Majalah Ilmiah Mektek

A STUDY ON PATTERN DAMAGE OF FINGER JOINTS IN BAMBOO LAMINATED BEAMS

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Abstract

The aim of this study was to know the pattern damage of finger joints in bamboo laminated beams. The dimension of laminated beams were manufactured in 1200 mm length, 140 mm deep and 50 mm wide, which consisted of horizontally laminate of 5 mm in thickness. The finger joint consisted of two variations that were horizontal and vertical directions. One variation of other beam was manufactured in the form of clear straight beams as comparator parameters. The bending shear test was conducted with a three-point static bending.

The result of research indicated that the joint areas, which the parameter of glue spread have to influence on the strength. Consequently, degradation of strength occurs on all of adhesive jointed beam can reach 48%, while the optimum strength of jointed beams can reach 82% of clear straight beams. This research identify that the pattern damage of laminated beams tends on a mixed mode failure between tension and compression. The strength of vertically finger joint more effective than horizontally finger joint.

Keyword*: seismic, Preserved Amplitude*

1. Introduction

The bamboo usage has been widely seen in so many construction forms. As a construction material, they has been found in the tropical and sub tropical regions. The natural dimension, stem form limit, and many traditional joint types affected to their structural efficiency.

As with any other glued-wood product, the objective when finger jointing is to adhere the two pieces of wood together to render the joint strong enough under ultimate load so that failure occurs in the wood rather than in the adhesive (Sellers et al, 1988). Finger joints have been proven suitable for use in connections for wood trusses (Hoyle et. al., 1973), corner and multiple member furniture joints (Richards, 1962), laminated beams (Wibbens, 1989), truck decking, as well as a variety of other structural and non-structural applications. Proof loading of end-jointed material has been implemented in many instances to eliminate substandard joints (Forest Products Laboratory, 1999). One aspect that is critical to the performance of finger joints in service is the overall geometry of the joint.

This study makes available important information about the use of bamboo as a wood suitable for finger jointing and shows how it compares with two important directions. One of the efforts to support bamboo application as universally construction material, which nowadays developed is lamination technique.

2. Materials and Methods

The bamboo used in this experiment is Wulung bamboo (Gigantochloa Sp.). The bamboo laminate based on the middle layer strip by trimming both side of the inner and outer layers. The glue used was Urea formaldehyde resin. The resin was applied to both side of the bamboo laminate. Resin application was about 60 gram per double glue line.

The glued bamboo laminate was put in between two steel plates with 8 mm in thickness. Five C-clips were used to add pressure to the beam mats. After pressed for 24 hours, the beams were trimmed to the target size of 1200 x 140 x 50 mm.

The finger-joint profile applied in this study had a pitch of 20 mm, a finger length of 50 mm, a fingertip of 2 mm, and the finger slope of 1:6.25. The laminated beams are shown in figure 1.

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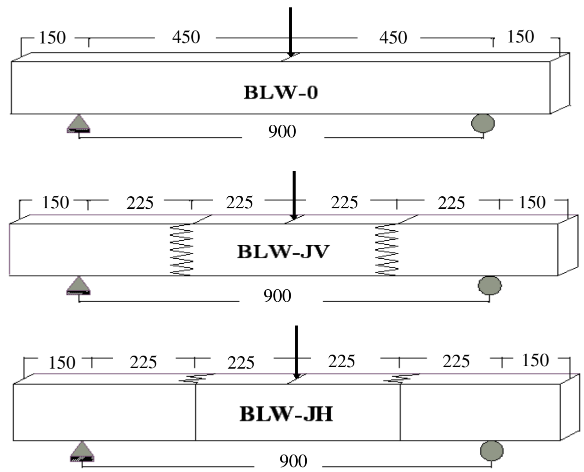

Figure 1. Direction of load in the bending test for finger jointed and laminated beam

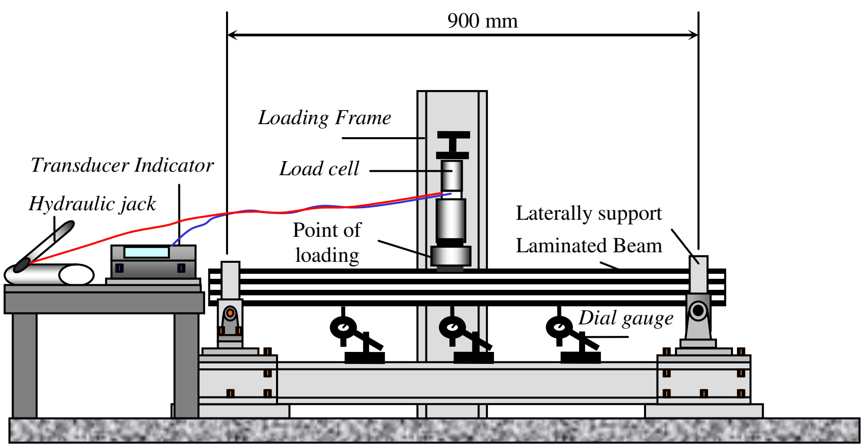

Figure 2. The three-point bending test apparatus

The equipments used in this experiment are circular saw, planner machine, hydraulic pressure, Universal of Testing Machine, hydraulic jack, load cell and load indicator, dial gauge, rigid frame, and clamp set.

The method used here includes the experimental method. Preliminary test based on the standard procedure of ISO-1975. These tests includes the density, moisture content, tensile strength parallel to grain, compression parallel and perpendicular to grain, shear strength, modulus of rupture and modulus of elasticity.

The bending shear test was conducted in a three-point static bending. The bending test in this study defines flexural properties with three-point loading. The bending apparatus used was a 3-point loading setup (two load supports and one loading points) with a half shear span of 450 mm. The supports for the test apparatus were fixed knife-edge reaction with rollers. Response variables measured and calculated for each sample were modulus of rupture (MOR) and modulus of elasticity (MOE). The setting up of the test is shown in figure 2.

3. Result and Discussion

3.1. The Physical and Mechanical Properties of Bamboo

a. Density and Moisture Content

Bamboo is a hygroscopic material. Conseqently the moisture content depends on the surrounding climate and changes accordingly. The density and moisture content of samples are shown in Table 1.

b. The Mechanical Properties of Bamboo

The mechanical properties of Wulung bamboo are presented in Table 2.

3.2. The Strength of Laminated Beams

Degradation of strength was caused by applying finger joint in laminated beams. The strength ratios of laminated beams are given in Tables 3.

Relationship between load and vertical deflection of test results are presented in Figure 3.

3.3 Stiffness Factor of Laminated Beams

In general, stiffness factor value of clear straight beams (no joint) is larger than jointed beams. The stiffness factor of each beam is given in Tables 4.

Table 1. Density and moisture content of samples

Samples	Density (g/cm^3)		Moisture content (%)		
	Range	Mean	Range	Mean	Spesification (LPMB'61)
Bamboo stem	0.50-0.59	0.53	14.67-14.51	14.56	6-16
Laminated beam	0.60-0.62	0.61	12 - 14	13	6-16

Table 2. The mechanical properties of bamboo

Number of specimens	The comp. // to grain	The comp. ⊥ to grain	The tension // to grain	The shear *strength*	*MOR*	*MOE*
	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)	(MPa)
1	40.69	7.11	148.74	5.73	74.34	14987.30
2	37.25	7.58	124.06	6.77	77.99	13765.78
3	38.94	6.80	153.85	5.39	72.32	13813.87
Mean	38.96	7.16	142.22	5.96	74.88	14188.98

Table 3. The strength ratio of laminated beams

Samples	Ultimate Load "P_u"		P_u/ (b.d)	
	kN	kN/m^2	mean	Ratio
BLW-01	32.96	4709	4516	1
BLW-02	29.43	4528		
BLW-03	28.45	4310		
BLW-JV1	24.58	3512	3723	0.82
BLW-JV2	28.74	4106		
BLW-JV3	24.86	3551		
BLW-JH1	12.75	1889	2336	0.52
BLW-JH2	21.97	3139		
BLW-JH3	13.66	1979		

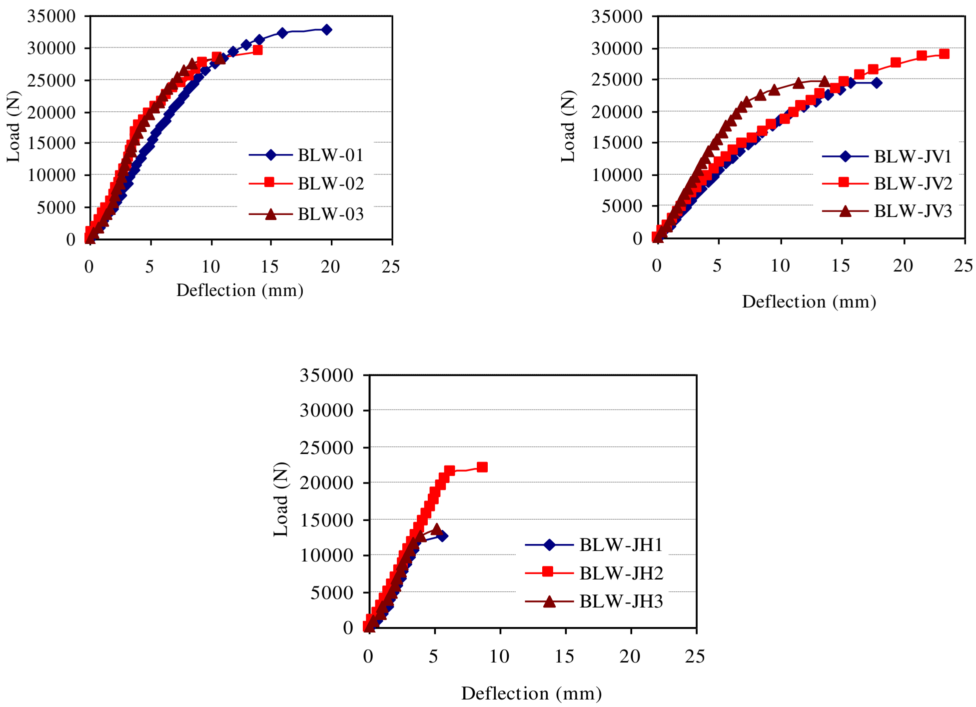

Figure 3. The load versus vertical deflection in mid-span curve

Table 4. The stiffness factor of each laminated beam

Samples	$(EI)_{max}$		Ratio
	KN.m^2	mean	
BLW-01	262.92		1.00
BLW-02	372.47	251.71	
BLW-03	119.72		
BLW-JV1	125.08		0.48
BLW-JV2	163.13	120.10	
BLW-JV3	72.09		
BLW-JH1	319.26		0.65
BLW-JH2	110.58	163.52	
BLW-JH3	60.73		

Table 5. Result of varians analisys with ANOVA for the stiffness factor

	Sum of Squares	df	Mean Square	F*	Sig.
Between Groups	26980.736	2	13490.368	1.095^{NS}	0.393
Within Groups	73934.718	6	12322.453		
Total	100915.454	8			

Note: Note: * 0.05 Level of significance, NS shows No significant effect or interaction

The analysis of variance (ANOVA) for the stiffness factor showed no significant in one-way interaction as seen in Table 5.

3.4. Modulus of Rupture (MOR) and Modulus of Elasticity (MOE)

The bending contribution determined by MOR and MOE. The result of MOR and MOE are given in Tables 6. The maximum MOR obtained by BLW-0, while percentage of MOR degradation in BLW-JV and BLW-JH are 21.10% and 49.80% to BLW-0.

The analysis of variance (ANOVA) for MOR (Tables 7) showed significant in one-way interaction. This indicated that difference of load direction given influence in bending strength. Inelastic behavior of materials was caused to different in both actual bending stress and calculated bending stress for MOR formula.

As for MOR, the analysis of variance (ANOVA) for MOE also showed significant effect as seen in Tables 8.

3.5. The Pattern Damage of Laminated Beams

a. BLW-0

The pattern damage of clear straight beams (no joint) is shear failure between laminate and glue-line. In this case, it is started with a horizontally crack (initial crack) in laminates, then it happened crack in loading point. Finally, the laminated beam was damage to the support area, which shear stress is critical. Visually, the pattern damage of beams is given in Figure 4.

Table 6. MOR dan MOE of laminated beams

Samples	MOR		MOE	
	(MPa)	Mean	(MPa)	Mean
BLW-01	45.41		3856	5882
BLW-02	47.02	45.50	7128	
BLW-03	44.08		6663	
BLW-JV1	33.87		2777	3339
BLW-JV2	39.60	35.90	2972	
BLW-JV3	34.24		4268	
BLW-JH1	18.89		4542	4758
BLW-JH2	30.27	22.84	4739	
BLW-JH3	19.36		4993	

Table 7. Result of variance analisys with ANOVA for the MOR

	Sum of Squares	df	Mean Square	F*	Sig.
Between Groups	776.437	2	388.219	21.604^{S}	0.002
Within Groups	107.819	6	17.970		
Total	884.256	8			

Note: * 0.05 Level of significance, S shows significant effect or interaction

Table 8. Result of variance analisys with ANOVA for the MOE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9746230.889	2	4873115.444	3.806^{S}	0.086
Within Groups	7682968.667	6	1280494.778		
Total	17429199.556	8			

Note: * 0.05 Level of significance, S shows significant effect or interaction

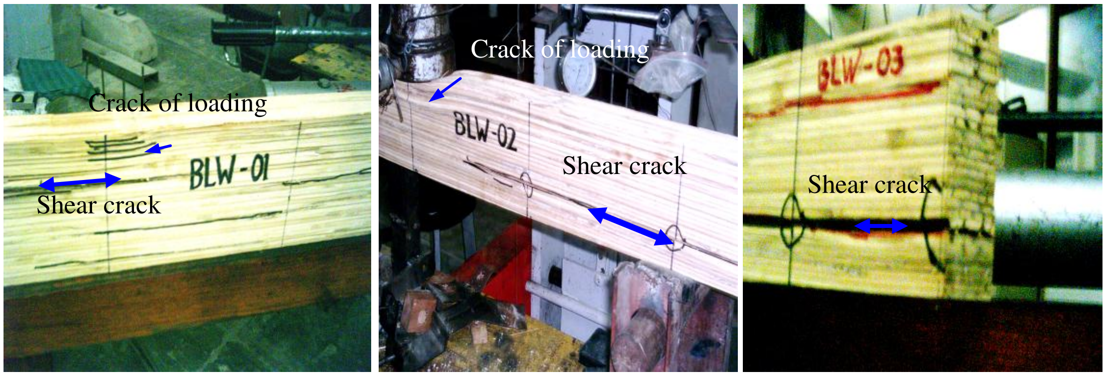

Figure 4. The pattern damage of BLW-0

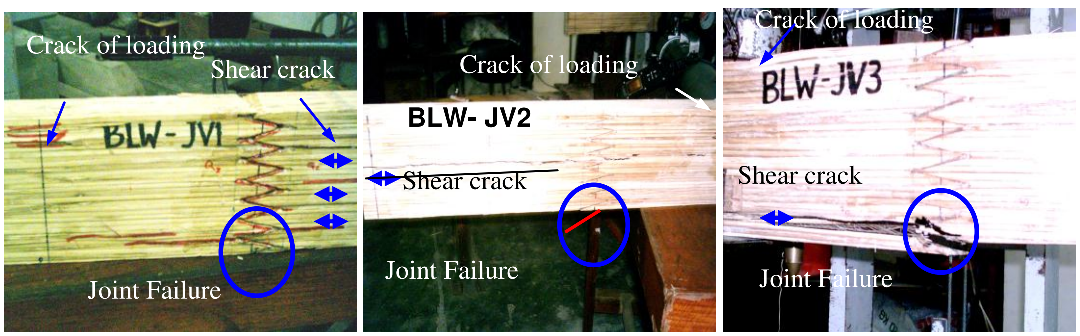

Figure 5. The pattern damage on BLW-JV

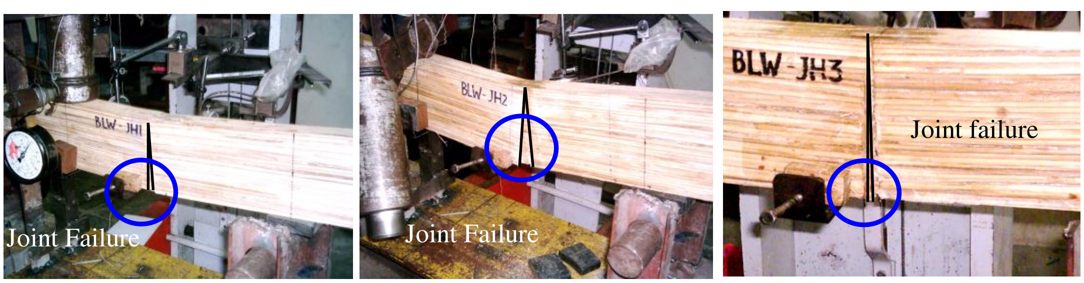

Figure 6. The pattern damage of BLW-JH

b. BLW-JV

The pattern damage of vertically finger-jointed beam is shear failure in laminates before broken at joint. It is started with a horizontally crack in laminate, and then happened crack in loading point. The pattern damage of joint expands to follow line inclination of finger joint. Shear failure was dominated in the mid-span until to the support area. Finally, laminated beam suddenly broken in finger jointing. The pattern damage of laminated beams is presented in Figure 5.

c. BLW-JH

The pattern damage of beam with horizontally finger joint is bending failure at joint. It is started initial crack in horizontal direction. There is no crack in loading-point like other beam. The laminated beams are spontaneously broken at the joint. The pattern damage of laminated beams is seen in Figure 6.

4. Conclusions

Glued laminated bamboo is a highly engineered building material, providing many advantages over bamboo stem or solid timber. Special attention must be given to the strength grading of the laminations, the quality of finger joints, glue line integrity and quality control.

There were three response variables, the stiffness factor, MOR, and MOE measured for each sample in the bending test that was used for statistical analysis. The analysis of variance (ANOVA) for the MOR and MOE showed significant one-way interaction or effect.

5. References

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