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# Herbudiman\_2017\_IOP\_Conf.\_Ser.\_Earth\_Environ.\_Sci.\_109\_012029.pdf

*by* Yosafat Pranata

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**Submission date:** 14-Jan-2025 06:59PM (UTC+0700)

**Submission ID:** 2563966601

**File name:** 1\_Herbudiman\_2017\_IOP\_Conf.\_Ser.\_Earth\_Environ.\_Sci.\_109\_012029.pdf (1.1M)

**Word count:** 3568

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## Design of pedestrian truss bridge with Sengon-Rubber laminated veneer lumber

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**Abstract.** Timber bridges are one of the bridge that has long been used, but nowadays, large dimension of sawn timber has limited supply and also it is not environmental-friendly. Laminated veneer lumber (LVL) is an engineered wood that becomes one of the promising alternative, because it is made from lower quality wood that processed to be used as a more quality one. The bridge planned to be a pedestrian truss bridge with length of 9 m, width of 3 m, height of 2.5 m, and using bolt and steel plate as its connection system. Mechanical properties of LVL obtained directly from laboratory test result. Bridge modeling and planning for wood construction refers to SNI 7973:2013, while the loading refers to SNI 1725:2016. Based on the modelling and calculation, the dimension of truss frame and girder beam which are 9 cm x 9 cm and 9 cm x 18 cm have adequate strengths and satisfy deflection requirement.

**Keywords:** timber bridge, truss frame, laminated veneer lumber

### 1. Background

Indonesia is filled with tropical forests and become the second largest in the world after forests in Brazil. Wood or timber is one of the most common used material in Indonesia. On the other hand, timber is a material that has long been used to make a pedestrian truss bridge or light vehicle. The advantages of this type of bridge are light weight, economical for medium spans and has aesthetic value. Timber also can be found easily in tropical area such as Indonesia.

However, nowadays illegal logging excessively occurred causing qualified timber stock decreased. Moreover, it caused the wood supply decrease and the timber value increasingly unaffordable for people to buy. Because of this case, engineered wood can be alternative.

Laminated veneer lumber is one of the alternatives with excellent prospect. It is an engineered wood consist of thin layers or wood veneers that glued together with sengon wood (density of 0.35 kg/m<sup>3</sup>) and rubber wood (density of 0.61 kg/m<sup>3</sup>) as base materials. Compared to ordinary woods, LVL is more flexible with consistent quality, and has anti-termite properties due to the use of adhesive in each layer. The purpose of this research is to design timber truss bridge with LVL that can withstand different types of load and apply SNI 7973:2013 about Design and Specification for Wood Construction. The benefit of this research is to make LVL as an alternative material of pedestrian truss bridge with medium span. Scope of this research are:

- Bridge structure is a truss bridge with span of 9 m, width of 3 m, and height of 2.5 m.
- Design loads consist of pedestrians, two-wheeled vehicles, and light vehicles.
- Connection system using steel plate and bolt.
- Wood mechanical properties obtained from laboratory test results.
- Structure analysis using software SAP2000 version 14.
- Bridge load specification using SNI 1725:2016
- Earthquake planning standards for bridges using SNI 2833:2008.
- Structural loads include dead load, live load, earthquake load, and wind load.



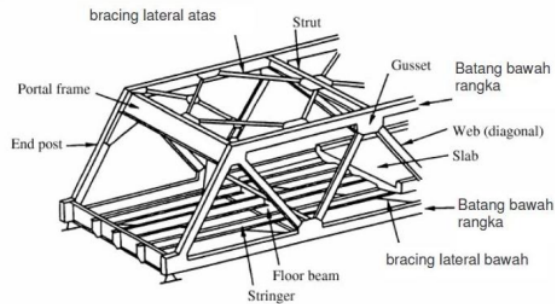
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Timber truss bridge consists of truss system which has tension or compression structural elements and girder which has flexure and shear elements. SNI 7973:2013 requires truss member which has axial capacity more than axial force due to external load, and the girder has flexural capacity more than ultimate bending moment. SNI 7973:2013 requires deflection of the timber bridge is  $\text{span}/700$ , then this LVL bridge should satisfies these requirements.

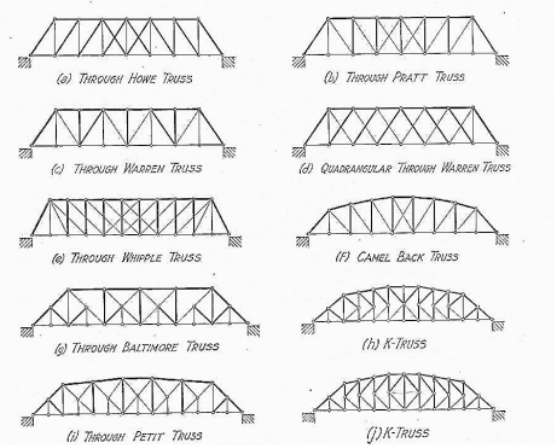
**2 Timber Truss Bridge Engineering**

**2.1 Truss Bridge.** Truss bridge consists of two main frames connected by girder and lateral stiffner. It has a triangular pattern fastened by bolts thus making the sctructure more stable. Truss bridge usually used for span of 20 to 375 m. Compared to other bridges, this bridge has higher stiffness value for the same length of span. In addition, it required less amount of material to pframeuce the same rigidity. This is possible because of the efficient truss configuration because of the loads supported axially by the frame in the structure so that the axial forces of the frame can be maximally utilized. An example of truss bridge component can be seen in figure 1.



**Figure 1.** Component of truss bridge (Source: Chen dan Duan, 1999)

Truss bridge has many types because m<sup>25</sup> experts are developing this type of bridge. In this research will be used warren truss. According to Ketchum in his book *Design of Highway Bridge*, several types of truss bridge as in figure 2.



**Figure 2.** Types of truss bridge (Source: Milo S, 1920)

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## 2.2 Laminated veneer lumber.

LVL (Laminated Veneer Lumber) is one of the promising alternative, because it is made from lower quality wood that processed to be used as a more quality wood. Technology utilization of engineered wood as a material of structural components in construction of engineered wood buildings in earthquake prone areas has the potential to fast-growing-wood from Industrial and Community of Plantation Forest (Junjunan, 2014).



Figure 3. Laminated veneer lumber

## 2.3 Loads of pedestrian bridge

Pedestrian bridge is a bridge designed for pedestrians and also include light vehicles such as bicycles, carts, animal-drawn vehicles, and motorcycles. The loads used in a pedestrian bridge modeling are dead load, live load, wind load, and earthquake load. Dead load is load that come from the bridge or section of the bridge that being reviewed, including any additional elements considered to be a single unit. Live load is the load that come from pedestrians, light vehicles, and farm animals. In this research, the bridge designed to be able to pass the pick-up truck. Some specifications related to the calculation and design of wooden bridge structure refers to Design Specification for Wood Construction (SNI 7973:2013), Bridge Loads (SNI 1725:2016), and for earthquake loads refer to Seismic Design Standards for Bridges (SNI 2833:2008).

2.3.1 *Dead Load.* Dead load is a permanent load that acts on the structure, it comes from the weight of its own structure from the weight of the truss frame, girder, and bridge deck. The bridge weight has been calculated automatically by the program, without manual input.

2.3.2 *Live Load.* Live load is a non-permanent and fluctuating load that works on the bridge deck, it comes from pedestrians and light vehicles. Because this bridge operates as an emergency bridge and earmarked for pedestrian. It is a distributed load and centered line load with 50% of design load. (Puslitbang Jalan and Jembatan, 2015). So the pedestrian load is 4.5 kPa that works on the bridge floor, and centered line load in the middle span is 24.5 kN/m.

2.3.3 *Wind Load.* Wind load works on the bridge structure and designed in extreme conditions, where the wind speed at this condition is 30 m/s if the location is more than 5 km from sea shore. The amount of wind load is calculated using:

$$TEW = 0,006 C_W V_w^2 A_b \quad (1)$$

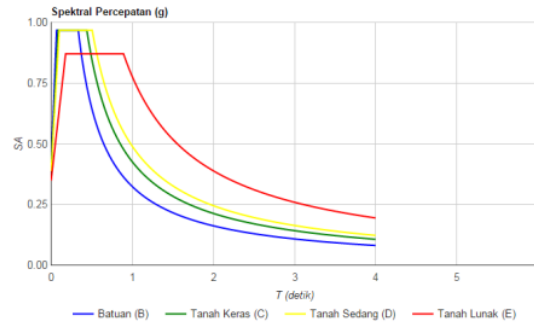
where:

$V_w$  = wind loads [m/s],

$C_W$  = drag coefficient,

$A_b$  = area equivalent to the side of the bridge [m<sup>2</sup>].

2.3.4 *Seismic Load.* Seismic loads are calculated based on PGA (Peak Ground Accelerations) in Indonesia Earthquake Hazard Map 2012 for Bandung. The method of seismic analysis using dynamic response spectrum. The design spectrum response curve for all soil types in Bandung is as shown in figure 4.



**Figure 4.** Response spectrum curve for Bandung (Source: <http://puskim.pu.go.id>, 2016)

Response spectrum function based on design response spectrum parameters for earthquake with soft soil categories to analyze the structure dynamically due to earthquake in Bandung, the design response spectrum parameter for soft soil of Bandung city can be seen in table 1.

**Table 1.** Design response spectrum parameter for soft soil of Bandung

Variable	Value	Variable	Value
$PGA$ (g)	0,577	$PSA$ (g)	0,519
$S_s$ (g)	1,450	$S_{MS}$ (g)	1,305
$S_1$ (g)	0,486	$S_{M1}$ (g)	1,166
$C_{RS}$	0,977	$S_{DS}$ (g)	0,870
$C_{R1}$	0,905	$S_{D1}$ (g)	0,777
$F_{PGA}$	0,900	$T_0$ (detik)	0,179
$F_A$	0,900	$T_S$ (detik)	0,893
$F_V$	2,400		

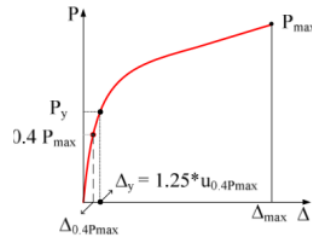
#### 2.4 CSIRO method of proportional point determination

Methods for determining the point or burden of proportional limit or often called the yielding point for the experimental test results in the laboratory are several ways, i.e. Karacabeyli and Ceccoti, CEN, CSIRO, EEEP, Yasumura and Kawai, and 5% Offset Method. In this research will be used CSIRO method. The schematic model of proportional point determination for the CSIRO method is shown in figure 5.

The steps for determining the proportional load with the CSIRO method are as follows:

- Create a graph between load and deformation, with X-axis as deformation and Y-axis as load.
- Calculate 40% of the maximum load and pull the horizontal line until it is tangent to the curve.
- Read the deformation at the point of the tangent line.
- Multiply the number of deformations by 1,25 and plot the number of multiplications on the Y axis.
- Drag a vertical line at the value of the multiplication until it is tangent to the curve.
- Read the load at the point of the tangent line and that is the point of proportionality.





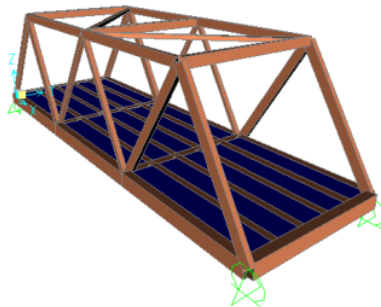
**Figure 5.** CSIRO Method of proportional point determination (Source: Munoz, 2007)

### 3. Research methodology

**3.1 Wood Mechanical Properties Testing.** Wood mechanical properties is a data for structural modeling, without this data modeling will not be possible. Therefore, to obtain accurate wood mechanical data and in accordance with the wood material used, testing is done in the laboratory. These requirements, tools and test methods refer to applicable Indonesian National Standard. Mechanical properties tested by considering which data will be used in the modeling and calculation, the tests are compressive strength test of wood (SNI 03-3958-1995), bending test of wood (SNI 03-3959-1995), shear test of wood (SNI 03-3400-1994).

#### 3.2 Bridge modelling

Bridge modelling includes defining material from laboratory test data, defining the size and shape of the frame, and loads the bridge frame. The extrude view of the bridge model is shown in figure 6.



**Figure 6.** Extrude view of the bridge (Pangestu, L., 2017)

#### 3.3 Structural analysis

Analysis of this structure can be done if the bridge modeling is completed and continued by running the structure in software. Structural analysis aims to determine the behavior of structures and forces acting on the bridge due to the work load. Output of the structural analysis are frame force, moment and shear force, which will then be used to design the dimensions of the truss and girder. According to SNI 7973:2013, for truss member, the nominal tension or compression force reduced with resistant factor should be more than ultimate tension or compression force ( $\phi P_n > P_u$ ). For girder, the nominal bending moment and shear force reduced with resistant factor should be more than ultimate bending moment and shear force ( $\phi M_r > M_u$  and  $\phi V_r > V_u$ ).

#### 3.4 Design of frame and wood connection

Calculation and analysis to design frame dimensions and wood connection, refers to the Design Specification for Wood Construction (SNI 7973: 2013). Failure of the connection system could be

caused by failure of connected members or failure of fasteners, such as fracture due to shear on fasteners. Number of fasteners should be designed to resist this failure

$$\phi F_{nv} A_b n_b > P_u \tag{2}$$

where:

- $\phi$  = resistance factor,
- $F_{nv}$  = nominal shear strength of fastener [MPa],
- $A_b$  = fastener cross area [mm<sup>2</sup>],
- $P_u$  = ultimate tension or compression force [N],
- $n_b$  = number of fasteners.

### 3.5 Check deflection

Maximum deflection at middle of span obtained from SAP2000 in *Deform Shape Fiture* with amount of 10.12 mm. In SNI 7973:2013 sub chapter 2.4, to fulfill the structure comfort criteria, a structure must have smaller deformation/displacement than allowed deflection. Allowed deflection for expose to weather frame is:

$$\delta_{max} < \frac{1}{700} l \tag{3}$$

Since the deflection of the bridge under dead and live loads of 10,12 mm less than the allowed deflection of 12,86 mm, then the bridge satisfies the deflection requirement.

## 4. Data and analysis structure

**4.1 Mechanical properties of laminated veneer lumber.** From laboratory test results, mechanical properties of LVL such as compressive strength of parallel fiber, flexural bending, and shear strength are obtained. Usually, the wood tensile strength is greater than the compressive strength, then the value of tensile strength refers to the compressive strength. Test results obtained value of compressive strength of 13.85 MPa with modulus elasticity of 3,998 MPa, bending strength of 32.04 MPa with E of 10,626 MPa, and shear strength of 2.87 MPa (Pranata, Y.A., et al, 2017).

**4.2 Output shear force diagram and moment bending diagram in SAP2000.** Based on the result of analysis, maximum deflection occurred at 10.12 mm, while the allowable deflection is 12.85 mm, it means allowable deflection condition is fulfilled. The largest tensile force occurs on Frame 66 is 116.065,83 N, the biggest compressive force occurs as seen in figure 7 that is equal to -119.682,64 N. The biggest moment occurs on Frame 40 is 5,021,378 Nmm. As for the maximum shear force also occurs on Frame 40 that is 14,648,33 N. These maximum forces will be used as a reference to design the dimensions of the truss frame and its connection. Names of the truss frame 1 can be seen in figure 8, while names of the girder in Figure 8. The result of force diagram of frame is shown in figure 10, while 3D moment diagram results are shown in figure 11.

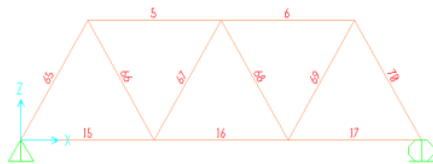


Figure 7. Names of the truss frame 1

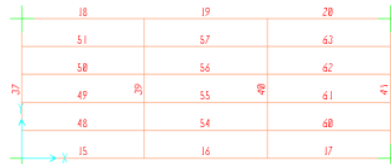
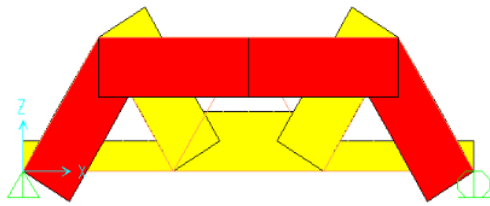
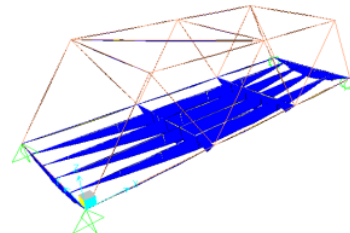


Figure 8. Names of the girder beam





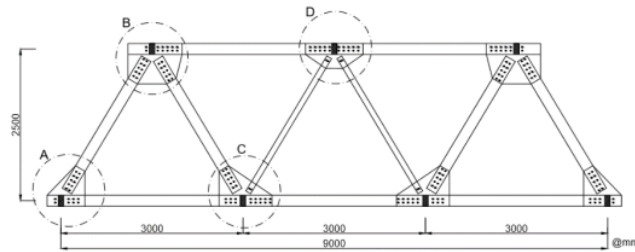
**Figure 9.** Force diagram of frame



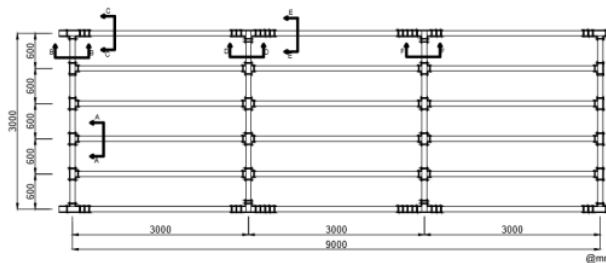
**Figure 10.** 3D Bending moment diagram

**4.3 Dimension of frame and girder**

Frame dimension used refers to the availability of LVL timber which provided by the manufacturer [13]. The size that provided by the manufacturer is multiple of 9 cm, the example size can be used are 9 cm x 9 cm, 9 cm x 18 cm, 18 cm x 18 cm, and 18 cm x 27 cm. The results of analysis, the frame with the largest force used as a reference in determining the dimensions of the frame. The largest tension member is located on the Frame 66 with the dimension 9 cm x 18 cm. The largest compression member is on the Frame 3 with the dimension 9 cm x 18 cm, meanwhile the frame with no force will be used dimension 9 cm x 9 cm. The greatest moment among all girder frame occurred in frame 40, then after that got the dimension of all girders are 9 cm x 18 cm. The side view of the truss bridge frame is shown in figure 11, while the top girder girder is shown in figure 12.



**Figure 11.** Side view of the frame



**Figure 12.** View of girder

Principles in designing compression and tension members are  $\phi P_n > P_u$  and for girders  $\phi M_n > M_u$ , as summarize on table 2, table 3, and table 4, respectively.

**Table 2.** Compression members design

Member	3	4	5	6	65	70	89	94
Ultimate axial load ( $P_u$ ) (N)	119683	118754	119607	118412	116603	115442	115483	116074
Design axial strength ( $\phi P_n$ ) (N)	120900	120900	120900	120900	120900	120900	120900	120900
Section capacity ratio	0,99	0,98	0,99	0,98	0,96	0,95	0,96	0,96
Check $\phi P_n > P_u$	OK	OK	OK	OK	OK	OK	OK	OK

**Table 3.** Tension members design

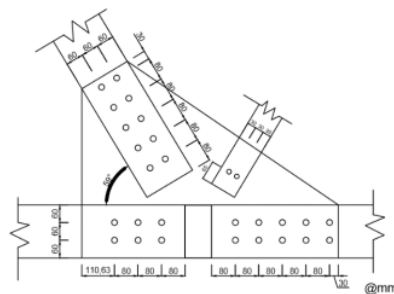
Member	15	16	17	18	19	20	69	90
Tension Strength ( $P_u$ ) (N)	78479	100467	75457	69567	109837	77836	114904	114740
Design tension strength ( $\phi P_n$ ) (N)	283295	283295	283295	283295	283295	283295	283295	283295
Section capacity ratio	0,28	0,35	0,27	0,25	0,39	0,27	0,41	0,41
Check $\phi P_n > P_u$	OK	OK	OK	OK	OK	OK	OK	OK

**Table 4.** Girder design

Batang	39	40	41	55	56	57
Factored moment ( $M_u$ ) (N.mm)	5018928	5021378	2854330	3195223	3195076	3127896
Design flexural strength ( $\phi M_n$ ) (N.mm)	20627108	20627108	20627108	20627108	20627108	20627108
Section capacity ratio	0,24 24	0,24	0,14	0,15	0,15	0,15
Check $\phi M_n > M_u$	OK	OK	OK	OK	OK	OK

#### 4.4 Design of connection

Refers to the greatest force in frame, the connection using bolt 20 mm, thick of steel plate 10 mm, number of bolts consist of 10 pieces made two lines with amount of 5 bolts one line. Steel connection details can be seen on figure 13.



**Figure 13.** Detail of connection C

#### 5. Conclusions

From the design of LVL pedestrian truss bridge, it can be concluded that with frame dimensions of 9 cm x 9 cm and 9 cm x 18 cm, the design of bridge is strong enough to withstand the working-loads. This is indicated by the fulfillment of the maximum bridge deflection, the truss frame design and girders are able to withstand the shear force and bending moment acting on the frame, as well as the connections designed able to distribute the force on trusses and girder beams.

### References

- [1] Badan Standardisasi Nasional. (2008). *SNI 2833:2008 Earthquake Planning Standards for Bridges*. Jakarta: Badan Standardisasi Nasional.
- [2] Badan Standardisasi Nasional. (2013). *SNI 7973-2013 Design and Specification for Wood Construction*. Jakarta: Badan Standardisasi Nasional.
- [3] Badan Standardisasi Nasional. (2016). *SNI 1725-2016 Specification of Bridge Loads*. Jakarta: Badan Standardisasi Nasional.
- [4] Chen, W.F., & Duan, L. (1999). *Bridge Engineering Handbook*. Washington DC: CRC Press.
- [5] Junjuran, M. (2014, September 2). *Technology Earthquake Resistant House with LVL*. Retrived June 15, 2017, from puskim.pu.go.id: <http://puskim.pu.go.id/teknologi-rumah-tahan-gempa-dengan-struktur-kayu-laminasi-lvl/>
- [6] Ketchum, M. S. (1920). *The design of highway bridges of steel, timber and concrete*. New York: McGraw-Hill.
- [7] Munoz, W., Salenikovic, A., Mohammad, M., & Quenneville, P. (2007). *Determination of Yield Point and Ductility of Timber Assemblies: In Search for a Harmonised Approach*. 7-9.
- [8] Pusat Penelitian dan Pengembangan Pemukiman. (2011). Retrived June 20, 2017, from *Design of Response Spectrum in Indonesia*: [http://puskim.pu.go.id/Aplikasi/desain\\_spektra\\_indonesia\\_2011/](http://puskim.pu.go.id/Aplikasi/desain_spektra_indonesia_2011/)
- [9] Pusat Penelitian Jalan dan Jembatan. (2015). *Presentation Report and Research of Temporary Bridge with Wood Material*. Bandung: Kementerian PUPR.
- [10] Pranata, Y.A., Herbudiman, B., Valiantine, N., Pangestu, L., Kawa, F. (2017). *Experimental Report of Mechanical Properties of Sengon-Rubber LVL*. Bandung: Universitas Kristen Maranatha Bandung.
- [11] Pangestu, L. (2017). *Perencanaan Jembatan Rangka Batang dengan Kayu LVL*. Bandung: Institut Teknologi Nasional Bandung.

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