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Flexural Reinforcement of Laminated-Concrete Camphor Composite Bridge Structure Elements Using Plain Reinforcement Steel Both Ends Anchored

Faizal Abdurahman[1,*] Mujiman[1]

[1] *Department of Civil Engineering, Bandung State Polytechnic, Bandung, Indonesia*
[*]*Corresponding author. Email: faizal.abdurahman.mtri19@polban.ac.id*

ABSTRACT
Wood has shrinkage properties, so it affects the availability of the maximum dimensions of wood available in the market. To meet the need for dimensions that are larger than the maximum dimensions available in the market, laminated boards and beams are made. The dimensions such as thickness, height and length of the laminated wood beams can be made based on the needs, so those dimensions can be much more than the maximum dimensions of the beams on the market. Thus, it is worthy to be used for the main beams or sub-beams of a bridge.
To overcome this, the laminated wood beams are composed with reinforced concrete slabs, so that they become a composite of laminated wood beams-reinforced concrete slabs. Reinforced concrete slabs serve as the bridge floors as well as protective laminated timber beams to protect them from heat and rain.
Wood has more elastic properties compared to reinforced concrete. To overcome this problem, the part of the wood fibres that experience the bending must be strengthened. The research method was carried out by testing the flexural testing of Laminated Camphor composite beams - reinforced concrete slabs reinforced using a second plain reinforcing steel ends are anchored using bolts. The variables used include the amount of reinforcement: 1, 2, and 3 plain reinforcing steel bars with a diameter of 8 mm, as well as unreinforced beams as the control beams.

Keywords: *Reinforced Concrete, Laminated Camphor Wood, Plain Steel Reinforcement.*

1. INTRODUCTION

Wood from artificial forests and natural forests is a building material produced from nature through the process of seeding, planting, care, felling, and processing into boards and beams. Dimensions of thickness and height and length of laminated wood beams can be made according to needs, so that thickness and height dimensions and lengths can reach twenty or even more than the maximum dimensions of beams on the market. Thus, it is recommended to be used as main beams or sub-beams of a bridge.

Reinforced concrete slabs as bridge floors as well as protective laminated wood beams is used to avoid heat and rain. Wood has more elastic properties than reinforced concrete. To overcome this problem, the parts of the wood fibres that experience the bending must be strengthened.

1.1. Formulation of the problem

Based on the above background, the formulation of the problem in this study are:

1) What is the flexural strength of the laminated camphor composite beam-reinforced concrete slab if it is not reinforced using plain reinforcing steel?
2) How much is the increase in flexural strength in the laminated camphor composite beam-reinforced concrete slab with reinforcement consisting of 1 (one) control beam (BK), 1 (one) test beam with the reinforcement of one reinforcing bar (B1P), 1 (one) test beam with two reinforcing bars (B2P), and 1 (one) test beam with three reinforcing bars (B3P)?
3) What is the failure model for the Laminated Camphor composite beam-reinforced concrete slab reinforced using plain reinforcing steel?

1.2. Research purposes

The objectives of this research include:

Analysing the flexural strength of the flexural reinforcement on the structural elements of the Laminated-concrete Camphor composite bridge using plain reinforcing steel, both anchored at both ends;

1) analysing the stiffness of the flexural reinforcement on the structural elements of the Laminated-concrete Camphor composite bridge using plain reinforcing steel anchored at both ends; and,
2) Analysing the ductility of the flexural reinforcement in the structural elements of the Laminated-concrete Camphor composite bridge using plain reinforcing steel, both anchored at both ends.

1.3. Scope

The scope of this research is needed to limit the problems in this research. The scope of this research is as follows:

1) The tests carried out are in the form of preliminary tests, namely testing the characteristics of wood, steel, and concrete composting materials. It is followed by testing the composite beam in the form of a flexural test. Meanwhile, the reinforcement used is plain reinforcing steel with a quality (f_y) of 240 MPa and anchors.
2) The material used is of concrete quality (f'_c) 22 MPa (K-250). The reinforcing steel is with a quality (f_y) of 240 MPa, and the type of wood used is camphor wood.

2. BACKGROUND

There are previous research conducted on flexural reinforcement of wooden beams using steel plates, flexural reinforcement of laminated wooden beams using steel plates. There is also the analysis of flexural behaviour of laminated Sengon beams reinforced using steel plates. The researcher, the title and outline of the content, and the results of the previous research are as follows;

1) Giovanni Metelli et al (2013)

The research title is “The Repair of Timber beams with controlled-debonding steel plates”. This study examines the flexural reinforcement using epoxy resin and steel plates on wooden building beam structures that are damaged due to the loss of moisture in the wood. Before the installation of structural reinforcement, the building has the beam experienced of a deflection of 6 mm in four years. The results showed that after the reinforcement was installed, the wooden beam structure experienced a deflection of 0.35 mm in four years or an increase in stiffness of 94.17% in four years. So, by strengthening the building beams using epoxy resin and steel plates, it can increase the stiffness by 23.54% / year.

2) Tomas Nowak et al (2016)

The title of the research is “Strength Enhancement of timber beams using steel plates - review and experimental test”. In this study, two test beams were used. The first test beam is reinforced in the flexural section utilizing a nailed steel plate. The second test beam was reinforced in the flexural part by using a steel plate which was nailed and smeared with adhesive at the junction of the steel plate surface and the wood surface. The results showed that the test beam reinforced in the flexural section using a steel plate that was nailed and smeared with adhesive at the junction of the steel plate surface and the wood surface was able to increase by 50% compared to the test beam reinforced in the flexural section using a nailed steel plate.

3) TM Wicaksono et al (2018)

Research title "Analysis of Flexural Reinforcement of Sengon Wood Laminated Beams Keruing Wood Laminated Composites Using Steel Plates". The purpose of this research is to analyse the flexural strength of composite beams from weak wood (Sengon) for the inside by using engineering in the compression section using a laminate of strong wood (Keruing) and the tensile section mounted with steel plates as flexural reinforcement. The composite laminate concept can increase the strength, stiffness, and flexural elastic modulus by 109%, 112.43%, and 49%, respectively, and can change the brittle to ductile properties. The results showed that Sengon wood is a non-structural wood that can be upgraded to structural wood by applying the concept of composite lamination.

4) Kundari R and Fajar DI (2018)

The title of the research is "Analysis of Compression of Wood-Steel Laminated Composites Based on SNI 7973-2013". The testing of the compressive behaviour of the lightweight steel-wood laminated composite was carried out by full-scale modelling, with a screw spacing of 200 mm on each side of the mild steel body. The length of the test specimen composite rods (Ltk) was 200 mm, 300 mm, 600 mm, 900 mm, and 1200 mm, with three repetitions of each test. The results showed that the laminated mahogany wood has 5 (five) times greater than the analysis of the theory of face transformation which refers to SNI 7973-2013. The failure model of the composite bar is in the form of buckling on the mild steel profile flange, and the overall buckling body and the failure model are experiencing global buckling due to the slenderness of the rod.

3. RESEARCH METHODOLOGY

Research methodology for flexural reinforcement on structural elements of Laminated Camphor Composites-

Reinforced Concrete Using Plain Steel Both Anchored Ends is generally made in the form of a flowchart which can be seen in Figure 1.

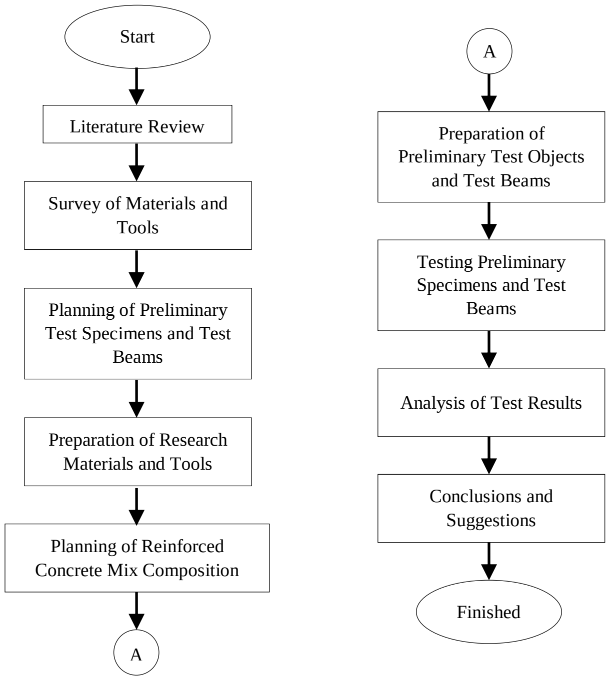

Figure 1 Research Flowchart

3.1. Formulation of the problem

Preliminary testing is carried out to determine the characteristics of wooden beams, including:

Table 1. Test Objects for Testing Preparation

No.	Test Object Code	Standard Title	Standard Number	Number of Test Objects
1	BJ-00	Method of testing the specific gravity of wood and wood materials by measuring	SNI 03-6844-2002	3 pcs
2	KA-00	Measurement test method with the moisture content of wood and wood materials	SNI 03-6850-2002	3 pcs
3	KG-00	Shear testing method with wood in the laboratory	SNI 03-3400-1994	6 pcs
4	KL-00	Flexural testing method with wood in the laboratory	SNI 03-3959-1995	3 pcs
5	KTR-00	Flawless small specimen wood testing method	SNI 03-3399-1994	3 pcs
6	KTN-00	Method of testing the compressive strength of wood in the laboratory	SNI 03-3958-1995	6 pcs
7	KK-00	Wood hardness testing method in the laboratory	SNI 03-6842-2002	3 pcs
8	KTB-00	How to test the compressive strength of concrete with a cylindrical test object	SNI 1974-2011	3 pcs

3.2. Test Object Making

The test object that will be used in this study is a laminated wood composite beam-reinforced concrete slab. The sizes used are as in Figure 2:

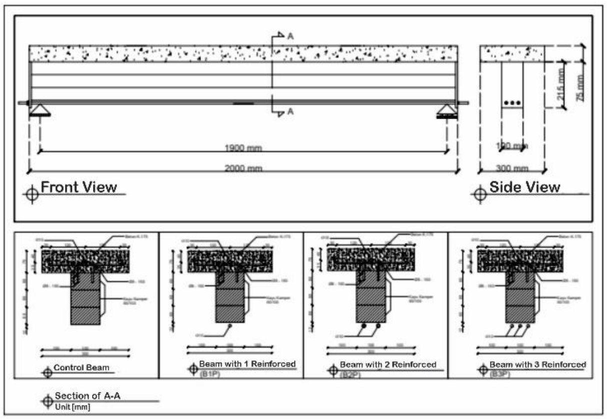

Figure 2 Test Beam

3.1. Specimen Object Test

Specimen carried out in the study of Flexural Reinforcement on Structural Elements of Laminated Camphor Wood-Reinforced Concrete Composite Bridges Using Plain Steel Both Anchored Ends were in the form of testing the bending of composite beams. The testing uses the following equipment:

1) *Universal Testing Machine* (UTM) is a tool used to determine the strength of the test object.
2) *Load cell* working to determine the magnitude of the load applied during the test.
3) LVDT (Linear Variable Differential Transformer) is used to measure the deflection value.
4) *Data logger* functions to record and print load and deflection data. Before being used, the Data Logger must first be set the loading speed and load-interval to be applied.

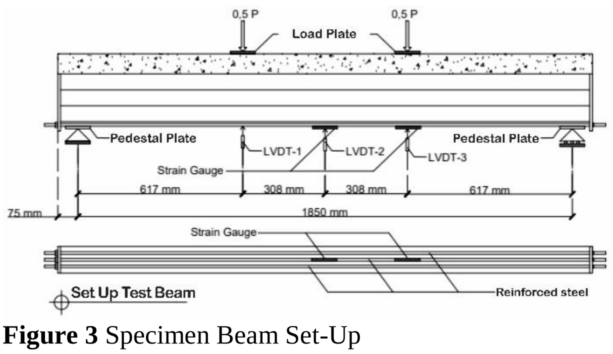

Figure 3 Specimen Beam Set-Up

4. ANALYSIS OF REINFORCED WOOD-CONCRETE COMPOSITE BEAM

4.1. Composite Bridge Beam Structure Data (Prototype)

The following data support the planning of composite bridge beams (prototype):

1) Composite Beam Length, L = 6000 mm
2) Concrete Quality, f'c = 22 MPa
3) Steel Quality, fy = 240 MPa

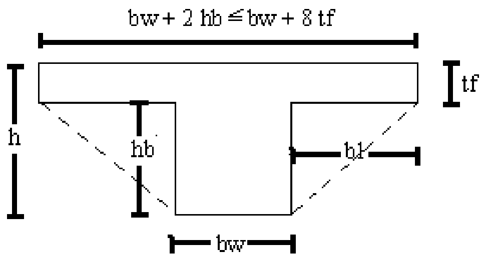

Figure 4 Cross-section Sketch

Based on the calculation results, several parameters of the composite T-beam structure were obtained, namely:

1) concrete width, be = 1000 mm
2) wood width, bw = 400 mm
3) beam height, h = 800 mm
4) concrete height, tf = 320 mm
5) wood height, hb = 480 m
6) beam length, L = 6000 mm

4.2. Model 1:4 Scale Beam Design (Geometry Scale)

Determination of this model scale beam is used for the manufacture of test objects based on preliminary calculations in the previous calculation; a 1:4 scale divides each parameter. The parameters is used because of the 1:4 scale conversion are as follows:

1) concrete width, be = 250 mm
2) wood width, bw = 400 mm
3) beam height, h = 200 mm
4) concrete height, tf = 80 mm
5) wood height, hb = 120 m
6) beam length, L = 1500 mm

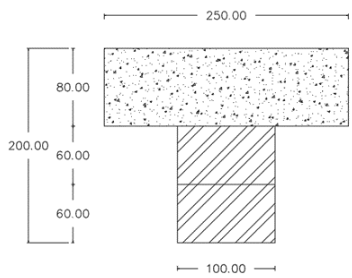

Figure 5 Geometric Scale Sketch

4.3. Determining the Balance of Style

To determine the force balance, it takes several variables that need to be calculated, namely the transformation factor, cross-sectional area, neutral line to the lower side, neutral line to the upper side, the moment of inertia, upper flexural stress, lower flexural stress, compressive force on concrete, the compressive force of the reinforcement, the yield capacity of the reinforcement, the compressive force of the wood and the tensile force of the wood.

1) Transformation Factor

$$n = \frac{E_{concrete}}{E_{wood}} \quad (1)$$

$= 2.24$

2) Cross-sectional area

$A_{con} = 20000\ mm^2$

$A_{wood} = 12000\ mm^2$

3) The neutral line to the downside and the upside

Bottom side:

$$y = \frac{[(n\ .\ be)\ .\ tf\ .\ (hb + \frac{tf}{2})] + [bw\ .\ hb\ .\ (\frac{tf}{2})]}{[(n\ .\ be)\ .\ tf] + (bw\ .\ hb)} \quad (2)$$

$= 134,65$ mm

Upside:

$c = (hb + tf) - y$

$= 65,35$ mm

4) Moment of Inertia

$$I = n\ .\ \frac{1}{12}\ .\ be\ .\ tf^3 + \frac{1}{12}\ .\ bw\ .\ hb^3 + n\ .\ be\ .\ tf\ .\ \left(c - \frac{tf}{2}\right)^2 + bw\ .\ hb\ .\ \left(c - \frac{tf}{2}\right)^2 \quad (3)$$

$= 74794291,33\ mm^4$

5) Upper wood bending stress

Determine the value of the upper wood bending stress:

$$\sigma_{wt} = E_w\ .\ \varepsilon_{wt} \quad (4)$$

$$= 9806,65\ .\ 0,003\ .\ \frac{(c - 80)}{c}$$

6) Lower flexural stress

Determine the value of the lower flexural stress of the wood:

$$\sigma_{wb} = E_w\ .\ \varepsilon_{wb} \quad (5)$$

$$= 9806,65\ .\ 0,003\ .\ \frac{(200 - c)}{c}$$

7) Compressive force on the concrete

Determine the value of the compressive force in concrete:

$$Cc = 0,85\ .\ f'c\ .\ be\ .\ a \quad (6)$$

$= 374000$ N, $= 374$ kN

8) Compressive force on reinforcement

Determines the minimum reinforcement ratio (ρ_{min}), wear reinforcement ratio (ρ), and maximum reinforcement ratio (ρ_{max}).

9) Reinforcement yield capacity

$$Cs = As\ .\ fy \quad (7)$$

$= 33354,3$ N $= 33,35$ kN

10) Press and pull force of wood

Wood press style:

$$C_w = \frac{\sigma wt}{c}\ .\ (c - 80)\ .\ 100 \quad (8)$$

$$C_w = 1471\ .\ \frac{(c - 80)^2}{c}$$

Wood pull style:

$$T_w = \frac{\sigma wb}{c}\ .\ (200 - c)\ .\ 100 \quad (9)$$

$$T_w = 1471\ .\ \frac{(200 - c)^2}{c}$$

11) Equilibrium Equation ΣH = 0

The equilibrium equation ΣH = 0 is used to be able to produce a value, to be able to provide a clear picture of the stress-strain diagram, to find the variable c.

$$Cc + Cs + Cw - Tw = 0 \quad (10)$$

$$374000 + 33354,3 + 1471\ .\ \frac{(c - 80)^2}{c} - 1471\ .\ \frac{(200 - c)^2}{c} = 0$$

$c = 98,08$ mm

12) Flexural strength of top and bottom wood

Upside:

$$\sigma_{wt} = 9806,65\ .\ 0,003\ .\ \frac{(98,08 - 80)}{98,08}$$

$\sigma_{wt} = 5,42\ N/mm^2$

Bottom side:

$$\sigma_{wb} = 9806,65\ .\ 0,003\ .\ \frac{(200 - 98,08)}{98,08}$$

$\sigma_{wb} = 30,57\ N/mm^2$

The following is a figure of the strain-stress diagram that is generated base on the calculations that have been done:

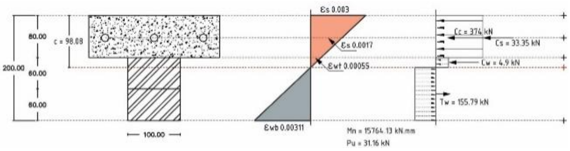

Figure 6 BK Strain-Stress Diagram

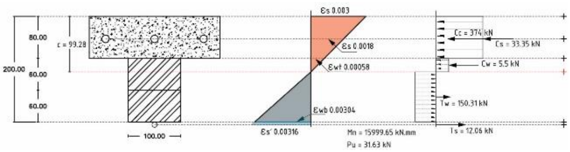

Figure 7 B1P Strain-Stress Diagram

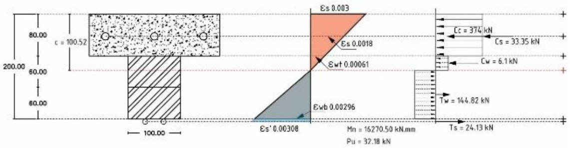

Figure 8 B2P Strain-Stress Diagram

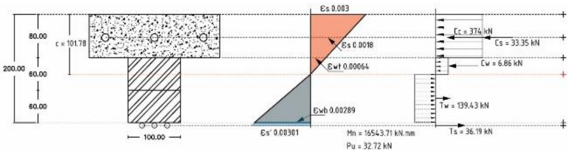

Figure 9 B3P Strain-Stress Diagram

4.4. Determining the Balance of Style

The maximum moment that occurs in the middle 1/3 of the span is 1/3 PL, at 1/3 of the middle of the span the beam only experiences pure bending without any influence from the latitude force. While at the support area, the beam bears a transverse force of P and experiences bending at the same time. With a load P = 50 kN.

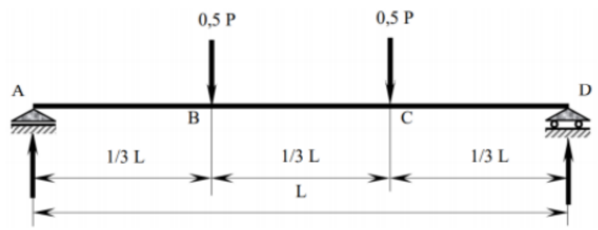

Figure 10 Geometric Scale Sketch

1) Cross-sectional Moment Capacity (Mn)

Here is how to find the value of the cross-sectional moment capacity:

$$Mn = Cc.\left(c-\frac{hf}{2}\right) + Cs.\left(c-\frac{hf}{2}\right) + Cw.\left(\frac{c-80}{2}\right) - Tw.\left(\frac{200-c}{2}\right) \quad (11)$$

= 15764,13 kNmm

2) Load (Qu)

The uniform load (qu) was obtained based on the use of the material, the dimensions used are concrete, and camphor wood, and then the load (Qu) is 0,648 N/mm.

3) Maximum Load (Pu)

By using the equation below, the Mu value is as follows:

$$Mu = P\ .\ a + \frac{1}{8}\ .\ qu\ .\ L^2 \quad (12)$$

Pu = 31,16 kN

4) Deflection (Δ)

The deflection calculation will be planned using the following equation with P of 50 kN:

$$\Delta = \frac{P\ .\ a}{24\ EI}\left(3L^2 - 4a^2\right) + \frac{5\ .\ qu\ .\ L^4}{384\ EI} \quad (13)$$

= 8,22 mm

Where the modulus of elasticity used is E_{wood} = 9806,65 MPa, where the moment of inertia used is the result of the transformation.

Table 2. Ultimate Moment each Test Objects

Test Object	Ultimate Moment (Mu)
BK	15764.13 kNmm
B1P	15999.65 kNmm
B2P	16270.50 kNmm
B3P	16543.71 kNmm

Based on the results from the table above, the addition of reinforcing steel under the beam produces different ultimate moments. The more reinforcement is added under the beam, the greater the ultimate moment.

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