JoSSEd
Journal of Science and Science Education
ISSN: 2774-1869 eISSN: 2774-2105

Original Paper

The Effect of Variations of Drilling Bolt Distances on Bending Strength of Composite Wood Beams

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DOI: 10.29303/jossed.v3i1.456

Article Info
Received: July 21, 2020
Revised: March 4, 2022
Accepted: April 23, 2022
Published: April 30, 2022

Abstrak: Wood products that are currently growing rapidly in many places in the world are laminated blocks (glulam). Laminate beam has many advantages in terms of size, strength and artistic. However, this laminated beam has a few drawbacks in terms of providing tools and materials for some areas. The laminated beam itself uses an adhesive material which is relatively expensive and requires a compression tool in its implementation. Therefore, an alternative is given in the form of composite beams. Composite beams that have developed so far use shear connectors in the form of bolts, nails, and pegs as the connecting tool. Meanwhile, shear connectors using drilling bolts have never been done. Therefore, based on this, it is necessary to research composite wood beams with an alternative, namely using drilling bolts as shear connectors in order to obtain the effect of variations in the distance of drilling bolts on the flexural strength of composite beams. The results of the flexural strength test obtained the strength of the composite beam with shear connectors with the largest distance of 3.125, followed by beams with shear connecting distances of 6.25 cm, 12.5 cm and 25 cm. This shows that the closer the shear connecting distance, the greater the strength obtained, with the percentage increase in variation of 31.5%, 38.737% and 46.072%, respectively.

Keywords: Composite wood beams; Flexural strength; Drilling bolts; Shear connectors

Citation: Noviadi, S.C., Sugiartha, I.W., & Fajrin, J. (2022). The Effect of Variations of Drilling Bolt Distances on Bending Strength of Composite Wood Beams . *Journal of Science and Science Education*, *3*(1), 30–35. https://doi.org/10.29303/jossed.v3i1.456

INTRODUCTION

Wood products that are currently growing rapidly in many places in the world are laminated beams (glulam) (Widyawati, 2010; Sulistyawati et al., 2008). Laminate beam has many advantages in terms of size, strength and artistic. However, this laminated beam has a few drawbacks in terms of providing tools and materials for some areas. The laminated beam itself uses an adhesive material which is relatively expensive and requires a compression tool in its implementation. Therefore, an alternative is given in the form of composite beams. Composite beams that have developed so far use shear connectors in the form of bolts, nails, and pegs as the connecting tools. Meanwhile, shear connectors using drilling bolts have never been carried out. Therefore, based on this, a study of composite wood beams using drilling bolts as shear connectors was carried out. So that in the study the theme was raised with the title "The effect of variations in the distance of drilling bolts on the flexural strength of composite wood beams" and is expected to have more efficient results in other composite wood beam products. Handana (2010) in his research for composite beams arranged on coconut wood with bolts as shear connectors with a distance of 500 mm, 250 mm, 125 mm, and 62.5 mm. In his research, the deflection was 4.33 cm (for the distance between the shear connectors 62.5 mm), the deflection was 4.87 cm (for the distance between the shear connectors

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125 mm), the deflection was 5.8 cm (for the distance between the shear connectors 250 mm) and the deflection was 5.85. cm (for the distance between the shear connectors 500 mm).

Panjaitan (2010) in his research on stacked beams with nails as shear connectors with variations in the number of nails, namely 5, 10 and 15 pieces. Based on the test results, it is obtained that the carrying capacity of a single beam is 200 kg, a beam made of plywood with 5 nails is 50 kg, a beam made of plywood with 10 nails is 70 kg, and a beam made of plywood with 15 nails is 90 kg and in percentage form are 25%, 35% and 45%, respectively.

Wirawan (2006) in his research on the bending behavior of structural laminated wooden beams with finger joints in various combinations. Where it is found that based on flexural testing with finger joints, the optimum flexural strength and load is the combination IV. The amount of flexural strength is 269.88 kg/cm2, or with a flexural strength efficiency level of 81.02% compared to combination I (Pure beam).

METHOD

The specimens used in this study were: Steel rivet drilling bolts with a diameter (Ø) 5 mm, forest Merak wood and Bajur wood which were both visually selected. Based on the type of activity, the tools used in the research are grouped into:

1. Preliminary test equipment.

Equipment for observing and measuring the physical properties of wood: Ovens, measuring instruments (digital caliper, Scales for calculating the weight of wood in the process of testing the moisture content of wood.

2. Tools for making test objects.

The tools used for the process of making the test object: Saws, machine planers, tape measure or other length measuring tools, fittings for mounting bolts such as hammers and markers, used to sketch and mark the test object.

3. Mechanical properties test equipment

The tools used for this test are: Tensile strength test equipment, namely the Universal testing Machine (UTM), and the flexural strength test equipment, namely the Universal Flexure and Transverse Testing Machine.

The tests and inspections that will be carried out on these wood specimens refer to the testing method applicable in Indonesia, namely testing based on the Indonesian National Standard (SNI). These tests include: (1) Inspection of water content (SNI 03-6850-2002) and specific gravity (SNI 03-6844-2002); (2) Tensile strength test (SNI 03-3399-1994); (3) Flexural strength testing (SNI 03-3959-1995) Research design and method should be clearly defined.

Table 1 Preliminary test specimen

Test Specimen	Wood Type	Dimension	Quantity
Moisture Content	forest peacock wood	5 cm × 5 cm × 5 cm	3
	Bajur wood	5 cm × 5 cm × 5 cm	3
Tensile Strength	forest peacock wood	46 cm × 0.95 cm × 2.50 cm	3
	Bajur wood	46 cm × 0.95 cm × 2.50 cm	3
Direct shear strength of drilling bolt	forest peacock wood	2,5 cm ×2.50 cm × 10 cm	3
	Bajur wood	2,5 cm ×2.50 cm × 10 cm	3
Flexural strength	forest peacock wood	76 cm× 5 cm × 5 cm	3
	Bajur wood	76 cm× 5 cm × 5 cm	3
Total Preliminary Test			24

Variation Design

In this test, wood specimens measuring 3.5 cm × 5 cm × 110 cm were used. Composite wood beams consist of 2 layers of wood measuring 4 cm × 2.5 cm × 110 cm which are then placed in stacks with forest peacock wood on the top layer and Bajur wood on the bottom layer. The direction of the fiber is parallel to the longitudinal direction of the specimen.

Table 2. Design Variation

Wood Type	Specimen	Size (cm)	Total	Distance Between *drilling* Bolts (mm)	Remark
forest peacock wood and bajur	Specimen 1	3 × 5 × 110	3	250	Handling 1
forest peacock wood and bajur	Specimen 2	3 × 5 × 110	3	125	Handling 2
forest peacock wood and bajur	Specimen 3	3 × 5 × 110	3	62.50	Handling 3
forest peacock wood and bajur	Specimen 4	3 × 5 × 110	3	31.25	Handling 4

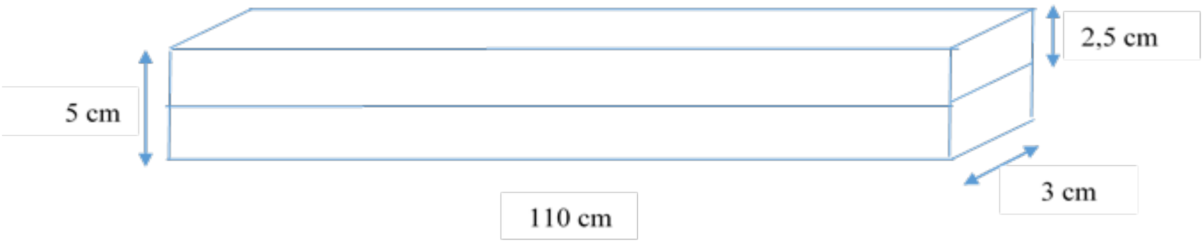

FIgure 1. Composite Beam test specimen

The placement of the bolts with the shear connector as shown above can be seen in the following sketch:

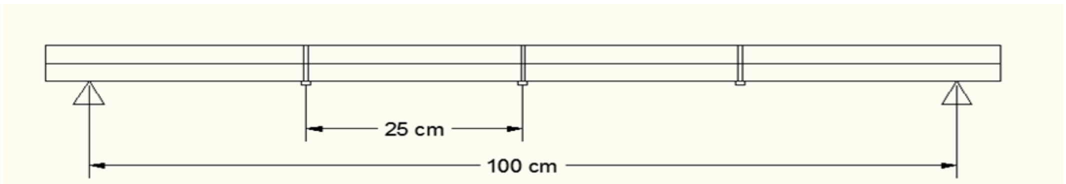

Figure 2. Treatment variation design 1

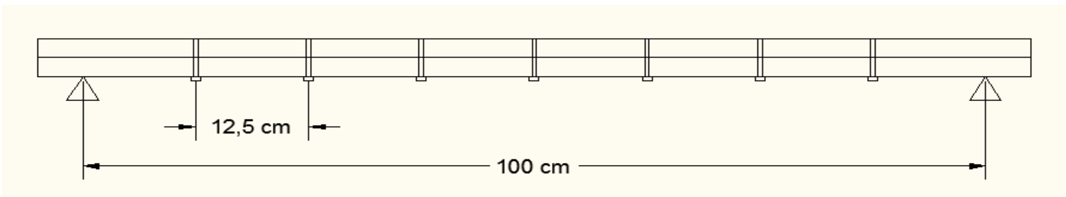

Figure 3. Treatment variation design 2

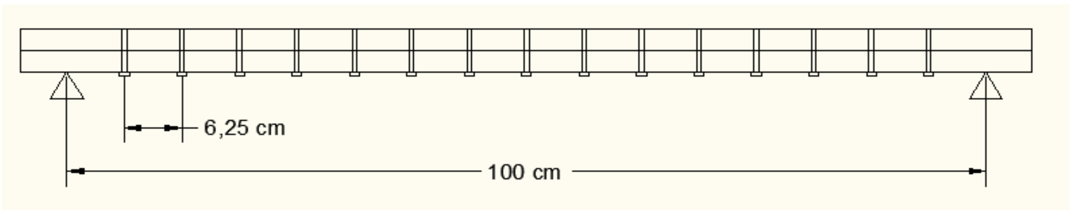

Figure 4. Treatment variation design 3

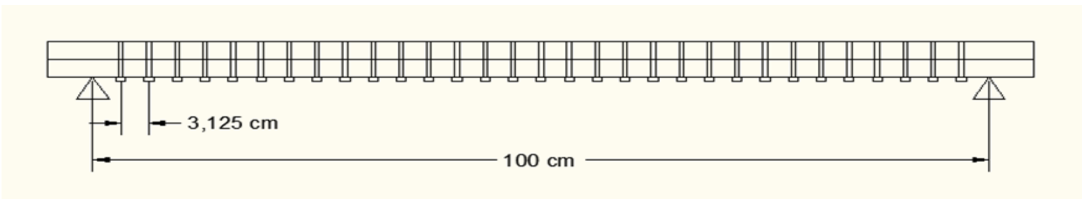

Figure 5. Treatment variation design 4

Composite Beam Test Set Up

This test was carried out based on SNI 03-3972-1995 and used the Cement Flextural Strength Testing Machine. Composite wood beams consist of 2 layers and then placed in stacks. In the middle of the specimen span, a settlement measuring device is installed. This tool is in the form of a dial that is associated with a drop gauge needle that can show the movement that occurs up to an accuracy of 0.001 mm.

Figure 8. Set Up Composite beam testing

RESULT AND DISCUSSION

Physical and Mechanical Properties of Wood

The results of testing physical and mechanical properties can be seen in table 3 below:

Table 3. Results of testing for physical and mechanical properties

No	Testing		Forest Peacok wood	Bajur Wood	Result	
Physical Properties Test						
1	Moisture Content	%	13.680	14.630	< 20%	Suitable for construction
2	Specific Gravity		0.493	0.523	0.3-0.8	
Mechanical Properties Test						
1	Tensile Strength	Mpa	39.082	43.807		
2	Flexural Strength	Mpa	43.433	47.488		
	Wood QUality		E18	E20		

Based on the results of physical properties, it was found that Bajur wood and forest Merak wood had a moisture content of <20% and a specific gravity between 0.3-0.8 so that the wood was suitable as a construction material. Meanwhile, in the mechanical properties test, the wood quality for Bajur wood was E20 and for Merak wood, E18.

Beam variation 1,2 3, and 4

The maximum load, maximum deflection, allowable load and allowable deflection of the four variations can be seen in the following table.

Table 4. Maximum load, maximum deflection, allowable load, and allowable deflection of the four variations

Specimen Code	Maximum Load (kN)	Maximum Deflection (cm)	Permissible Load (kN)	Permissible deflection (cm)
BKK 1	0.922	2.150	0.310	0.333
BKK 2	0.942	2.070	0.310	0.333
BKK 3	0.911	2.080	0.210	0.333
Average	0.925	2.100	0.277	0.333
BKK 4	1.200	2.750	0.330	0.333
BKK 5	1.240	2.850	0.350	0.333
BKK 6	1.210	2.820	0.310	0.333
Average	1.217	2.810	0.330	0.333
BKK 7	1.310	3.360	0.370	0.333
BKK 8	1.303	3.380	0.380	0.333
BKK 9	1.300	3.430	0.360	0.333
Average	1.304	3.390	0.370	0.333
BKK 10	1.380	3.500	0.380	0.333
BKK 11	1.400	3.565	0.370	0.333
BKK 12	1.420	3.540	0.370	0.333
Average	1.400	3.540	0.373	0.333

Based on Table 4, it is found that in variation 4 (BKK 10, BKK 11, and BKK 12) the largest deflection value with the maximum load and the largest allowable load is obtained, this is because the shear connector which functions as a union between the upper beam and the lower beam on the variation 4 is denser than the others. So it can be concluded that the tighter the shear connector, the higher the solid properties of a composite beam, where the shear connector makes the two beams combined into a composite beam have properties that work together in accepting the load. The bending that occurs in the two beams is more solid when the shear connector is getting tighter.

The deflection of the beam is strongly influenced by the shear strength of the shear connector, the closer it is, the greater the stress. Deflection is directly proportional to the load received by the beam in the condition of a beam of the same length, modulus of elasticity and cross section.

The permit load obtained is the load that can be received by the composite wood beam structure in an elastic condition. The allowable load is a safe load that can be accepted by the composite beam. While the maximum load is the ability of the composite wood beam to collapse or this area is called the plastic area.

Comparison of Bending Strength of Variation Beams

From the research that has been done, it can be seen the comparison of the flexural strength values that occur in the variation beam. The comparison value can be seen in Table 5.

Table 5 Comparison of flexural strength in beam variations

Variation	Flexural Strength Variation (kN/m^2)	Percentage Increase (%)
I	18014.315	-
II	23694.505	31.532
III	25401.807	38.737
IV	27264.909	46.072

Based on Table 5, it can be seen that the load that can be carried in variation IV is higher than the others so that the flexural strength of variation IV is the one with the highest flexural strength, which is 27264.909 kN/m2. This is because the beam variation IV has a tight shear connecting distance (3.25 cm) when compared to others so that the bond between the layers that unites the two beams is getting stronger. On the other hand, variation I has the lowest flexural strength, which is 27264,909 kN/m2. This is due to the shear link distance which is more tenuous when compared to the others. The distance between the shear connectors affects the strength of the composite wood beam, so the tighter the shear connector, the more a wooden beam will have a high flexural strength.

The stress on the composite beam is strongly influenced by the solid level in the two beams that are put together the more solid or the connection is tighter, the higher the stress of the beam, this is because the beam that has a denser shear connector will work together in carrying the load. Based on the shear flow formula where the maximum clearance distance (s) is influenced by the magnitude of the shear force (V) that occurs in the composite wood beam. Where the relationship between the maximum clearance distance (s) and the shear force (V) is inversely proportional. The closer the distance between the shear connectors, the greater the shear force that can be carried.

CONCLUSION

Based on the results of the variations made, the following conclusions can be drawn: (1) The results of the flexural strength testing of composite wood beams for Variation 1, Variation 2, Variation 3, and variation 4 were able to withstand the average maximum load, respectively, which were 0.925, 1.217, 1.304 and 1.4 (in kN). And the permit load is 0.277, 0.33, 0.37 and 0.373 (in kN); (2) Based on the pattern of failure that occurs, the first crack occurs in the flexural zone. This is indicated by the failure in the flexural area, namely in the lower beam (Bajur wood) and is located in the middle of the span where the cracks occur because in this area the largest tensile force is experienced; (3) The results of the flexural strength test showed that the flexural strength for variation 1, variation 2, variation 3, and variation 4 were 18014,315, 23694,505, 25401,807 and 27264,909 (in kN/m2). So that the percentage increase to the addition of the shear connector is 31.5%, 38.737%, and 46.072%.

ACKNOWLEDGMENTS

The Author would like to appreciate the Civil Engineering Program, University of Mataram.

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