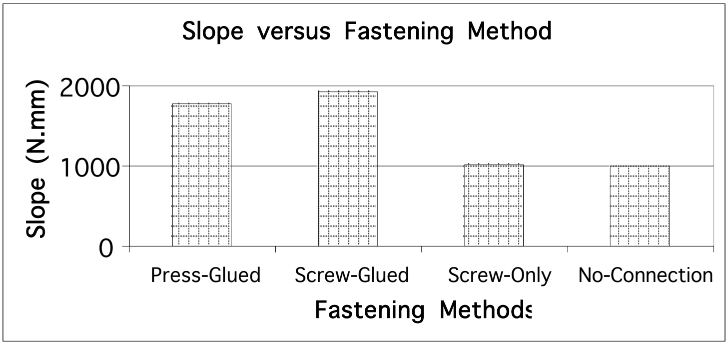

Fig. 4: Slope of different fastening methods.

Comparisons of mean MOR and slope values as they were affected by the adhesive addition were made by the Bonferroni (Dunn) t-test (Tab. 6 and 7). When the differences exceeded $\alpha=0.05$ level of probability, the differences between means were considered significant. There were no significant differences between mean MOR and slope of PG/SG components. The SG fastening method showed satisfactory performance and can be used instead of PG method where necessary due to size, manufacturing and construction conditions. Also SO/NC components were similar in strengths but both were significantly lower in strength than PG/SG components.

CONCLUSIONS

The study determined the importance of adhesive addition as a means of providing bonding for SSPs. The results showed that bending strength was affected by addition of the adhesive. It is clear that the adhesive greatly enhances the strength of components. All components bonded with the adhesive had higher strength. The average MOR and slope of PG/SG components are 76.04 and 84.39 percent higher than corresponding MOR and slope values of SO/NC components. Fastening only by the SG method is not recommended. SG fastening proved to be as an alternative adequate method fastening method to the PG method for the fabrication of SSCs. The experimental findings may be useful to bring this method of construction one step closer to structurally sound and cost efficient type of commercial production.

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