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Analysis and calculation of wooden framework structure by using Structural Analysis Program (SAP)-2000 and method of joint

S P Tampubolon* and A S Mulyani

Civil Engineering, Universitas Kristen Indonesia, Jakarta, Indonesia

*sudarno.tampubolon@uki.ac.id

Abstract. Find out the force of the structure wooden framework is one indication in determining the dimensions of compression chord, tension chord, diagonal chord, and vertical chord. The value of each chord force is the main requirement in the planning dimension and joints connections in the structure planning of the wooden framework. Analysis/calculation of each of the chord forces in the wooden framework (tension chord, compression chord, vertical chord, and diagonal chord) using a method of joint and Structural Analysis Program (SAP-2000). Wooden framework span is 7 m, $(\alpha) = 30^\circ$, and the number of compression chord is 6. Results of the two methods will show the value of each of the chord force structures, the value of the chord force compared to see the accuracy of the structural analysis program. Analysis and calculation found the ratio of maximum and minimum value for each chord force using a method of joint and structural analysis program are 0.15 and 0. Based on research results, a Structural Analysis Program (SAP-2000) can be used to design and analyze a wooden framework, to simplify and save time in planning the structure of the wooden framework.

1. Introduction

Good and proper structural design is one of the main requirements in designing building structures. One of them is the roof/easel planning used in high and low-level buildings. The roof is a part of the building structure used to cover the influence of rain, dust, wind, heat, and protection. For that reason, in its position as the topmost building structure of residential building construction or high-rise building, the roof relates to the construction of the easel, where the arrangement of the trusses, press, pull, diagonal, and vertical chord functions to receive its own weight load that is the burden of the easel and upholstery used which are vertically directed and then forwarded to the beam/ring beam continued on the column and foundation. Generally, the construction of the easel/roof truss consists of a series of trunks that form a triangle, where each arrangement of vertical, diagonal, tensile, and compressed truss must have strong and sturdy ties that will be able to bear the burden of acting on the easel without changing. shape, and the selection of material that is good and right. Roof/easel construction is building construction that functions to support the roof located above it. In addition, the framework of the roof/easel has a more specific function, among others, is to receive its own weight, namely the weight of the easel and the coating material (roof/tile). In general, the roof truss used in Indonesia is a truss with wooden construction (wooden framework). But along with the development of industry and technology today many roof construction providers provide lightweight steel truss. In this case, we can also see that the use of wooden roof construction (wooden framework), as well as lightweight steel truss, have their respective advantages and disadvantages in holding the forces acting on the structure, [1]. Where is known that the steel is very good in holding the tensile force and is weak against the compressive force,



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while the wood is strong against the compressive and weak against the tensile force. The value of each bar's force is the main requirement in the planning dimension and joints connections in the structure planning of the wooden framework [2]. Analysis/calculation of the value of each of the bars force in the wooden framework (tension chord, compression chord, vertical chord, and diagonal chord) using the method of joint and structural analysis program (SAP-2000). All the results of the method of joint and structural analysis program (SAP-2000) will be compared to show the accuracy of the analysis.

2. Literature review

2.1. Wood roof frame truss

Analysis of the forces in a good and right is very necessary for the planning of the structure of the easel to determine the dimensions/size of the rod pull, press, vertical, and horizontal [3],[4]. This also affects the type of joint that will be used in easel structure planning [5]. In the world of construction, limitations in the use of wood materials occur because of the limitations of natural wood, and wood with high quality/strength decreases. For this reason, connection technology and composite materials are very important in the design of wooden structures [1]. Figure 1 shows the wooden framework with detailed structure.

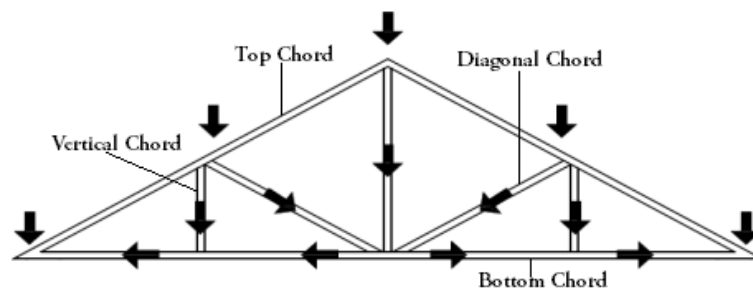


Figure 1. Wooden framework [4].

2.2. Bottom chord/ tension chord

In planning the structure of the roof/easel it is important to calculate/analyze the magnitude of the force acting on each rod press, pull, diagonal, and vertical, from the calculated value already obtained it will be determined the amount of wood permit tension on each element of the trunk easel [6]. The wood permit voltage can be different if the direction of the fiber and the direction of the style is different. Thus the tension of a wood permit is highly determined by the quality of the wood. For this reason, it is necessary to calculate good and correct tensile rod force calculations because of the value of these calculations will be used in determining the size/dimension of the rod to be used.

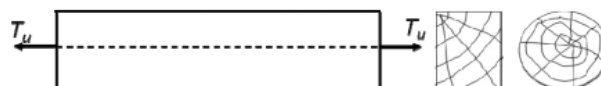


Figure 2. Pull rod.

2.3. Top chord/ compression chord

In addition to the pull rod, there are also compressive rod elements found in the roof truss/easel construction. Compressive rod is a structural element that accepts the normal force in the form of compressive force, the principle is almost the same as the pull rod, in determining the dimensions to be used [3].



Figure 3. Press bar.

2.4. Vertical chord

The vertical chord is a truss structure on the wooden framework which has the function to withstand the push load. The force that occurs will result in bending the stem if the stem is unable to withstand the force exerted. The value of the buckling factor depends on the condition of the supporting structure and its slimmness. For this reason, it is necessary to analyze the vertical chord that is good and right in determining the forces at work, because the value obtained will be used in determining the dimensions of the chord used in planning the wooden framework and the joints used [5].

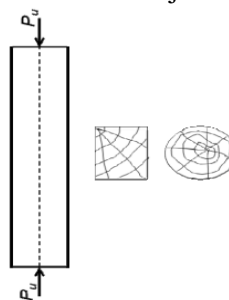


Figure 4. Vertical chord.

3. Methods

This research used two methods to analyze the wooden framework. That method in between Structural Analysis Program (SAP-2000) and Method of joint.

3.1. Structural Analysis Program (SAP-2000)

Structural Analysis Program (SAP-2000) is a software that is used in analyzing the forces in the wooden framework. The internal forces calculated using Structural Analysis Program (SAP-2000) are tensile chord, compressive chord, diagonal chord, and vertical chord. To calculate the trunk forces that occur in the framework of the easel using the Structural Analysis Program (SAP-2000), we must first calculate the loading of the truss by SNI. From the loading calculation data, we get input into Structural Analysis Program (SAP 2000) to get the forces acting on the easel. From the simulation results that use, the value of the internal forces that have been obtained will be compared with the results of the method of joint to get a comparison of the results between the simulation Structural Analysis Program with the method of joint.

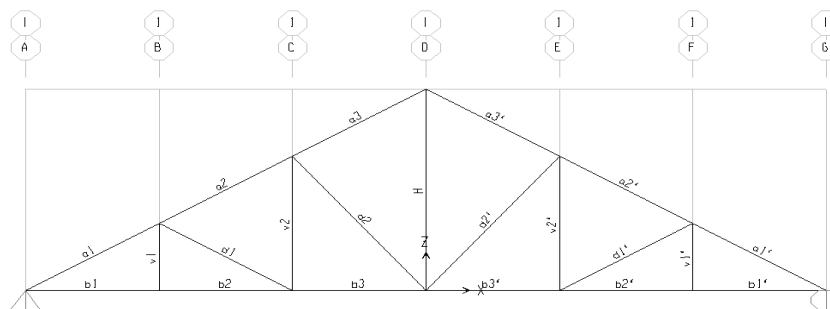


Figure 5. Modeling Wooden Framework by SAP 2000 [5],[7].

3.2 Method of Joint

In the roof truss construction, the forces that work must be in a balanced state at each vertex/gusset point. In this case, the external force and the chord forces that occur on the wooden framework intersect at the unknown node/gusset point can be calculated/determined using the method of joint. In this analysis at each knot/ node, a value of $\sum H = 0$ (horizontal) is obtained; $\sum V = 0$ (vertical); $\sum M = 0$ (Moment), ignored. For that in this analysis and calculation method, there are 2 equations where the value of each vertex will be searched for force the chord must only have 2 or 1 chord whose unknown chord style can only be solved using a method of joint. Thus the value of each knot point/vertex can be searched one by one to get the value of the compressive chord, tensile chord, diagonal chord, and vertical chord so that the entire construction can be known the value of each bar style.

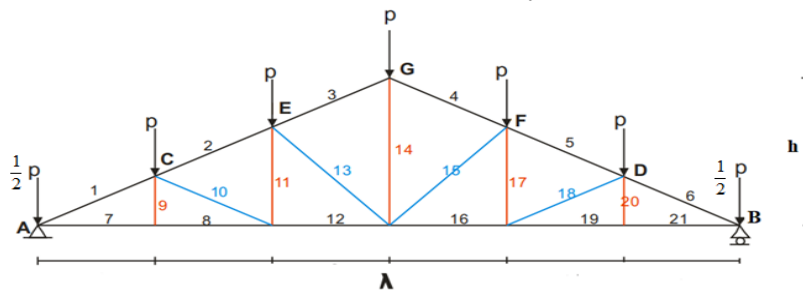
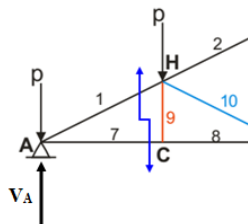


Figure 6. Modeling Wooden Framework by Joint of Method

Based on the Figure 6, found the number of joint wood roof trusses 1 and 7. Analysis by method of joint A can explained as follow:

Joint A:



$$\begin{aligned} \sum Ky &= 0 \\ RA - p - S1 \times \sin \alpha &= 0 \\ \sum Kx &= 0 \\ S7 - S1 \times \cos \alpha &= 0 \end{aligned}$$

Figure 7. Joint A

4. Results and discussion

4.1. Calculation of Loading and Design Details of the wooden framework

In planning the construction of a wooden framework, the connection/ relation between the pull/ tension chord, the push/ compression chord, the diagonal chord, and the vertical chord must properly be considered [8],[9]. That is why, the loading plan must be following applicable standards, namely the Indonesian National Standard (SNI), the angle of slope used ranges from 30° - 35°. The following will explain the loading design (live load and dead load) used in planning the wooden framework in this research. The data as follows: Long span of a wooden framework (L) = 7 m, the distance between the wooden framework (B) = 3 m, the angle of the wooden framework (α) = 30°, roof Cover weight (tile) = 50 kg/m² (PPIUG, page 12), ceiling weight/ number of chord press up (n) = 18 kg/m²/ 6, wood specific gravity (SG) = 650 kg/m³, order trunks use/ gording size = boards/ block (7/14) cm [5][9][10][11].

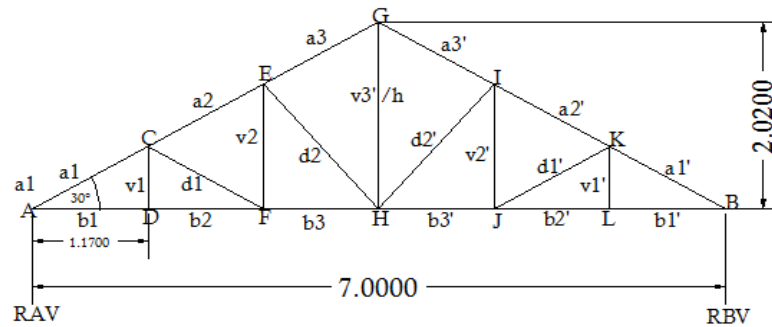


Figure 8. Calculation of Loading and Design Details of the wooden framework

Design loading of wooden framework:

- a. Loading of wooden framework / The weight of the wooden framework

$$= \frac{(\text{bottom chord} + \text{top chord} + \text{diagonal chord} + \text{vertical chord}) \cdot \text{specific gravity} \cdot \text{size of wooden framework}}{\text{Number of Bars Press Up (n)}}$$

$$= \frac{(7.0000 + 8.0994 + 6.2676 + 8.08) \cdot 650 \text{ kg/m}^3 \cdot 7.14 \cdot 10^4}{6} = 31,26 \text{ kg}$$

- b. Weight of gording = $\{(7 \times 14) \text{ cm} / 10000\} \times 650 \text{ kg/m}^3 \times 3 \text{ m} = 19,11 \text{ kg}$

- c. Weight of roof = $3 \text{ m} \times 1.3499 \text{ m} \times 50 \text{ kg/m}^2 = 202,485 \text{ kg}$

- d. Live load / people of load = $(100 \text{ kg} / 6) = 16,6 \text{ kg}$

Total Weight = 269,455 kg

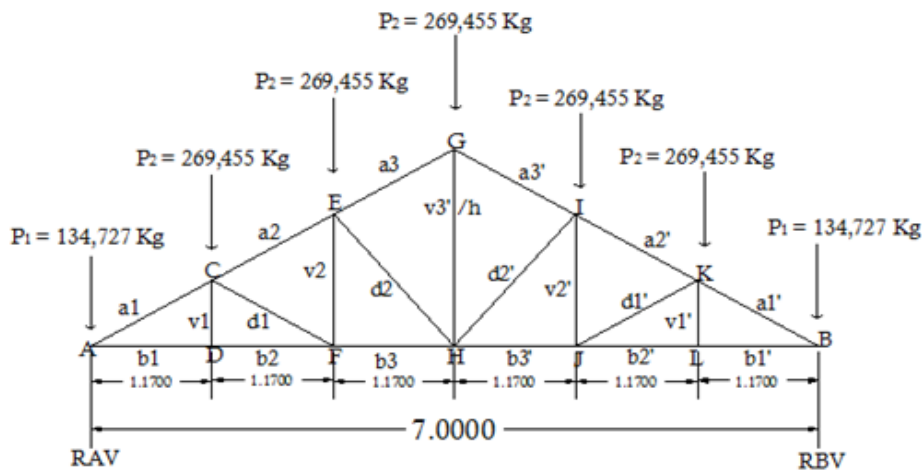


Figure 9. Design loading of wooden framework.

4.2. Analysis/ calculations of Structural Analysis Program (SAP-2000) and method of joint

From the results of calculations that have been done using Structural Analysis Program (SAP-2000) and the method of joint obtained the results for each rod force. Table 1. Show upper/ compression chord, Table 2. Show lower/ tension chord, Table 3. Show diagonal chord, and Table 4. Show vertical chord.

Table 1. Upper/ compression chord.

No	Code of Compression Chord	SAP- 2000 V-14 (kg)/ (A)	Method of Joint (kg)/ (B)	Ratio = B - A
1	a1	- 1347,64	- 1347, 582	0,05
2	a2	- 1078,11	- 1078,11	0
3	a3	- 808,58	- 808,52	0,06
4	a3'	- 808,58	- 808,52	0,06
5	a2'	- 1078,11	- 1078,11	0
6	a1'	- 1347,64	- 1347, 582	0,05

Table 1. showed a value comparison of upper/ compression chord between SAP-2000 and Method of joint with the value of ratio calculation 0-0.06.

Table 2. Lower/ tension chord.

No	Code of Tension Chord	SAP- 2000 V-14 (kg)/ (A)	Method of Joint (kg)/ (B)	Ratio = B - A
1	b1	+ 1167,19	+ 1167,14	0,05
2	b2	+ 1167,19	+ 1167,14	0,05
3	b3	+ 933,75	+ 933,79	0,04
4	b3'	+ 933,75	+ 933,79	0,04
5	b2'	+ 1167,19	+ 1167,14	0,05
6	b1'	+ 1167,19	+ 1167,14	0,05

Table 2. showed a value comparison of lower/ tension chord between SAP-2000 and Method of joint with the value of ratio calculation 0.04-0.05.

Table 3. Diagonal chord.

No	Code of Diagonal Chord	SAP- 2000 V-14 (kg)/ (A)	Method of Joint (kg)/ (B)	Ratio = B - A
1	d1	- 269,53	- 269,57	0,04
2	d2	- 356,51	- 356,36	0,15
3	d2'	- 356,51	- 356,36	0,15
4	d1'	- 269,53	- 269,57	0,04

Table 3. showed a value comparison of diagonal chord between SAP-2000 and Method of joint with the value of ratio calculation 0.04-0.15.

Table 4. Vertical chord.

No	Code of Vertical Chord	SAP- 2000 V-14 (kg)/ (A)	Method of Joint (kg)/ (B)	Ratio = B - A
1	V1	0	0	0
2	V2	+134,73	+ 134,78	0,05
3	V3 / h	+538,91	+ 538,886	0,02
4	V3'/h	+538,91	+ 538,886	0,02
5	V2'	+134,73	+ 134,78	0,05
6	V1'	0	0	0

Table 4. showed a value comparison of vertical chord between SAP-2000 and Method of joint with the value of ratio calculation 0 -0.05.

5. Conclusion

Some of the conclusions that we can get from the results of simulation wooden framework using SAP-2000 and Method of joint are:

- Simulation Structural Analysis Program (SAP-2000) can predict all the value of member wooden framework based on simulation Structural Analysis Program (SAP-2000) and method of joint all the value of roof truss relatively the same
- From the analysis and calculation found the ratio of maximum and minimum value for each bar force using the calculation method of joint and Structural Analysis Program (SAP-2000) are 0.15 and 0.
- By using Structural Analysis Program (SAP-2000) simulation and method of joint all the value of roof truss relatively the same, this case made simplify to predict dimension of upper/ compression chord, lower/ tension chord, diagonal chord, and vertical chord.

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