The flexural strength of retrofitting tectona grandis wood's beam structures

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Abstract. Indonesia has thousands of ethnic groups with a variety of traditional buildings. Traditional buildings made of wood almost all experienced problems of material damage due to insect attacks and weathering due to weather influences.The community tends to dismantle building elements that have been damaged by hoisting insects. This happens because of the lack of knowledge about techniques in repairing or retrofitting wood structures. Wood material is susceptible to problems with elemental damage due to weathering and insect attacks. Damage to the structural elements of the wooden beam does not occur as a whole but only in certain areas. To maintain the strength of the wood in order to carry the burden, it is necessary to strengthen only the damaged area. So the structural elements of the wooden block do not need to be replaced in total but only on the damaged part. Testing the tensile strength of the flexural strength of the whole *Tectona grandis* wood block as many as 6 pieces, 6 pieces of Teak wood without adhesive, Tectona grandis using 6 pieces of adhesive with a size of 120 x 8 x 6 cm, and Tectona grandis wood as 6 pieces of adhesive with the size 10 x 4 x 6 cm, and the adhesive used is epoxy glue. The results of the study stated that the maximum flexural strength is occurring in Teak wood beams with adhesive (D-1, D-2, D-3) able to have stronger flexural strength of 59.8455 N/mm², 52.22533594 N/mm², 54.54848438 N/mm² , compared to solid beams (F-1, F-2, F-3) of 39.72684375 N/m², 53.01527344 N/mm², 60.58877344 N/mm². This research also shows that the connection of Teak wood blocks with adhesives has better flexural strength.

1. Introduction

As one type of construction material, wood has the advantage of being earthquake resistant, lightweight and easy to carry out its construction. Wood material has a weakness that is susceptible to weathering and is not resistant to insect or termite attack. Termite attack causes damage to the structure of wood construction. Support force by wood fibers ie stronger tensile strength // (parallel) fibers than direction $\perp$ (perpendicular) fibers (σtr //>σtr$\perp$), stronger compressive forces // (parallel) fibers than directional $\perp$ (perpendicular) fibers (σds //>σds$\perp$), stronger tensile strength // (parallel) fibers than compressive forces in directional direction of fibers (σtr //>σds //) with a ratio of σtr // / σ ds // = 2 - 2½ and stronger shear force $\perp$ (perpendicular) to the direction of the fiber, than shear direction // (parallel) to the fiber ($\tau$$\perp$>$\tau$ //).

Indonesia has thousands of ethnic groups with a variety of traditional buildings. Traditional buildings made of wood almost all experienced problems of material damage due to insect attacks and

weathering due to weather influences. So for traditional buildings to survive, special treatment must be given in the form of reinforcement or repairs. In Figure 1 various examples of traditional wooden buildings.

Figure 1. Wood's Construction of Tradionally Buildings.

The community tends to dismantle building elements that have been damaged by hoisting insects. This happens because of the lack of knowledge about techniques in repairing or strengthening wood structures. Total dismantling or replacement of the rods of wood structure elements is carried out even though the entire element is not severely damaged. To maintain the structure's reinforcement from wood construction, evaluation of wood structural improvement and reinforcement is needed. There are various methods of reinforcing wood structures commonly used, among others, replacement of damaged components, reinforcement with Fiber Reinforced Polymer (FRP), and reinforcement with steel plates. So research on the strength of retrofit wood structures is needed.

2. Literature review

The need for wood materials for interior and exterior construction is increasing from time to time. Natural treatment of structural and non-structural wood surfaces is more often done by the community [1]. [2] and [3] state that to reduce the effects of weathering on the use of wood externally it is recommended to use wood materials which naturally have high durability, the correct use of wood structure elements and proper care of wood surfaces. Sunlight and water have a significant effect on wood quality degradation [4[; [5]; [6]. Degradation of wood surface quality is also caused by the influence of temperature, dust grains, acid rain and free air [7]; [8]; [9]; [10]. The photochemical reaction of ultra violet light causes the decomposition of lignin and hemi cellulose in wood [11]; [12]. Fungal growth on wood surfaces causes discoloration of wood to turn yellow or brown then turn gray. Dust particles in the air penetrate the wood pore structure [13] Changes in temperature and humidity cause cracks so that the surface of the wood becomes rough [14].

The use of wood wood materials for construction of traditional and contemporary architectural buildings has increased over the past few decades. Insects and termites make damage to the structure of wood can cause health problems for humans, namely causing fine dust [15]. Bostrichidae family insects attack hardwood which is rich in starch. These insects, both those that are still in the form of larvae and adults, can make wood rot and eat the starch contained in parenchyma cells. This type of insect attacks especially on newly cut stems with high water content. Insects Lyctidae family attacks

large porous hardwoods as a place to lay eggs. The life cycle of these insects is shorter than other types of wood insects. The Lyctidae family insects very aggressively attack wood into flour powder [16]. In Fig. 2 and Fig. 3 shows species of insects that attack wood elements.

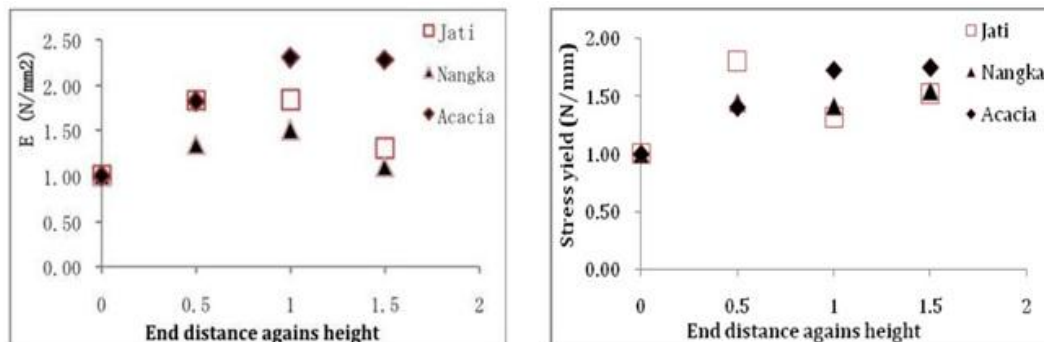**Figure 2.** Surface holes due to *Lyctus* spp. attack and *B. capucinus* attack [15].

Figure 3. *Bostrichus capucinus* recently swarmed adults [15].

[17] has examined retrofitting materials for traditional Javanese wooden houses. The study aims to determine the optimization of the repair of reinforced wood beams that have been damaged. The wood used in the research was Tectona grandis, Artocarpus heterophyllus, Dalbergia latifolia, Terminalia catappa, Acacia manginum and Paraserianthes falcataria. Table 1 shows the mechanical properties of the specimens while Figure 4 shows an increase in Young's modulus. The results showed that Acacia manginum, Tectona grandis and Artocarpus heterophyllus experienced an increase in Young's modulus.

Table 1. Result of Mechanical Properties Testing [15].

Name of Species	Type of specimen	E (N/mm²)	Yield stress (N/mm²)	Max Stress (N/mm²)	Density (Kg/m³)	Moisture Content (%)
Jati	A40	427.11	9.26	10.67	571.91	0.119
	B80	781.95	16.72	18.76	590.46	0.126
	B120	786.29	12.22	15.90	574.92	0.130
	B160	556.83	14.11	17.11	572.94	0.133
Nangka	A40	493.09	11.21	12.08	500.27	0.112
	B80	661.60	16.27	18.05	487.46	0.114
	B120	744.91	15.91	18.38	479.31	0.115
	B160	542.03	17.40	19.16	487.99	0.119
Sonokeling	A40	692.94	14.20	15.96	666.65	0.123
	B80	725.45	18.45	21.77	676.14	0.126
	B120	986.15	19.25	23.28	692.77	0.125
	B160	956.98	18.17	22.44	685.51	0.126
Ketepeng	A40	662.61	13.33	14.48	649.34	0.144
	B80	724.59	17.17	19.98	651.39	0.147
	B120	934.69	17.16	20.68	646.84	0.144
	B160	948.49	17.81	21.60	657.44	0.145
Falcata	A40	275.60	3.65	3.75	225.12	0.138
	B80	228.16	4.97	5.76	239.62	0.117
	B120	203.78	4.65	5.63	232.10	0.125
	B160	201.19	4.64	5.55	228.96	0.125
Acacia	A40	297.57	5.49	5.91	417.34	0.157
	B80	542.35	7.71	8.92	413.53	0.173
	B120	685.22	9.48	11.34	426.76	0.174
	B160	677.13	9.60	11.38	414.62	0.171

Figure 4. Comparison of increasing Young's modulus ratio and yield stress of three species [17].

[18] examines the flexural strength of damaged wooden beams with repairs using the vacuum-adhesive method. The research aims to know the comparison of the flexural strength of wood beams between before and after repairs are made. Displacement that occurs due to load can be seen in Fig. The following 4.
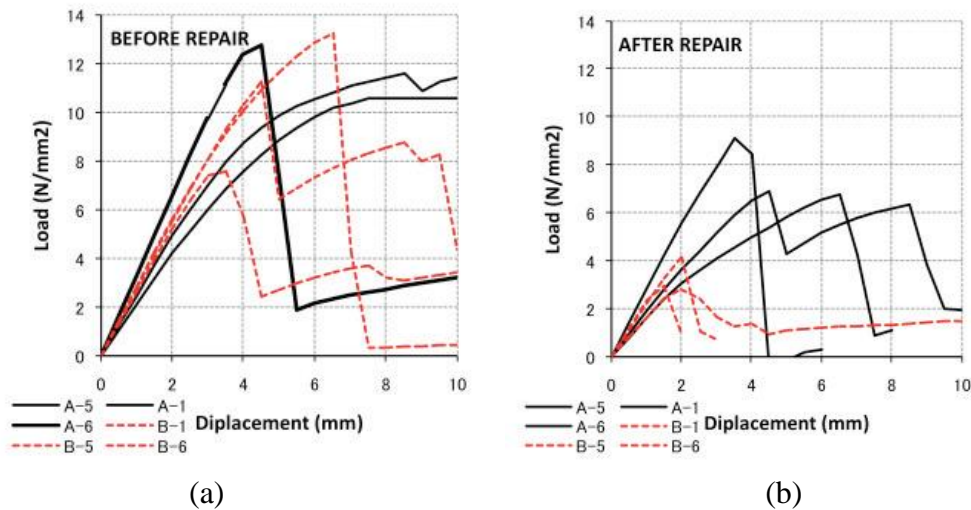
Figure 5. (a) Bending and deformation curves before testing; (b) After testing [17].

[19] examined the structural repairs of old age wood beams which had undergone weathering. The research aims to evaluate the use of wood parts connected to the original elements by connecting steel plates that are glued together and to determine the behavior of structural elements. The analysis is based on the maximum load value (Fmax), the bending moment acting on the connection (Mj), the flexural stress achieved by the specimen in the failure zone (m) and the observed form of failure. The form of structural failure as contained in the following table 2. The experimental test results are seen in the curve of Figure 5. The test results show that specimens with diagonal connections behave better.

Table 2. The Analysis Result[19].

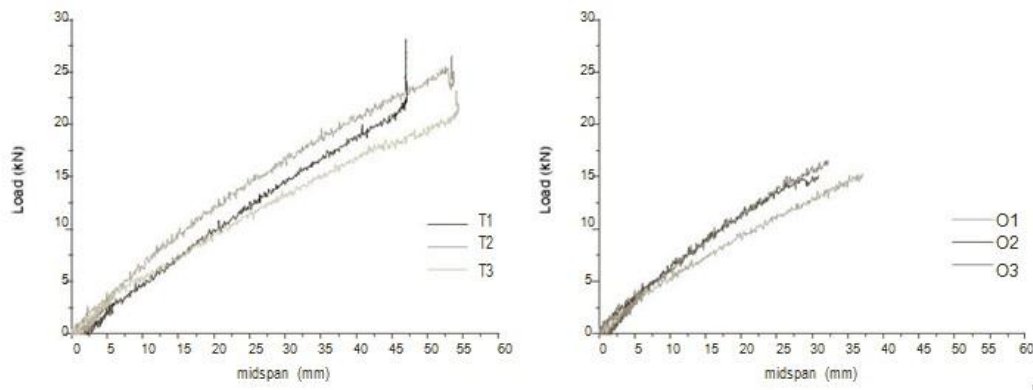| Specimen	Technique	F_{max} (kN)	M_j (kNm)	$_{\sigma}$ m (MPa)	Failure Mode
01	One element screwed in single shear	28.21	4.02	10.72	Wood splitting
02		26.57	3.97	10.60	
03		23.22	4.33	11.56	
T1	Two elements screwed in double shear	15.32	7.41	19.75	Joint rotation
T2		15.13	6.97	18.60	
T3		16.51	6.10	16.25	
GV1	Glued-in steel rods with a vertical joint	20.60	7.62	18.30	Rod withdrawn
GV2		20.60	7.62	19.30	
GV3		18.00	6.70	15.90	
GD1	Glued-in steel rods with a diagonal joint	19.70	7.28	17.40	Rod withdrawn
GD2		28.30	10.47	25.10	
GD3		24.00	8.90	21.40	
GM1	Glued-in steel rods with a mixed joint	17.20	6.38	20.70	Wood failure
GM2		14.80	5.47	13.10	Rod withdrawn
GM3		23.40	8.70	20.70	

Figure 6. Perimental displacement load curve [19].

[20] has examined the strength of perforated wood patched with a mixture of sawdust and adhesive. The purpose of the study was to determine the magnitude of dutambal flexural strength with a mixture of sawdust, planer powder, and wood sand powder. Figure 6 shows an increase in the load that is able to be held by a block of wood that has been patched on a piece of wood, although it cannot match the load received by a whole block of wood.
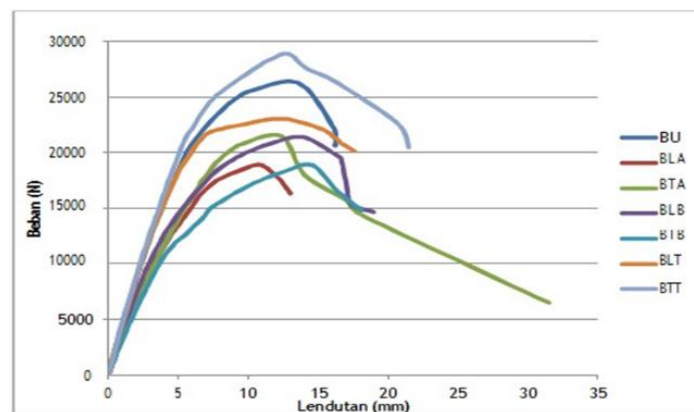

Figure 7. Average graph of the relationship between load increments and deflection that occurs in the test specimen [20].

[21] has examined the strengthening of CFRP on the wooden beam stiffness. The research aims to strengthen the structural elements of the use of composite materials as penguant for wooden beams under flexural load. Experimental research conducted by A C Ianasi (2015) shows that the flexural strength increases for wood beams reinforced with CFRP composite plates and sheets compared to those without CFRP reinforcement.
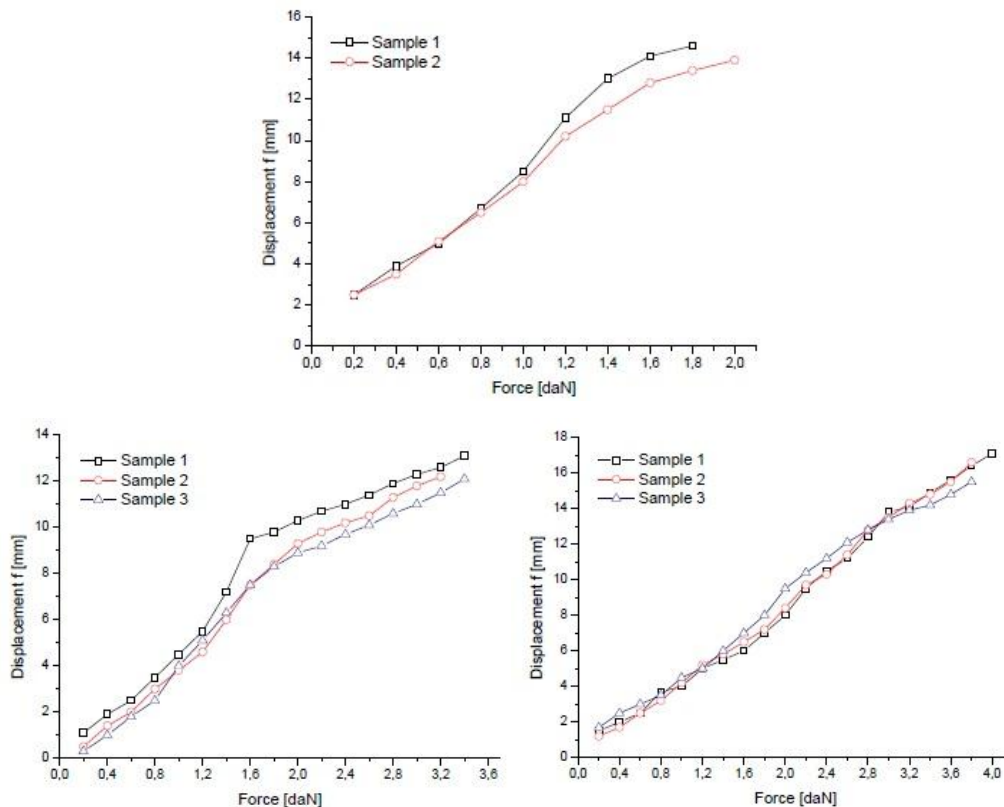
Figure 8. Voltage failure: (a) Beam tension without reinforcement; (b) With one carbon fiber plate and one wooden slide down; (c) With two carbon fiber plates and two wooden top and bottom slides [21].

3. Problem identification

Wood material is susceptible to problems with elemental damage due to weathering and insect attacks. Damage to the structural elements of the wooden beam does not occur as a whole but only in certain areas. To maintain the strength of the wood in order to carry the burden, it is necessary to strengthen only the damaged area. So the structural elements of the wooden block do not need to be replaced in total but only on the damaged part. This is advantageous because it does not require a lot of costs when compared to replacing all the wooden beam structural elements.

4. Objectives

This study aims to determine the mechanical properties of the wooden beam structural elements that have been strengthened. The effectiveness and optimization of reinforcement in certain areas of damaged logs needs to be assessed.

5. Methodology

Testing the tensile strength of the flexural strength of the whole *Tectona grandis* wood block as many as 6 pieces, 6 pieces of Teak wood without adhesive, Tectona grandis using 6 pieces of adhesive with a size of 120 x 8 x 6 cm, and Tectona grandis wood as 6 pieces of adhesive with the size 10 x 4 x 6 cm, and the adhesive used is epoxy glue. The beam reinforcement testing was carried out at the UGM PSIT metabolite. The following is a picture of the test set-up of the tensile strength test object to the flexural strength of the Tectona grandis wooden beam.

Figure 9. Setting-up Flexural Strength of Retrifitting Wood Beam.

6. Results and discussion

The results of the flexural test of wood beams with adhesive on the D-2 specimen achieved the lowest flexural stress of 52.2253359375 N/mm². While code D-1 beam has the highest flexural stress of 59.8455 N/mm², while code D-3 beam has a bending stress of 54.54848438 N/mm². It appears that the three beams have the highest flexural stress obtained by the D-1 code beam. From these three beams, the average flexural stress of the beams with adhesive is 55.53977344 N/mm².

From the results of the flexural test teak wood without adhesive, there is the lowest stress value on the B-II specimens with a stress strength value of 7,899 N/mm². Whereas the B-I test shows the value of the stress strength of 13,103 N / mm2. While B-III specimens obtained the greatest load strength, which was 15,984 N/mm². Of the three test specimens, there is an average value of 12,329 N/mm².
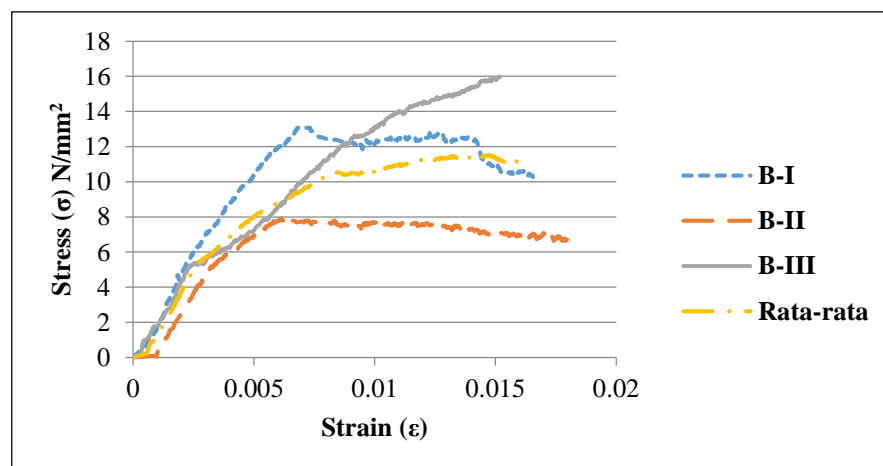

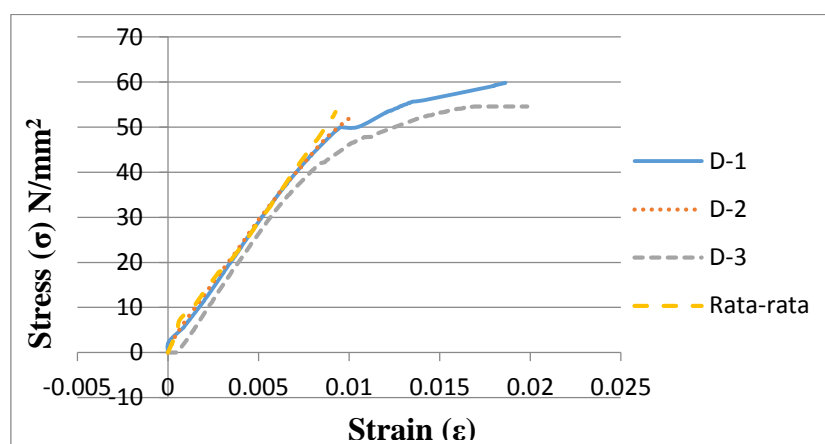**Figure 10.** Beam tension and strain chart without adhesive on the tensile area strengthening.

Figure 11. Graph of flexural stress of teak beams with adhesive on the reinforcement of the compressed area.

7. Conclusion

The results of the study stated that the maximum flexural strength is occurring in Teak wood beams with adhesive (D-1, D-2, D-3) able to have stronger flexural strength of 59.8455 N/mm², 52.22533594 N/mm², 54.54848438 N/mm² , compared to solid beams (F-1, F-2, F-3) of 39.72684375 N/m², 53.01527344 N/mm², 60.58877344 N/mm². This research also shows that the connection of Teak wood blocks with adhesives has better flexural strength.

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