COMPARATIVE ANALYSIS OF LIGHT STEEL ROOF FRAMES AND WOODEN ROOF FRAMES BASED ON STRUCTURAL STRENGTH AND CONSTRUCTION COSTS (CASE STUDY: EMERGENCY OPERATIONS CENTER BUILDING AT JUWATA TARAKAN AIRPORT)

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ABSTRACT

The Emergency Operations Center (EOC) building is a strategic facility that functions as a coordination and control center in emergency situations. Its purpose is to design a roof truss structure that meets safety and structural strength standards in accordance with Indonesian National Standards. The results of modeling the lightweight steel and wooden roof frames using SAP 200 V22 software show that the lightweight steel roof frame trusses using CNP 100 x 50 x 20 x 3.2 mm and CNP 50 x 35 x 20 x 2 mm purlins. The wooden roof frame uses Class II meranti wood with dimensions of 8/12. The lightweight steel frame experienced the largest deflection of 1.754 mm, while the wooden structure recorded a larger deflection value of 2.137 mm. The ratio of lightweight steel is 0.8, while wood is 0.312. The cost comparison for lightweight steel results in a total budget of Rp66,452,530.00, while wood reaches Rp70,431,061.

Keywords: *Juwata Tarakan Airport, Steel Roof Frame, Timber Roof Frame, EOC, RAB.*

1. INTRODUCTION

After taking off from Juwata Airport in Tarakan, North Kalimantan, on March 8, 2024, a Smart Air cargo plane lost communication. At 09:25 WITA, the aircraft was scheduled to land in Binuang, Krayan, and Nunukan. Basarnas collaborated with the police, KKP, the airport, Airnav, and other relevant organizations. To determine the aircraft's location and direction, they also conducted a search using a floating area. The coordination center was located in the administrative building of Juwata Airport in Tarakan. The coordination center location is not conducive due to overcrowding and insufficient space. The coordination center, which should be located at the Emergency Operations Center (EOC), had to be established at the administrative building due to the absence of an Emergency Operations Center (EOC) facility at Juwata Airport.

Based on Law No. 1 of 2009 concerning Aviation and Ministerial Decree No. 8 of 2010 concerning the National Aviation Safety Program, every airport is required to have an Emergency Operation Center (EOC) facility. This facility is a requirement to support the implementation of the Airport Emergency Plan (AEP) for airport certification. The Emergency Operations Center (EOC) plays a crucial role in every phase of emergency management, from serving as a coordination center during incidents to facilitating and directing recovery/cleanup efforts. Every airport operator is required to provide an Emergency Operations Center (EOC) as a facility for handling emergency situations. Based on the above issues, a study was conducted to analyze the structure of lightweight steel roofs and wooden frames in the construction of the Emergency Operation Center (EOC) building.

The problem statement is as follows:

1. How to plan the lightweight steel roof frame and wooden roof frame of the Emergency Operations Center (EOC) building at Juwata Airport?
2. How to load and model the lightweight steel roof frame and wooden roof frame structures using SAP2000 V22 software?
3. What are the results of the cost comparison analysis for constructing the roof structure of the Emergency Operations Center (EOC) building at Juwata Airport using lightweight steel and wood?

2. METHODS

The implementation of this research required several data collected from the airport as well as some data calculated based on applicable standards and regulations, resulting in the following data:

Building Name : Emergency Operations Center (EOC) Building Location: Juwata Tarakan Airport

Building Function : The primary function of the building is to provide services, disseminate information, and implement initial response plans during emergency situations at the airport.

Number of Floors : 1

Building Height : 4 meters

Roof Frame Height : 3.17 meters

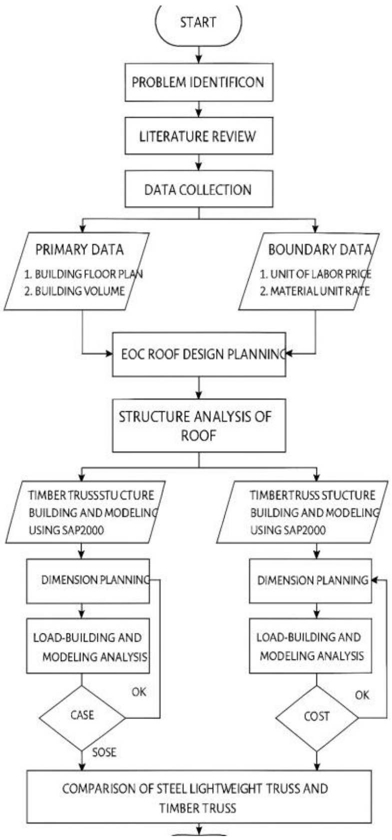


Figure 1 Flow Chart

3.RESULT AND DISCUSSION

1. Roof Frame Design

The following presents the planning data for the lightweight steel roof frame structure that will be used as the basis for the analysis and calculation process.

Material = Channel C (Non Parallel Channel)

Rafter span = 11 m Rafter spacing = 1 m
Girder spacing = 1 m
Roof pitch = 30°
Roof height = 0.5 x 11 x tan (30°)
=3.17 m

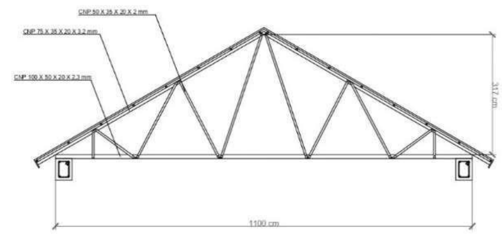


Figure 2 Lightweight Steel Roof Truss

The following presents the planning data for the wooden roof truss structure which will be used as the basis for the analysis and calculation process.

Material	= Meranti Wood (Grade II Wood)
Span of the truss	= 11 m
Spacing of horses	= 2,5 m
Wording distance	= 1 m
Roof slope angle	= 30°
Roof height (30°)	= 0.5 x 11 x tan
	= 3,17 m

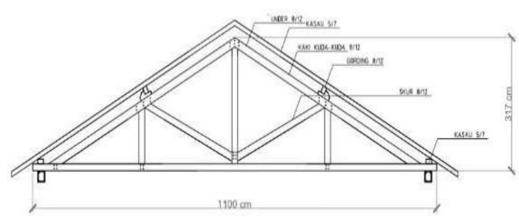


Figure 3 Wood Roof Frame

2. **Loading**

1. Additional Dead Load (SIDL)
   1. Roof cover load
      = 4.55 kg/m2 x1 m x 1 m

      = 4.55 kg/m

2. Live Load
1. Rain Load (SNI 1727:2020)
   = 20 kg/m2 x 1 m x 1 m

   = 20 kg/m

2. Worker's live load
   = 100 kg

3. Wind Load (SNI 1727:2020)
   Category I = 38.3

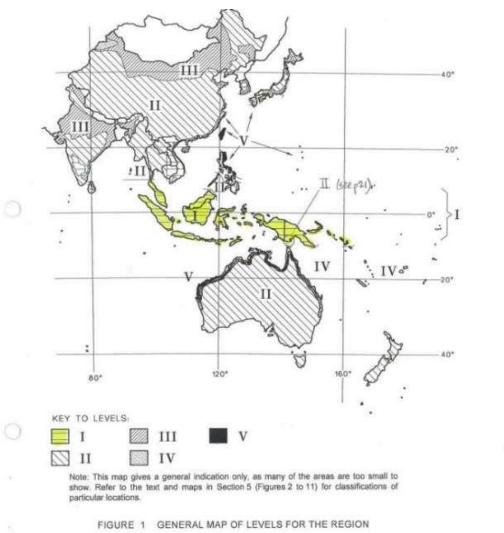


Figure 4 Wind speed map

Risk Category	Periode Ulang	Wind Speed
I	300	38.3
II	700	40.9
III	1700	43.4
IV	1700	43.4

Figure 5 Wind speed table

KASUS BEBAN A

Sudut atap θ (derajat)	Permukaan Bangunan Gedung							
	1	2	3	4	1E	2E	3E	4E
0-5	0,40	-0,69	-0,37	-0,29	0,61	-1,07	-0,53	-0,43
20	0,53	-0,69	-0,48	-0,43	0,80	-1,07	-0,69	-0,64
30-45	0,56	0,21	-0,43	-0,37	0,69	0,27	-0,53	-0,48
90	0,56	0,56	-0,37	-0,37	0,69	0,69	-0,48	-0,48

KASUS BEBAN B

Sudut Atap θ (derajat)	Permukaan Bangunan Gedung											
	1	2	3	4	5	6	1E	2E	3E	4E	5E	6E
0-90	-0,45	-0,69	-0,37	-0,45	0,40	-0,29	-0,48	-1,07	-0,53	-0,48	0,61	-0,43

Figure 6 Roof Wind Loading

Modeling

a. Modeling of Light Steel Roof Truss

1. Defining the lightweight steel roof truss material.

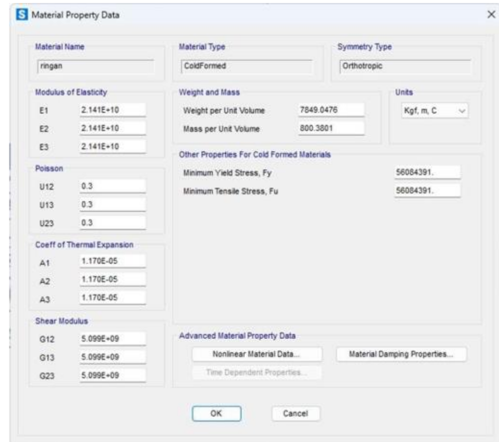


Figure 7 Definition of Mild Steel Material

2. Determining the cross-section of lightweight steel roof trusses, namely truss and gording. The data entered are the dimensions of the cross section and the quality of mild steel.

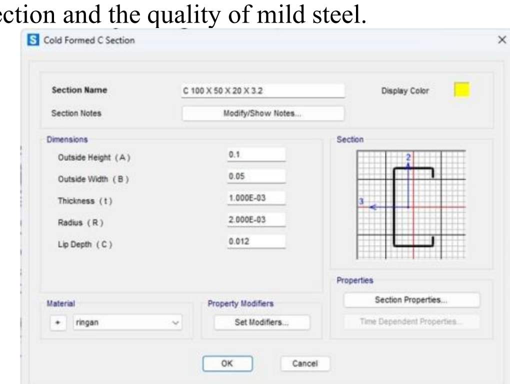


Figure 8 Definition of Mild Steel Frame

3. Entering the type of load consisting of live load (Live), structural weight (Dead), additional dead load (SIDL), and wind load (Wind).

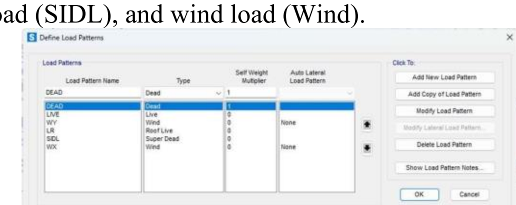


Figure 9 Mild Steel Load Definition

4. Entering the loading combination used based on SNI 1729: 2020.

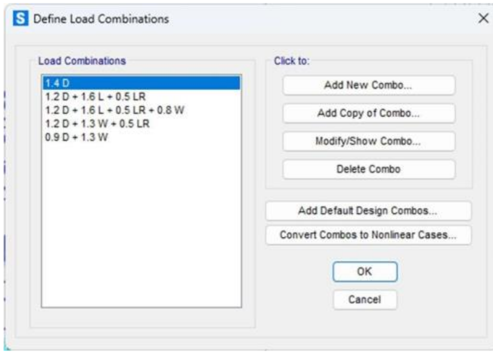


Figure 10 Mild Steel Loading Combination

5. Entering the loading on the gording, namely dead load, live load, and wind load by selecting the gording frame.

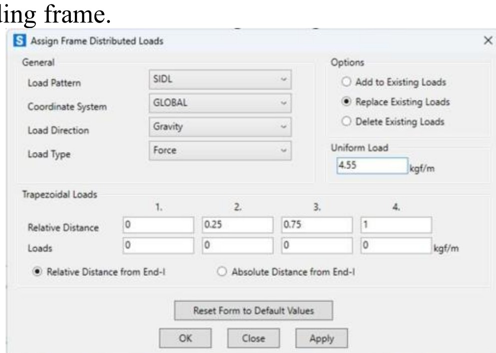


Figure 11 Loading on Lightweight Steel Gording

6. Checking the load that has been entered on the frame in the example below is an additional dead load.

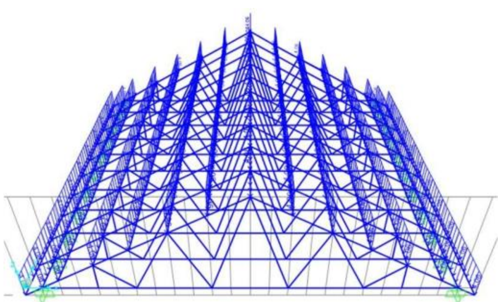


Figure 12 Additional Dead Load of Light Steel Roof Truss

7. Modeling *output*.

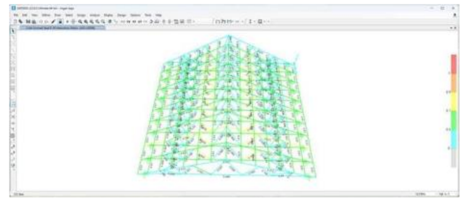


Figure 13 Lightweight Steel Loading Results

b. Timber Roof Truss Modeling

1. Define the timber roof truss material.

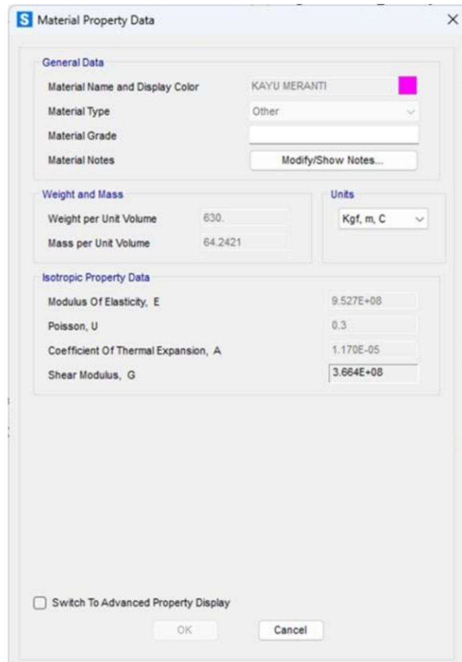


Figure 14 Wood Material Definition

2. Determining the cross section of the wooden roof truss, namely the truss and gording. The data entered are the dimensions of the cross section and the quality of mild steel.

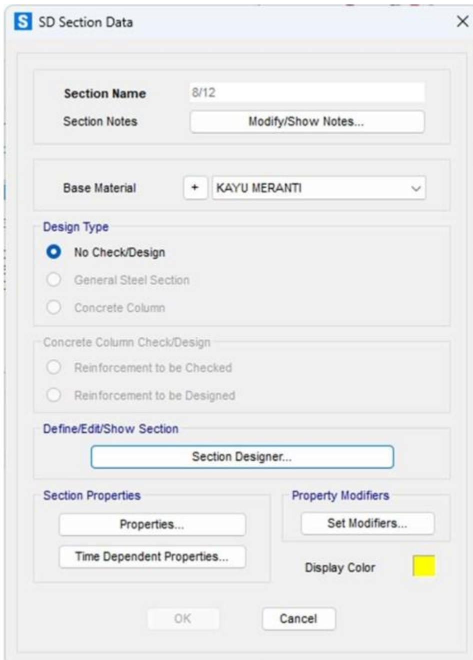


Figure 15 Timber Frame Definition

3. Entering the type of load consisting of live load (Live), structural weight (Dead), additional dead load (SIDL), and wind load (Wind).

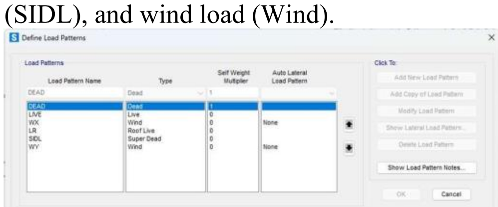


Figure 16 Timber Load Definition

4. Entering the loading combination used based on SNI 1729:2020.

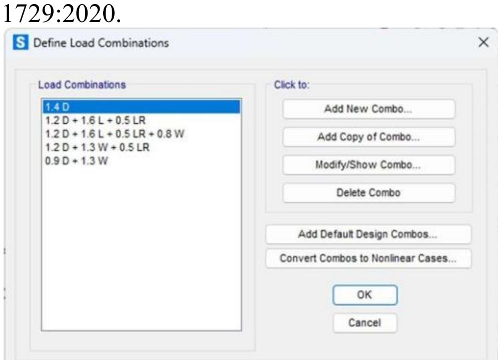


Figure 17 Timber Loading Combination

5. Entering the loading on the gording, namely dead load, live load, and wind load by selecting the gording frame.

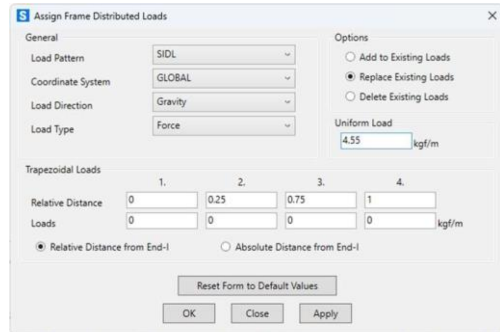


Figure 18 Loading on Wooden Gording

6. Checking the load that has been entered on the frame in the example below is an additional dead load.

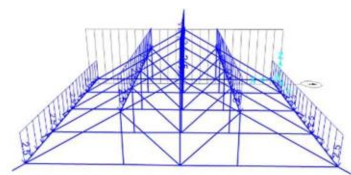


Figure 19 Additional Dead Load of Wooden Roof Frame

7. Modeling *output*.

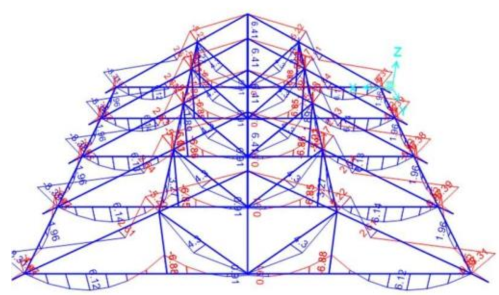


Figure 20 Wood Roof Truss Modeling

4. **Connection**

a. Mild Steel Connection

The profile used has a straight hole with a screw type of Screw 12-14 x 20. Screw diameter, df = 6.3 mm. The ring head diameter of the screw is Dk = 14.2 mm and t2 = 2 mm, t1 = 2 mm.

Yield stress capacity (fy) = 550 Mpa Tensile stress capacity (fu)= 550 Mpa

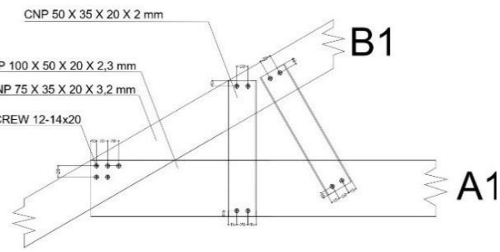


Figure 21 Mild Steel Connection

Shear capacity

Tensile rod A1

Hollowing with screws $_{t1/t2}$ = 1 ≤ 1 Bearing capacity of :

$Vb = 4{,}2\sqrt{t^3.df}\ .\ fu$ (1)

$= 4{,}2\sqrt{2^3.6{,}3}.\ 550$

$= 16399{,}373$ N

$Vb = C.t_2.d_f.fu_2$ (2)

$= (2{,}7).(2).(6{,}3).(550)$

$= 18711$ N

Due to *tiltiing* condition,

V_b = 16399.373 N

ϕV_b = 0.5 x (16399.373 N)

= 8199,6865 N

Required shear capacity of 1.25. ϕV_b

V_n = 1.25 x (8199.6865 N)

= 10249,61 N

Number of screws required:

P_u = 4671,81 N

$n_s = \frac{P_u}{V_{bn}}$ (3)

= 0.45

n_s = 2

Check the shear capacity of the screw:

$n_s.V_n$	≥ 4671,81 N
2x(10249,61 N)	≥ 4671,81 N
20499,22 N	≥ 4671,81 N (OK)

Tensile capacity

Push Rod B1

$t_1/t_2 = 1 \leq 1$

$V_b = 4{,}2\sqrt{t^3.df}\ .\ fu$ (1)

$= 4{,}2\sqrt{2^3.6{,}3}\ .\ 550$

$= 16399{,}373$ N

$V_b = C.t_2.d_f.f_{u2}$ (2)

$= (2{,}7).(2).(6{,}3).(550)$

$= 18711$ N

Because *tiltiing*,

So V_b = 16399,373 N

ϕV_b = 0,5 x (16399,373 N)

= 8199,6865 N

Required shear capacity of 1,25. ϕV_b

V_n = 1,25 x (8199,6865 N)

= 10249,61 N

Number of screws required:

P_u = 20776,77 N

$n_s = \frac{P_u}{V_{bn}}$ (3)

= 2.02

n_s = 3

Check the shear capacity of the screw:

$n_s.V_n$	≥ 20776,77 N
3x(10249,61 N)	≥ 20776,77 N
30748,83 N	≥ 18566,9 N (OK)

Tensile Capacity

Tensile rod A1

a. *Pull Out*

N_{ou} = 0,85 x 2 x 6,3 x 550

= 5890,5 N

b. *Pull Over*

N_{ov} = 1,5 x 2 x 12,7 x 550

= 20955 N

Pull out , Nt = 5890,5 N

ϕ = 0,5

ϕN_t = 0,5 x 5890,5 N

= 2945 N

Screw tensile strength required

1,25 x 2945 = 3681,25 N

Push Rod B1

a. *Pull Out*

N_{ou} = 0,85 x 2 x 6,3 x 550

= 5890,5 N

b. *Pull Over*

N_{ov} = 1,5 x 2 x 12,7 x 550

= 10477,5 N

Pull out lebih menentukan sehingga Nt = 5890,5 N

ϕ = 0,5

ϕN_t = 0,5 x 5890,5 N

= 2945 N

Screw tensile strength required

1.25 x 2945 = 3681.25 N

The installation distance between screw centers is 3D = 3 x 6.3 = 18.9 mm rounded to 20 mm.

The required installation distance between the center of the screw and the element is 1.5 D =

1.5 x 6.3 = 9.45 mm rounded to 10 mm.

b. Wood Connection

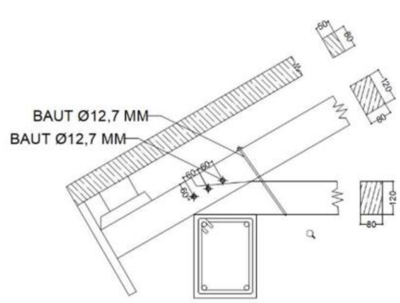


Figure 22 Wood connection

2-section connection

Using Ø½" or 12.7 mm bolts

S = 125 db3 (1 - 0.6 sin α) (4)

= 125 x 1.27 x 8 (1-0.6 sin 30)

= 889 kg

S = 250 db1 (1 - 0.6 sin α) (5)

= 250 x 1.27 x 8 (1-0.6 sin 30)

= 1778 kg

$S = 480\ d^2\ (1-0.35 \sin \alpha)$ (6)

$= 480 \times 1.27^2\ (1-0.35 \sin 30)$

= 638.70 kg

So the strength of the connection is 638.70 kg Required bolts

n $= \frac{2470.4}{638,70}$

n = 3.86

= 4 bolts

Edge spacing (1.5 D) = 19.05 mm rounded 40 mm

In-row spacing (4 D) = 50.8 mm rounded up to 60 mm

Distance between rows (1.5 D) = 19.05 mm rounded 40 mm

5. **Structure Durability Analysis**

a. *Structure Durability Analysis Mild Steel*

Table 1 Table of Ratio and Deflection of Mild Steel Structures

No	Ratio	Deflection (mm)
1	0,437	1,347
2	0,437	1,754
3	0,8	1,271
4	0,012	0
5	0,266	0,039
6	0,019	0,192
7	0,692	0,192
8	0,051	0,62
9	0,051	0,62
10	0,692	0,06
11	0,019	0,192
12	0,266	0,192
13	0,012	0
Max value	0,8	1,754

b. Timber Structure Durability Analysis

1. Tensile capacity

Pu ≤ 0.8 Ft A (8)

Pu ≤ 0.8 x 22900 x 0.0096

Pu ≤ 175.872 kN

Pu(max) = 9.57 kN

9,57 ≤ 175.872 kN (SAFE)

2. Compressive capacity

Pu ≤ 0.9 Ft A (9)

Pu ≤ 0.9 x 22900 x 0,0096

Pu ≤ 197.856 kN

Pu(max) = 5.453 kN

5.453 kN ≤ 197,856 kN (SAFE)

3. Working moment of x-axis

Mnx(major)≤ 0.85 Fb Sx (10)

≤ 0.85 x 26000 x 0.000192

≤ 4.2432 kNm

Mny(max) = 1.015 kNm

1.15 m≤ 4.2432 kNm (SAFE)

4. Y-axis working moment

Mny(*minor*) ≤ 0.85 Fb Sy (11)

≤ 0.85 x 26000 x 0.000128

≤ 2.8288 kNm

Mny(*max*) $= 1.297x\ 10^{-15}$kNm

$1.297x\ 10^{-15}$kNm≤ 2.8288 kNm

Persamaaan interaksi :

$$\frac{Pu}{\phi Pn} + \frac{Mux}{\phi Mnx} + \frac{Muy}{\phi Mny} \leq 1$$

$$\frac{9,57}{0,8\ x\ 175,872} + \frac{1,015}{0,85\ x\ 4,2432} + \frac{1.297\ x\ 10^{-15}}{0,85\ x\ 2,8288} \leq 1$$

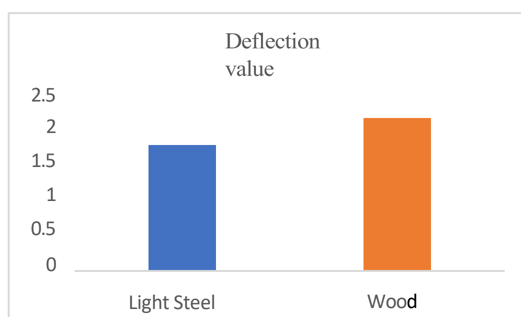
0,3120 ≤ 1 (SAFE)

Tabel 1 Wood Deflection Table

No	Deflection control (L/180)	Deflektion (mm)	Ket
1	38,88	0,417	SAFE
2	38,88	0,417	SAFE
3	61,11	2,137	SAFE
4	11,20	0	SAFE
5	15,77	0,71	SAFE
6	17,61	0	SAFE
7	15,77	0,71	SAFE
8	11,20	0	SAFE
	Nilai maksimal	2,137	

6. Comparison of Structure Durability

The following are the results of analyzing the deflection value of wooden and light steel roof truss structures:



Based on the measured deflection values, it can be seen that the lightweight steel roof truss structure experienced the largest deflection of 1.754 mm, while the wood structure recorded a larger deflection value of 2.137 mm. This comparison shows that mild steel has better rigidity than wood in resisting loads, resulting in smaller and more stable deformation (deflection).

Deflection in lightweight steel roof trusses is smaller than wood because steel has a very high modulus of elasticity (E) (200,000 Mpa), beyond wood grade II meranti (9,600 MPa). This difference makes steel is very rigid and able to withstand load deformation better. Steel is also isotropic, meaning its mechanical properties are uniform in all directions, in contrast to wood which is anisotropic, meaning its strength is highly dependent on fiber direction.

The following are the results of the analysis of the ratio value of wood and light steel roof truss structures:

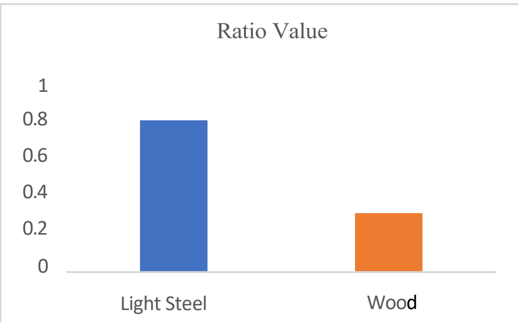


Image graph shows a comparison of ratio values between two types of roof truss materials, namely mild steel and wood. This ratio value generally refers to the ratio of the acting force to the structural permitting capacity, in this case the result of the analysis of the interaction of moment and axial force. The closer it is to 1, the greater the strength utilization of the material. The ratio value for mild steel was recorded at 0.8. This means that mild steel was utilized close to the limit of its material allowable strength, but still within safe limits (≤ 1.0). This means that mild steel is able to withstand structural loads efficiently with a high level of material utilization. In contrast, timber shows a lower ratio value, which is around 0.312. This indicates that the utilization of wood strength in the roof structure is still far from its maximum capacity.The graph shows a comparison of the ratio values between two types of roof truss materials, namely mild steel and timber. This ratio value generally refers to the ratio of the acting force to the allowable capacity of the structure, in this case the results of the moment and axial force interaction analysis.

7. Cost Budget Plan Comparison

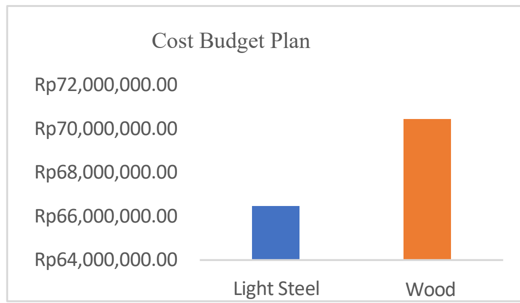
Table 3 Mild Steel Cost Budget Plan

No	Uraian Pekerjaan	Vol	Sat	Harga Satuan (Rp)	Jumlah Harga (Rp)
1	Pemasangan 1 m² rangka atap baja ringan	127	M²	Rp328,192.00	Rp41,680,384.00
2	Pemasangan 1 m² atap *zincalume*	139	M²	Rp130,840.00	Rp18,186,760.00
	JUMLAH				Rp59,867,144.00
	PPN 11%				Rp6,585,385.84
	TOTAL				Rp66,452,529.84
	PEMBULATAN				Rp66,452,530.00

Table 4 Wood Cost Budget Plan

No	Uraian Pekerjaan	Vol	Sat	Harga Satuan (Rp)	Jumlah Harga (Rp)
1	Pemasangan 1 m³ kuda kuda konvesional kayu kelas II	1,811	M³	Rp7,023,400.00	Rp12,721,815.92
2	Pemasangan 1 m³ konstruksi gording kayu kelas II	0,48	M³	Rp5,819,400.00	Rp2,793,312.00
3	Pemasangan 1m² usuk dan reng	139	M2	Rp152,150.00	Rp21,148,850.00
4	Pemasangan 1 m² atap *zincalume*	139	M²	Rp130,840.00	Rp18,186,760.00
5	Pemasangan *nok zincalume*	3	M	Rp85,640.00	Rp256,920.00
6	Pemasangan 1 m listplank	47,7	M	Rp91,250.00	Rp4,352,625.00
7	Pelapisan anti rayap	95,14	M²	Rp41,950.00	Rp3,991,123.00
	JUMLAH				Rp63,451,405.92
	PPN 11%				Rp6,979,654.65
	TOTAL				Rp70,431,060.58
	PEMBULATAN				Rp70,431,061.00

The following is a comparison of the cost budget plans:



At the cost budget planning analysis stage, a comparison was made between the two main types of materials used in roof truss construction, namely mild steel and wood. Based on the calculation results visualized in the bar chart, it is known that the use of mild steel results in a total budget of Rp66,452,530.00, while wood reaches Rp70,431,061.00. This shows that the use of wooden roof trusses requires a higher cost with a difference of Rp3,978,531.00 compared to lightweight steel roof trusses.

The cost difference is caused by several technical and economic factors. In wooden structures, the cross-sectional size must be larger in order to withstand the load of the structure and roof, so the volume of material required is more. In addition, the process of installing wooden roof trusses takes longer and requires higher labor skills, which causes labor costs to increase. Wood also requires additional treatments such as termite repellents and protective coatings, which adds a cost component to the cost budget plan.

In contrast, lightweight steel roof trusses have many advantages in terms of efficiency and practicality. Lightweight steel materials weigh less while remaining strong, and can be produced and installed quickly through a prefabricated system. In addition, lightweight steel is relatively resistant to weather and pests, so it does not require intensive maintenance, such as like wood.

By considering the efficiency of material costs, implementation time, and maintenance costs, lightweight steel becomes the more economical and effective choice in planning roof truss structures. economical and effective in planning the roof truss structure of the building.

4.CONCLUSION AND SUGGESTION

Conclusion

The following conclusions were obtained:

1. Roof truss planning uses a gable shape with a height of 3.17 m and a slope angle of 30o and building dimensions of 11 x 10 m. The wooden roof truss uses grade II meranti wood with a size of 12/8 for the truss, 5/7 usuk, and 2/3 battens. While planning for a lightweight steel roof truss using CNP 100 x 50 x 20 x 3.2 mm for the truss and CNP 50 x 35 x 20 x 2 mm for the truss.
2. Modeling using software SAP 2000 V22 by entering live load, dead load, and wind load. The results obtained from mild steel experienced the largest deflection of 1.754 mm while the wooden structure had the largest deflection value of 2.137 mm. The ratio value of mild steel is 0.8 while wood is 0.312.
3. Comparison of lightweight steel costs resulted in a total budget of Rp66,452,530.00 (Sixty Six Million Four Hundred Fifty Two Thousand Five Hundred and Thirty Rupiah), while the timber structure has a total budget of Rp66,452,530.00 (Sixty Six Million Four Hundred Fifty Two Thousand Five Hundred and Thirty Rupiah). wood reached Rp70,431,061.00 (Seventy Million Four Hundred Thirty One Thousand Sixty One Rupiah).

Suggestion

From the above results, the suggestions that can be applied to roof truss planning are as follows:

1. Comparative analysis of lightweight steel roof truss and wooden roof truss based on structural strength and construction cost is expected to be a reference for Juwata Tarakan Airport for the construction of the Emergency Operation Center building.
2. The use of lightweight steel roof truss is more recommended because it can
3. save costs, easy to find materials, and have consistent structural strength.
4. Research Further research can add an analysis of the overall structure of the building.
5. Research Further research can take into account the implementation time.

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