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The Reinforcement of Flexible Composite Beams Laminated Camphor – Reinforced Concrete

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ABSTRACT

Indonesia has a lot of abundant material resources. One of them is the availability of solid wood that can be used for bridge construction. The wood used as a bridge structural element has a 15-20 meters span with class III road loading capacity. However, wood has limited dimensions. Therefore, it is needed for wood to be composited into reinforced concrete laminated beams as planned. The planning of reinforced concrete laminated wood beams refers to the materials' characteristics, including the mechanical properties of Camphor wood. These characteristics are used as the basis for analyzing the performance of Laminated-concrete-reinforced Camphor composite beams. The dimensions of the composite beam specimen are 250 x 30 x 25.5 cm in the scale of a 1:3 model with actual measurements. The analysis was carried out manually to determine the strength of the Laminated-concrete-reinforced Camphor composite beams. The variables used in this analysis include the number of layers of CFRP as flexural reinforcement compared to beams without CFRP reinforcement. The number of layers of CFRP consists of 1 layer, 2 layers, 3 layers. Composite beams were analyzed with two concentrated loads in the area 1/3 of the span length from the supports. The results of the analysis show that the composite beam using CFRP can carry an additional load of 86.86 kN (101.68%) for 1 layer of CFRP; 87.99 kN (103.07%) for 2 layers of CFRP; and 93.81 kN (109.83%) for 3 layers of CFRP compared to the experimental load that can be received by standard composite beams of 85.42 kN (100%).

Keywords: *Laminated Wood Beams, Composite Beams, Wood Characteristic Testing, Flexural Reinforcement, CFRP.*

1. INTRODUCTION

The beam structure of the bridge can be concrete, a steel structure, a wooden structure, and a composite structure. The composite structure is a structure that consists of two or more different materials that strengthen each other to withstand the workload. Composite structures can provide good structural performance and work more effectively in increasing loading capacity, stiffness, and ductility.

Indonesia's has big natural resource potential, such as large tropical forest, supports constructing a composite timber bridge. Wood has different strengths in carrying the loads compared to steel or concrete. The strength of the wood is related to the direction when it receives the load. When receiving parallel forces, the wood will have greater strength and vice versa; when the load is perpendicular to the wood grain's direction, the wood's strength will weaken. With the increasing use of timber in the construction sector, the availability of large-sized timber with good quality is increasingly limited. In fulfilling the increasingly limited demand for wood, wood structural materials can be made from particles or small pieces of wood glued or composited with other materials to obtain better dimensions and homogeneity [1].

Based on the direction of the laminate arrangement to the loading, laminated beams are divided into horizontal and vertical laminated beams. This concept adopts the principle of the strength of bamboo from within to most of the layers [2]. Composite materials utilize the physical and mechanical properties of each material to form a new and better material. It also has different characteristics compared to the characteristics of the constituent material [3]. The wood is suitable for resisting tensile, compressive, and bending forces. The compressive stress can be resisted by the concrete layer and the tensile stress by the wood. It is difficult to produce sufficient strength and rigidity for long-span wood. The use of Carbon Fiber Reinforced Polymer (CFRP) sheets on the flexural portion of the laminated wood beam can increase the maximum load [4]. The reinforcement using CFRP and GFRP on the laminated wooden beam, especially on the stress side, has increased flexural stiffness using CFRP [5].

The number of sheets, length, and width of the FRP bond greatly determines by the increase in the strength, stiffness, and ductility of laminated beams [6]. Wood as part of the composite cross-section is expected to reduce the volume of concrete. The experimental analysis of composite beams aims to analyze the number of CFRP sheets on the load (P). Then it will be used in conducting the experimental structure of the wood-reinforced concrete composite beam.

2. LITERATURE REVIEW

The structural wood in buildings will get the loads such as compressive, tensile, shear, or flexural loads. The loading experienced by the wood is obtained from the external forces that affecting on the wood. These forces trigger the structure to experience stress and strain [7]. Every time a change in pressure occurs. It will be a change in strain proportional to the magnitude to a certain limit called the elastic limit. The changes that appear depend on the materials used. Laminate wood beams can change in strain and stress.

Laminated beams have flexibility and efficiency in terms of maximum span. It is necessary to know the effect of the connection on the flexural capacity of the beam to obtain an accommodative design parameter for weakening the connection [8]. Laminated beams combined with other materials such as concrete are referred to as composite structural systems. The composite structure system is formed by the interaction between 2 different types of materials by optimizing the characteristics of each material [9].

Composite materials utilize each constituent material's physical and mechanical properties to form new, better materials. It has different characteristics compared to the characteristics of the constituent materials [10]. Composite beam planning needs to be considered to obtain the specified composite beam strength. The cross-sectional transformation method is an alternative way to analyze the bending stress in composite beams. This method is derived from the principle of elasticity theory which changes the cross-section of a composite beam into an equivalent cross-section of an imaginary beam composed material (called a transformed cross-section) [11].

The use of FRP (Fiber Reinforced Polymer) in the beam structure can increase the strength of the beam. The CFRP-reinforced beams have greater ductility than the unreinforced beams. The beam with CFRP reinforcement has a ductility of 2,333, while the beam without reinforcement has 2,053. The percentage increase in ductility of CFRP reinforced beams is 13.736% of unreinforced beams [12].

3. RESEARCH METHODS

The research methodology for flexural reinforcement of laminated wood-reinforced concrete slab composite beams with a layer of Carbon Fibre Reinforcement Polymer (CFRP) and wood screw anchors is camphor's physical and mechanical testing properties wood as a laminate material in the design of composite beams. The tests carried out were in the form of testing the water content and specific gravity of the wood, testing the compressive strength and flexural strength of the wood, and testing the tensile strength and hardness of the wood. The tests were referred to ASTM D 143-52 (Reapproved 1978), book of ASTM Standards, 1982, and Guidelines for testing the physical and mechanical properties of Special wood publication LPHH Bogor, 1974. Tests were carried out with test objects, as shown in Figure 1. The used materials in this research are camphor wood with dimensions of 6/10 cm, 5x5x20 cm, 5x5x15 cm, 5x5x76 cm, and 5x5x5 cm, and cylindrical concrete 15/30 cm.

The test results were used to plan laminated concrete reinforced camphor composite beams using Carbon Fibre Reinforcement Polymer (CFRP) in the flexural area and the application of anchors in the form of wood screws on the camphor wood laminate. Planning is done using the transformation method.

Figure 1 Research Tested Subject

4. ANALYSIS

The analysis carried out is the results testing analysis of the characteristics of the composite beam base material and the study of the composite beam cross-section.

4.1 The Testing of the material properties

Data on the results of material properties were data testing on the physical and mechanical properties of wood and the compressive strength of concrete. Based on the preliminary testing results on wood, it was used to determine the quality of wood grade. The process of making test beams to determine the moisture content in the required forging process was used to compare the results of flexural strength, shear strength of wood, and theoretically and experimentally laminated adhesive.

Table 1 . The Results of Camphor wood Physical and Mechanical Properties

No.	Subject test code	Type of subject test	Preliminary Test Results
1	BJ-00	Wood Specific Gravity	0,8 gr/cm³
2	KA-00	Water Content Wood	16,09%
3	KG-00	Shear Strength Wood	6,78 MPa
4	KL-00	Flexural Strength Wood	2186 MPa
5	KTR-00	Tensile	48,51 MPa
6	KTN-00	Strength Compressive Strength Parallel Wood	118,67 MPa
		Grain Compressive Strength Perpendicular Wood	8,52 MPa
7	KK-00	Hardness Wood	Radial : 30,92 Mpa Tangensial : 27,9 Mpa Longitudinal : 51,18 MPa

Based on the table above, the testing results of the moisture content of camphor wood reach the compression requirement > 16%. Thus, the use of timber in field applications needs a drying process before pressing.

4.2 Composite Beam Section Analysis

Composite beam section analysis was performed on normal composite beam cross-section (without reinforcement) and composite beam analysis using CFRP reinforcement. Composite beam analysis using the transformation section method. The calculation stages carried out are as follows:

a. Designing a composite beam with a model size or 1:3 scale from the actual composite beam size. The scale of the model was carried out to determine the composite beam used in the experiment.

b. Calculating the transformation factor using the equation:

$$n = \frac{E_{Concrete}}{E_{Wood}} \qquad (1)$$

Description:

n = transformation factor

$E_{concrete}$ = concrete elasticity

E_{wood} = wood elasticity

c. Calculating the cross-sectional area using the equation:

$$A_{concrete} = n \,.\, b_{eff} \,.\, h_f \qquad (2)$$

$$A_{wood} = b_w \,.\, h \qquad (3)$$

Description :

A_{beton}= concrete cross-sectional area (mm^2)

A_{kayu} = cross-sectional area of wood (mm^2)

b_{eff} = concrete slab width (mm)

h_f = concrete slab height (mm)

b_w = wooden beam width (mm)

h = beam height wood (mm)

d. Calculating the neutral line to the bottom side using the equation:

$$y = \frac{\{[(n.b_{eff})h_f.(h+\frac{h_f}{2})]+[b_w.h.(\frac{h}{2})]\}}{((n.b_{eff})h_f)+(b_w.h)} \qquad (4)$$

$$c = (h_f + h) - y \qquad (5)$$

Description :

y = neutral line to the bottom side (mm)

n = neutral line to the top side (mm)

e. Calculating the moment of inertia using the equation:

$$I = n.\frac{1}{2}.\, b_{eff}.h_f^3 + .\frac{1}{2}.\, b_w.h^3 + n.b_{eff}.h_f \,(c-.\frac{h_f}{2})^2 + b_w.\, H\,(y-\frac{h}{2})^2 \qquad (6)$$

Description :

I = moment of inertia (mm^4)

f. Calculating the maximum concrete stress, maximum wood stress, and maximum shear stress.

g. Calculating the cross-sectional moment (Mn) for normal composite beams, composite beams using 1 layer of CFRP, composite beams using 2 layers of CFRP, and composite beams using 3 layers of CFRP.

h. Calculating the maximum load (P) of normal composite beams, composite beams using 1 layer of CFRP, composite beams using 2 layers of CFRP, and composite beams using 3 layers of CFRP.

i. Designing the shear connector.

Based on the cross-sectional analysis of the composite beam, it was found that the composite beam had increased capacity to accept loads, as shown in Figure 2.

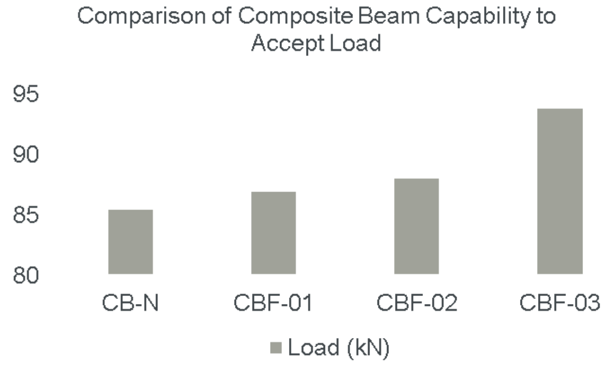

Figure 2 The Capacity of Composite Beams in Receiving Load.

Normal composite beams (CB-N) can receive a maximum load of 85.42 kN. The composite beams with 1 layer of CFRP (CBF-01) can receive a load of 86.86 kN, composite beams with 2 layers of CFRP (CBF-02) can receive a load of 87.99 kN, and a composite beam with 3 layers of CFRP (CBF-03) can receive a load of 93.81 kN. The reinforced concrete laminated camphor wood composite beam's design is shown in Figure 3 and Figure 4.

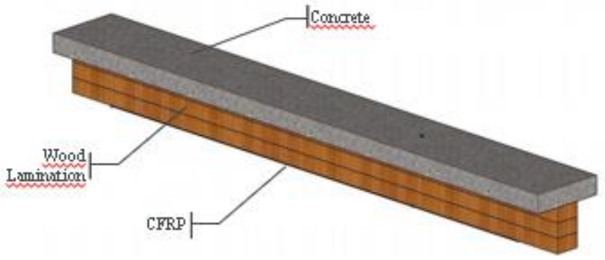

Figure 3 Composite Beam Illustration

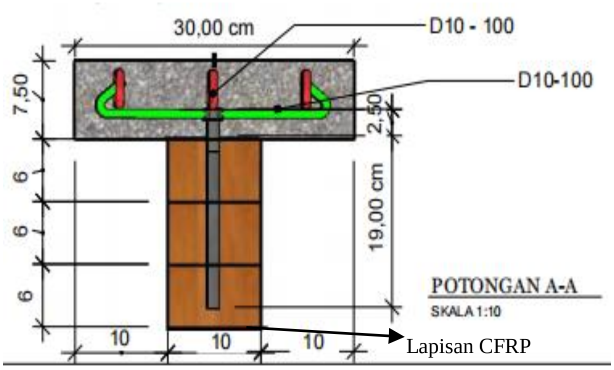

Figure 4 Composite Beam Details

The dimensions of the laminated concrete reinforced camphor composite beam were designed with a composite beam length of 250 cm, a camphor wood laminate height of 18 cm with a laminated wood width of 10 cm, and a concrete slab height of 7.5 cm with a reinforced concrete slab width of 30 cm. The use of wood screws was designed using bolts with a diameter of 10 mm and 17.5 cm, while the application of CFRP in the bending area with a surface area was 210 cm x 10 cm.

5. CONCLUSION

Based on the results of the physical and mechanical testing properties of camphor wood. The moisture content of camphor wood reaches the compression requirement > 16%. Thus, the use of timber in the experiment needs to be dried before pressing. In applying CFRP as flexural reinforcement, the laminated concrete reinforced camphor composite beam can bear a load of 85.42 kN with a 250 x 25.5 x 30 cm composite beam dimension. The addition of the CFRP reinforcement layer on the composite beam can increase the ability of the composite beam to accept the load. The increase in load acceptance on each composite beam using CFRP is 86.86 kN (101.68%) for composite beams with 1 layer of CFRP, and 87.99 kN (103.07%) for composite beams with 2 layers of CFRP, and 93.81 kN (109.83%) for composite beams with 3 layers of CFRP.

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