

Optimal Design-Based Efficiency Analysis of Roof Truss Construction for Construction Industry Recovery

Sudarno P Tampubolon
Universitas Kristen Indonesia

Corresponding Author: Sudarno P Tampubolon, sudarno.tampubolon@uki.ac.id

ARTICLE INFO

Keywords: Efficiency, Roof Truss, Appropriate, SAP-2000.

Received : 27, June

Revised : 29, July

Accepted: 25, August

©2026 Tampubolon : This is an open-access article distributed under the terms of the [Creative Commons Atribusi 4.0 Internasional](https://creativecommons.org/licenses/by/4.0/).



ABSTRACT

The demand for simple, efficient, and functional roof structures has increased significantly due to the need for economical and sustainable construction solutions. This study develops an optimized roof truss design by integrating conceptual planning, structural analysis, and material quantity estimation. Structural performance was evaluated using both the Structure Analysis Program and the Ritter Method. Comparative analysis revealed no significant discrepancies between the two methods, indicating that the proposed design approach can be reliably applied in regions with limited access to advanced design software and technological resources. Based on the proposed construction and implementation methodology, the total material requirement was calculated at 33.57 m from an available material length of 36.00 m, leaving a residual length of only 2.43 m. The resulting material utilization efficiency reached 93.3%, highlighting the potential of the proposed design to reduce material waste and improve construction efficiency while ensuring structural performance

INTRODUCTION

A roof is the uppermost covering of a building that serves to protect the interior space from environmental factors such as rain, dust, wind, solar heat, and other external influences, while ensuring the safety and functionality of the structure, (Awuy et al., 2023). The roof configuration significantly influences the aesthetic appearance of a building. Therefore, the selection of an appropriate roof type should consider local climatic conditions, available budget constraints, and the accessibility of construction materials, (Ginting & Novrial, 2022a; Purwanto et al., 2006). Various materials are commonly used for roofing systems, including clay and concrete roof tiles, corrugated metal sheets, asbestos sheets, and reinforced concrete slabs. Among these alternatives, metal roof tiles have become increasingly popular due to their lightweight properties, durability, corrosion resistance, and favorable performance under seismic loading conditions. The roof-supporting structure employed in this study is a roof truss system. A roof truss is an assembly of interconnected structural members designed to support roof loads, including its self-weight, while simultaneously defining the roof geometry. In general, a truss structure consists of members arranged in a series of triangular configurations, which provide structural stability and enable efficient load transfer throughout the system. Considering the influence of roof dead loads and roofing materials, roof truss configurations may differ in terms of geometry and structural arrangement. Consequently, each truss assembly should function as a rigid and stable structural system capable of carrying the imposed loads while maintaining its shape and structural performance throughout its service life. A roof serves multiple functions in a building system. Primarily, it protects the structure and its occupants from environmental effects such as rain, wind, lightning, and solar radiation, while also reducing heat gain within the building. Structurally, the roof system carries its self-weight, including the truss system and roofing cover, and transfers these loads to the supporting columns and foundations. In addition, the roof contributes to the architectural aesthetics of the building, thereby enhancing its visual quality and overall value. It also functions as a sound barrier by reducing noise transmission from surrounding traffic and environmental sources, provides protection for occupants, and prevents rainwater infiltration, (Ginting & Novrial, 2022b; Nuryanto, 2021; Sudarmadji, 2014).

Along with advances in technology, structural systems in civil engineering are required to achieve higher performance in terms of strength, economic efficiency, and constructability. One structural system that has recently gained significant attention is the roof truss system constructed using lightweight steel sections. Lightweight steel roof truss systems are now widely adopted by communities and residential developers in Indonesia. Their application is no longer limited to upper- and middle-class housing developments, as lower-income communities have also begun to utilize lightweight steel truss systems as an alternative roofing material due to their practical advantages and cost-effectiveness, (Husnah et al., 2019; Sutrisno & Simanjuntak, 2017). One of the main driving factors is the increasing cost and declining quality of timber materials. Consequently, the selection of lightweight steel roof truss systems has become an appropriate alternative in response to the current timber scarcity in Indonesia. In addition to addressing resource limitations, lightweight steel offers

advantages such as resistance to termite attack, corrosion resistance, and improved durability. Roofing systems are available in various forms, such as hip roofs, gable roofs, conical roofs, and other configurations. The geometry of roof trusses often reflects the cultural identity of a region, as each area typically possesses distinctive architectural characteristics, particularly in traditional house roof designs. A roof system, which consists of both the roofing cover and the supporting truss structure, is the uppermost component of a building. As the highest structural element, the roof should be designed to be as lightweight as possible in order to minimize the loads transmitted to the lower structural components.

In the past, timber was widely used as a material for roof truss construction due to its relatively light weight and adequate strength for structural applications. However, with the increasing scarcity of timber resources, the use of conventional steel has become a common alternative for roof truss systems. With the advancement of technology, lightweight steel materials have been developed, offering higher strength-to-weight ratios and lower self-weight. Consequently, lightweight steel has emerged as an alternative material for roof truss construction, (Harshavardhan et al., 2021; Kyvelou et al., 2020; Rafiq, 2014). Based on the aforementioned background, this study is entitled “Optimal Design-Based Efficiency Analysis of Roof Truss Construction for Construction Industry Recovery”

THEORETICAL REVIEW

Light gauge steel

Light gauge steel is a high-quality steel material characterized by its thin and lightweight properties; however, its strength is comparable to that of conventional steel. Light gauge steel can be classified into several types based on its tensile strength. In the market, the typical thickness of light gauge steel ranges from 0.20 to 2.00 mm. This variation in thickness is determined by the magnitude of the applied loads and the span length of the structural element. The relatively small thickness compared to conventional steel is intended to reduce the overall structural dead load of the building. For roof truss applications, light gauge steel members generally have thicknesses ranging from 0.45 to 1.00 mm. In contrast, structural columns, which are designed to carry higher loads, typically use thicker sections ranging from 1.00 to 2.00 mm (C-channel profiles). For metal roofing sheets, the typical thickness is approximately 0.20 mm, as they are not designed to carry structural loads; thus, this thickness is considered sufficient for roofing applications. Steel is primarily composed of iron and carbon (Fe and C). When exposed to water and oxygen, these elements can react and initiate corrosion processes, leading to rust formation. Therefore, lightweight steel materials are required to be coated with anti-corrosion protection. The application of protective coatings is essential to ensure material durability and long service life. The advantages of using light gauge steel include high tensile strength combined with low self-weight, the ability to withstand significant deformation without structural failure under tensile loading, and material homogeneity due to factory-controlled production processes. In addition, light

gauge steel is resistant to termite attack and corrosion, making it less susceptible to deterioration over time. Its installation process is efficient and relatively fast, as the members can be easily connected using bolts, welding, or coupling plates. Furthermore, light gauge steel is non-combustible, meaning it does not contribute to fire propagation.

Advantages of Light Gauge Steel Roof Truss Systems

Light gauge steel roof truss systems have the following advantages:

1. Light gauge steel roof truss systems possess high tensile strength. Although lightweight in nature, light gauge steel exhibits a high tensile strength of approximately 550 MPa, which is higher than that of conventional steel, which is about 300 MPa. This is attributed to its ductile behavior, allowing the material to absorb a larger amount of energy. Unlike timber, which is more brittle and prone to sudden failure, light gauge steel demonstrates superior structural performance. This high tensile strength enables the roof truss system to resist structural collapse and maintain overall building stability.
2. Installation of light gauge steel roof truss systems is simple and efficient. Due to the lightweight nature of the material, the installation process can reduce construction time and labor costs. In addition to its low self-weight, light gauge steel also utilizes relatively simple connection systems. Joints can be made using screws, bolts, rivets, or welding. These connection methods also allow light gauge steel roof trusses or canopies to be easily integrated with other structural systems such as concrete or timber structures.
3. Light gauge steel roof truss systems can be designed in various configurations, allowing them to follow different roof geometries according to architectural requirements. However, the configuration of the roof truss must be properly adjusted to the anticipated loads that the structure is required to support.
4. Light gauge steel roof truss systems are resistant to corrosion and termite attack. The use of light gauge steel not only eliminates the risk of termite damage but also provides inherent corrosion resistance due to its metallic composition. This characteristic is advantageous for applications where the roof truss is exposed in architectural design, as it reduces the need for periodic finishing or maintenance.
5. Light gauge steel roof truss systems have long-term durability. Being made of metal, the material exhibits excellent durability performance. Light gauge steel is not prone to decay or dimensional changes due to weather variations. High-quality light gauge steel should not be excessively lightweight or overly flexible, as appropriate stiffness is required to ensure adequate structural performance.
6. Light gauge steel roof truss systems have a lower cost compared to other roofing structural materials. Steel-based roof trusses can be considered more economical than alternative materials. For instance, timber is not only becoming increasingly difficult to obtain but also has a relatively high market price. In addition, timber is susceptible to decay over time, which may require maintenance and further increases overall life-cycle costs.

Structure Analysis Program (SAP- 2000)

To determine the internal member forces in the designed roof structure, this study employs the Structural Analysis Program (SAP2000) to obtain the required analytical results, (Deshariyanto et al., 2022; Suriani, 2024; Tampubolon, 2023; Tampubolon & Mulyani, 2021).



Figure 1. Structural Analysis Program (SAP2000)

Ritter Method

In addition to the Structural Analysis Program (SAP2000), this study also employs the Ritter method to determine the internal forces acting on the designed roof structure, (Mohammad et al., 2012).

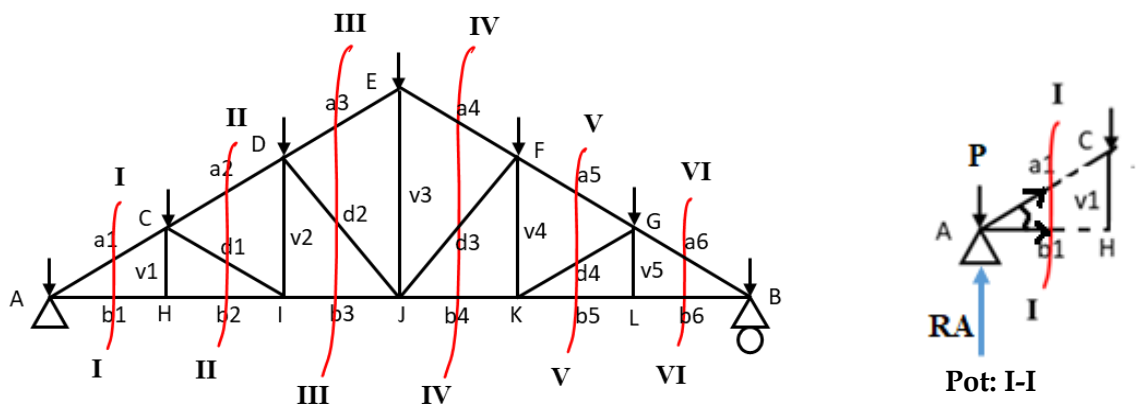


Figure 2. Ritter Method

By using the angle α° , the force in section I-I can be calculated as follows:

$$\sum M_I = 0$$

$$(R_{AV} \cdot \ell b_1) - (P_1 \cdot \ell b_1) + (a_1 \cdot \sin \alpha^\circ \times \ell b_1) = 0$$

$$a_1 = - \frac{(R_{AV} \cdot \ell b_1) - (P_1 \cdot \ell b_1)}{\sin \alpha^\circ \times \ell b_1}$$

METHODOLOGY

This study adopts a quantitative descriptive approach, employing structural analysis using SAP2000 and verification of member force calculations through Ritter's method to evaluate the efficiency of the roof truss design. The planned roof geometry in this study has a slope of 30° , which is intended to improve structural efficiency and reduce the vulnerability of the roof to strong wind and rain loads. The following presents the design description of the light gauge steel roof truss system:

- Roof Shape : Leter L
- Span Length : 1 meter
- Slope : 30°
- Height : 0.3 meter
- Steel section : C 75.35.0,65, Reng 30.15.0,45

Plan and Design of Roof Truss Type

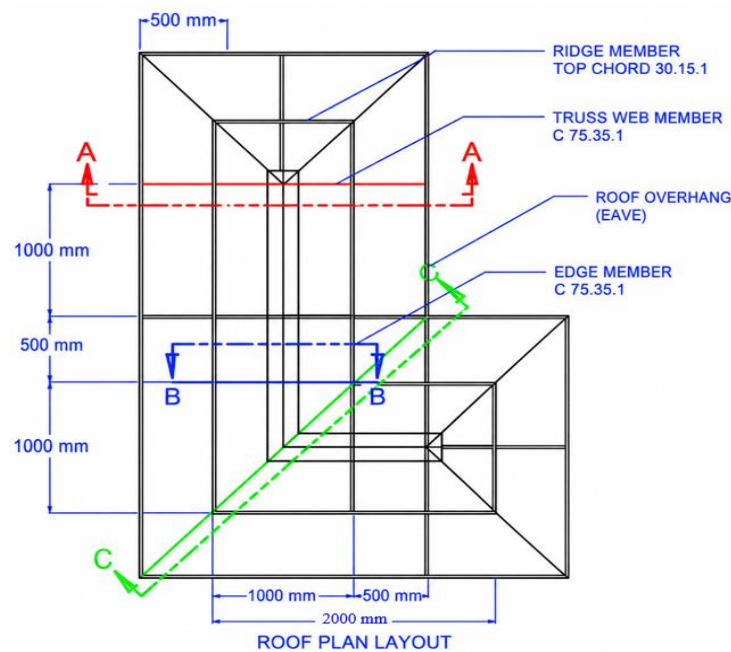


Figure 3. Roof Plan Layout

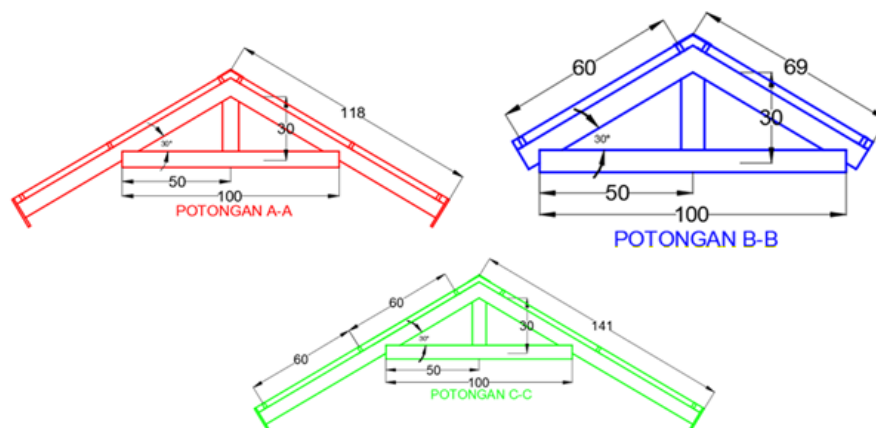
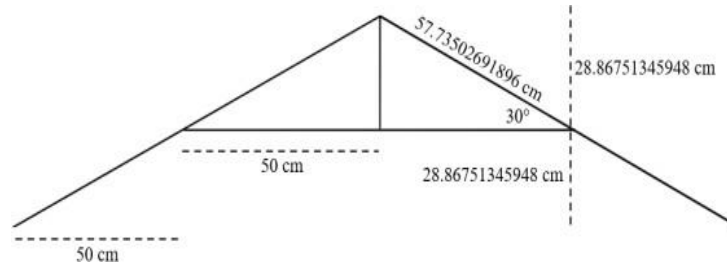


Figure 4. Types of Roof Truss Design

RESEARCH RESULTS

Roof Load Design

Before performing the structural analysis of the roof truss, load calculations must first be carried out on the designed truss system. The roof load calculations include the following:



Approach:

$$28.86751345948 \text{ cm} \approx 30 \text{ cm} \approx 0.3 \text{ m}$$

$$57.73502691896 \text{ cm} \approx 60 \text{ cm} \approx 0.6 \text{ m}$$

Dead Load

$$\text{Roof covering (50 cm spacing): } 2 \text{ kg/m}^2 \times 0.5 \text{ m} \times 0.6 \text{ m} = 0.60 \text{ kg}$$

$$\text{Ceiling and suspension system: } 10 \text{ kg/m}^2 \times 0.5 \text{ m} \times 0.6 \text{ m} = 3.00 \text{ kg}$$

$$\begin{array}{r} 0.60 \text{ kg} \\ 3.00 \text{ kg} \\ \hline Q = 3.60 \text{ kg} \end{array}$$

Live Load

Live load (occupancy load) according to PPPURG, $P = 100 \text{ kg}$

Rain load (R)

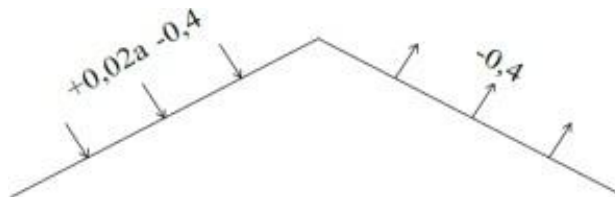
$$\text{Rain load} = 40 - (0.8 \times \alpha) = 40 - (0.8 \times 30^\circ) = 16 \text{ kg/m}^2$$

According to PPPURG, the minimal rain load 20 kg/m^2 ; Area load conversion => pointload:

$$P = \text{Rain load} \times \text{compressive member length} \times B = 20 \text{ kg/m}^2 \times 0.5 \times 0.6 = 6 \text{ kg}$$

Wind Load

Wind pressure diagram for enclosed building:



Wind pressure

$$\text{Coefficient} = (0.02\alpha) - 0.4 = (0.02 \times 30^\circ) - 0.4 = 0.2$$

$$W_t = W \cdot \text{Coefficient} \cdot \text{purlin spacing} = 25 \times 0.2 \times 0.5 = 2.5 \text{ kg}$$

$$W_{tx} = 2.5 \times \cos(60) = 1.25 \text{ kg (point load at joint)}$$

$$W_{ty} = 2.5 \times \sin(60) = 2.17 \text{ kg (point load at joint)}$$

Wind suction

$$\text{coefficient} = -0.4$$

$$W_h = W \cdot \text{coefficient} \cdot \text{purlin spacing} = 25 \times (-0.4) \times 0.5 = -5 \text{ kg}$$

$$W_{hx} = -5 \times \cos(60) = -2.5 \text{ kg (point load at joint)}$$

$$W_{hy} = -5 \times \sin(60) = -4.33 \text{ kg (point load at joint)}$$

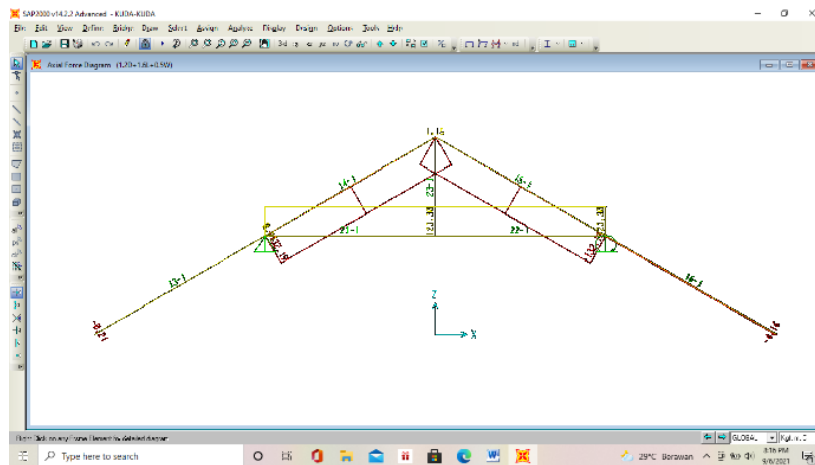
Table 1. Load Summary

Load		Value (kg)	Total (kg)
DL	Roof covering	0.60	0.60
	Ceiling dead load	3.00	3.00
Total			3.60
LL	Live load (workers)	100	100.00
	Total		100.00
RL	Rain load	6,00	6.00
	Total		6.00
WL	Wind pressure in the X-direction	1.25	1.25
	Wind pressure in the Y-direction	2.17	2.17
	Wind suction load in the X-direction	2.50	2.50
	Wind suction load in the Y-direction	4.33	4.33

DISCUSSION

Roof Truss Analysis Using SAP-2000

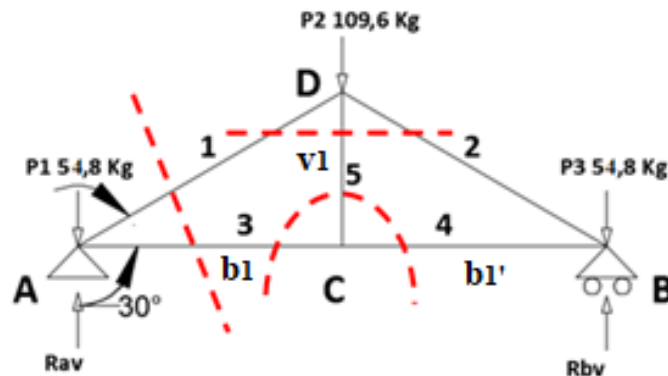
In this analysis, the internal forces obtained from the SAP-2000 analysis will be presented..



From the SAP2000 analysis results, the axial (normal) force values in the roof truss are obtained as follows:

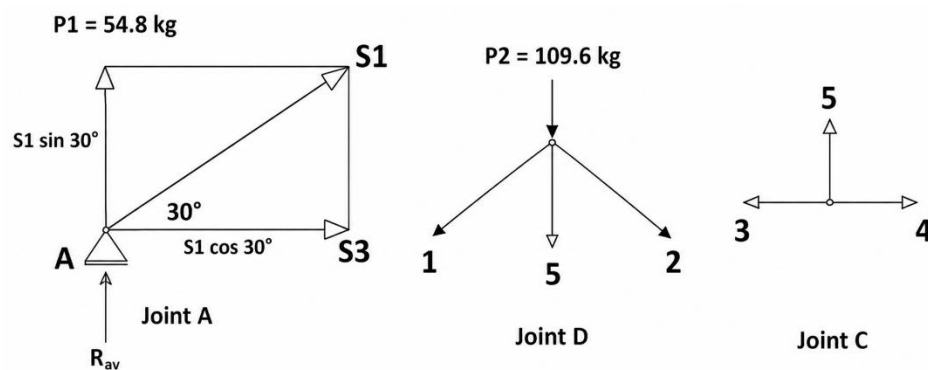
- Axial force in the member 13-1 = -0.21 kg
- Axial force in the member 14-1 = -132.19 kg
- Axial force in the member 15-1 = -133.77 kg
- Axial force in the member 16-1 = -3.74 kg
- Axial force in the member 21-1 = 123.30 kg
- Axial force in the member 22-1 = 123.30 kg
- Axial force in the member 23-1 = 1.15 kg

Roof Truss Analysis Using the Ritter Method



$$R_{av} = R_{bv} = \frac{1}{2} (53.8 + 109.6 + 53.8) = 109.6 \text{ kg}$$

Based on the reaction results from the manual calculations presented in the previous discussion, the values are consistent with the reactions obtained from the SAP-2000 analysis (as shown in the figure above), with a support reaction of 109.6 kN.



$$\Sigma M_D = 0$$

$$\begin{aligned} (R_{AV} \cdot \ell b_1) - (P_1 \cdot \ell b_1) - (S_3 \cdot \ell v_1) &= 0 \\ (109.6 \times 0.5) - (54.8 \times 0.5) - (S_3 \times 0.2886) &= 0 \\ S_3 &= 94.94 \text{ kg (tension)} \end{aligned}$$

$$\Sigma H = 0$$

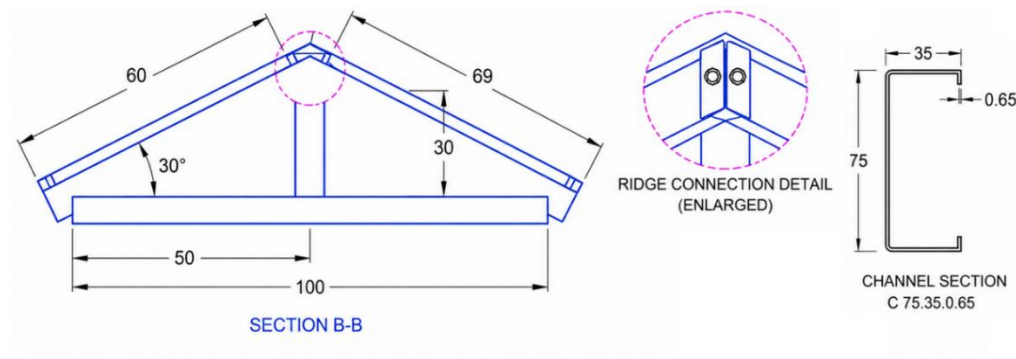
$$\begin{aligned} S_3 + (S_1 \cdot \cos 30) &= 0 \\ 94.94 + (S_1 \cdot 0.866) &= 0 \\ S_1 &= -109.6 \text{ kg} \quad (\text{compression}) \end{aligned}$$

Design of Structural Connections

Connection detail of C 75.35.1

$$h = d = 75 \text{ mm} - 1 \text{ mm} = 74 \text{ mm}$$

$$tw = 1; tf = 1; r_0 = 1$$



$$A_s = 3.823 \text{ cm}^2 = 382.3 \text{ mm}^2; I_x = 27.30478152 \text{ cm}^4; I_y = 4.4952994 \text{ cm}^4$$

Steel grade BJ-55; $f_y = 410 \text{ MPa}$; $f_u = 550 \text{ MPa}$

Factored ultimate load, $P_u = -132.19 \text{ kg}$

Bearing Resistance (Bolt D12 - 410 MPa)

$$\phi R_n = 0.75 \cdot 2.4 \cdot d_b \cdot t_p \cdot f_u = 0.75 \cdot 2.4 \cdot 12 \cdot 1 \cdot 410 = 8856 \text{ N} = 885.6 \text{ kg}$$

Shear Resistance (Bolt D12 - 410 MPa)

$$\phi R_n = 0.75 \cdot 0.5 \cdot m \cdot A_b \cdot f_u = 0.75 \cdot 0.5 \cdot 2 \cdot (1/4 \pi 12^2) \cdot 410 = 34759 \text{ N} = 3475.9 \text{ kg}$$

Number of bolts

$$n = 132.19 / 885.6 = 0.14 \text{ pcs} \approx 2 \text{ pcs (safety factor)}$$

Bolt spacing and thickness of the connecting plate: $t_p \geq (h + b) / 90$

$$t_p \geq (75 + 35) / 90 \Rightarrow t_p \geq 1.22 \text{ mm}$$

$$t_p = 2 \text{ mm}$$

Maximum spacing:

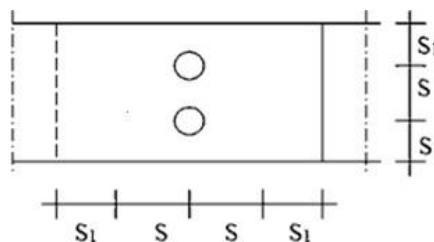
$$S < 15t_p = 30 \text{ mm}$$

$$S_1 < 4t_p + 100 = 108 \text{ mm} = 110 \text{ mm}$$

Minimum spacing:

$$S > 3d_b = 36 \text{ mm}$$

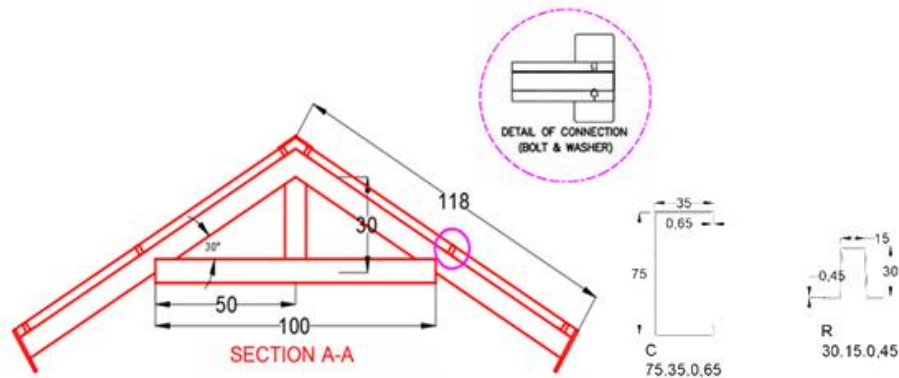
$$S_1 > 1.5d_b = 18 \text{ mm} \Rightarrow 20 \text{ mm}; \text{ used } S_1 = 2 \text{ cm}; S = 3.6 \text{ cm}$$



Connection detail of Canal - Purlin C 75.35.1

$$h = d = 75 \text{ mm} - 1 \text{ mm} = 74 \text{ mm} = 3 \text{ in}$$

$$t_w = 1; t_f = 1; r_0 = 1$$



$$A_s = 3.823 \text{ cm}^2 = 382.3 \text{ mm}^2; I_x = 27.30478152 \text{ cm}^4; I_y = 4.4952994 \text{ cm}^4$$

R 30.15.0.45

$$h = d = 30 \text{ mm} - 1 \text{ mm} = 29 \text{ mm}; b = 20$$

Steel grade BJ-55; $f_y = 410 \text{ MPa}$ $f_u = 550 \text{ MPa}$

Factored ultimate load, $P_u = -132.19 \text{ kg}$

Bearing Resistance (Bolt D10 – 410 MPa)

$$\phi R_n = 0.75 \cdot 2.4 \cdot d_b \cdot t_p \cdot f_u = 0.75 \cdot 2.4 \cdot 10 \cdot 1 \cdot 410 = 7380 \text{ N} = 738.0 \text{ kg}$$

Shear Resistance (Bolt D10 – 410 MPa)

$$\phi R_n = 0.75 \cdot 0.5 \cdot m \cdot A_b \cdot f_u = 0.75 \cdot 0.5 \cdot 2 \cdot (1/4 \pi 10^2) \cdot 410 = 24138 \text{ N} = 2413.8 \text{ kg}$$

Number of bolts:

$$n = 132.19 / 738.0 = 0.179 \text{ pcs} \approx 2 \text{ pcs (safety factor)}$$

Bolt Spacing and thickness of the connection plate: $t_p \geq (h + b) / 90$

$$t_p \geq (30 + 20) / 90 \Rightarrow t_p \geq 0.55 \text{ mm}$$

$$t_p = 1 \text{ mm}$$

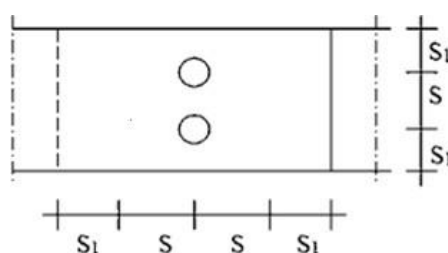
Maximum spacing $S < 15t_p = 15 \text{ mm}$

$$S_1 < 4t_p + 100 = 104 \text{ mm} = 110 \text{ mm}$$

Minimum spacing

$$S > 3d_b = 30 \text{ mm}$$

$$S_1 > 1.5d_b = 15 \text{ mm} = 20 \text{ mm, used } S_1 = 2 \text{ cm}; S = 1.5 \text{ cm}$$



Efficiency of Material Use

From Figure 3, the roof design plan can be observed, which is used as the basis for calculating the required amount of steel materials. The quantities of materials used are presented in Table 2.

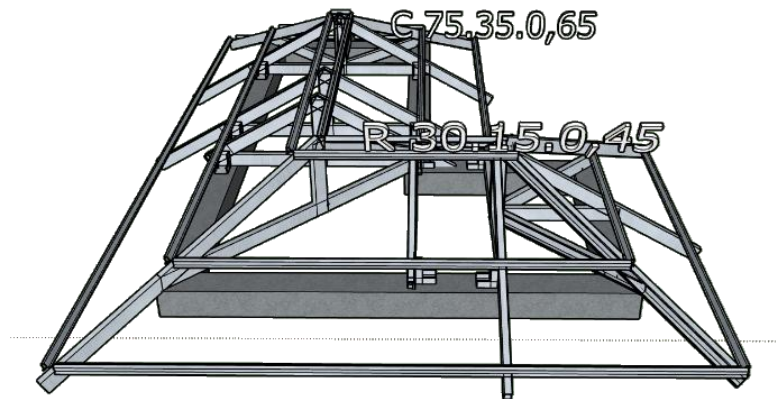


Figure 5. 3D View of the Roof Design

Table 2. Material Quantity Calculation

Number of Roof Trusses	Member name	Span (m)	Quantity (pcs)	Total (m)
3	K-1			
	Diagonal	1.17	4	4.68
	Horizontal	1.00	5	5.00
	Vertical	0.30	1	0.30
2	K-2			
	Diagonal	0.585	4	2.34
	Horizontal	1.00	5	5.00
	Vertical	0.30	1	0.30
1	K-3			
	Diagonal	1.535	3	4.62
	Horizontal	1.41	1	1.41
	Vertical	0.30	1	0.30
2	K-4			
	Diagonal 1	1.17	4	4.68
	Diagonal 2	1.54	3	4.62
	Horizontal 1	0.50	2	1.00
	Horizontal 2	0.71	4	2.84
	Vertical	0.30	8	2.40

Table 3. Summary of Total Materials

Span (m)	Quantity (pcs)	Total (m)
1.54	6	9.24
1.41	1	1.41
1.17	8	9.36
1	5	5
0.71	4	2.84
0.58	4	2.32
0.5	2	1
0.3	8	2.4
Total	38	33.57

Based on the total material quantity calculation, a cutting analysis was conducted to optimize material utilization. Table 4 shows the material cutting calculations.

Table 4. Material Cutting Calculation

Member (m)	Material length (m)	Cutting (m)	Total (m)	waste (m)
1	6	1.54	5.92	0.08
		1.54		
		1.54		
		1		
		0.3		
2	6	1.54	5.92	0.08
		1.54		
		1.54		
		1		
		0.3		
3	6	1.41	5.93	0,07
		1.17		
		1.17		
		1.17		
		0.71		
		0.3		
4	6	1.71	5.69	0.31
		1.71		
		1.71		
		1.71		
		0.71		
		0.3		
		1.17		
		1		
		1		

5	6	<u>0.71</u>	5.69	0.31
		<u>0.71</u>		
		<u>0.5</u>		
		<u>0.3</u>		
		<u>0.3</u>		
6	6	<u>1</u>	4.42	1.58
		<u>0.58</u>		
		<u>0.58</u>		
		<u>0.58</u>		
		<u>0.58</u>		
		<u>0.5</u>		
		<u>0.3</u>		
		<u>0.3</u>		
Total		33.57	2.43	
Efficiency		93.3 %		

From the results of the material quantity analysis, the total required material length was found to be 33.57 m, while the available total material was 36 m. Therefore, the remaining material in the implementation process is 2.43 m, and the material efficiency is obtained at 93.3%. This indicates that well-planned and properly calculated material estimation can significantly reduce material waste during construction.



Figure 4. Roof Truss Assembly Drawing

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the analysis and calculations, the following conclusions can be drawn:"

1. The proposed roof design is a simple structure that is widely preferred by the community.
2. The results of the structural analysis using Structure Analysis Program and the Ritter Method show no significant differences. Therefore, the proposed design can be implemented in various locations without necessarily relying on advanced software or technology in its design process.

3. Based on the proposed construction method and working procedures, a material utilization efficiency of 93% was achieved.
4. From the total available material of 36 m, only 33.57 m was used, leaving a remaining 2.43 m, as shown in the analysis results.

REFERENCES

- Awuy, J., Tjakra, J., & Pratas, P. A. (2023). Metode Pelaksanaan Konstruksi Pekerjaan Atap dan Plafon pada Proyek Pembangunan Christian Center. *Tekno*, 21(84).
- Deshariyanto, D., Diana, A. I. N., & Fansuri, S. (2022). Perbandingan Struktur Rangka Batang Statis Tertentu Menggunakan Metode Mekanika Klasik dan Program (SAP 2000). *Jurnal Ilmiah MITSU (Media Informasi Teknik Sipil Universitas Wiraraja)*, 10(1). <https://doi.org/10.24929/ft.v10i1.1614>
- Ginting, S. G. B., & Novrial. (2022a). Pengaruh Material dan Bentuk Atap Terhadap Kenyamanan Termal dalam Bangunan Rumah Tinggal. *TALENTA Conference Series: Energy & Engineering*, 5(1).
- Ginting, S. G. B., & Novrial. (2022b). Pengaruh Material dan Bentuk Atap Terhadap Kenyamanan Termal dalam Bangunan Rumah Tinggal. *TALENTA Conference Series: Energy & Engineering*, 5(1).
- Harshavardhan, P., Venkat Das, T., Reddy Kumar Reddy, K., & Borusu, V. (2021). Modelling and design analysis of light gauge steel systems against conventional structural systems. *Materials Today: Proceedings*, 47. <https://doi.org/10.1016/j.matpr.2021.05.505>
- Husnah, Darfia, N. E., & Hidayat, F. (2019). Analisis Struktur Rangka Baja Ringan dan Baja Berat Dengan Aplikasi Bricscad. *Siklus : Jurnal Teknik Sipil*, 5.
- Kyvelou, P., Nethercot, D. A., Hadjipantelis, N., Kyprianou, C., & Gardner, L. (2020). The Evolving Basis for the Design of Light Gauge Steel Systems. *International Journal of Structural Stability and Dynamics*, 20(13). <https://doi.org/10.1142/S0219455420410084>
- Mohammad, S., Md Tahir, M., Tan, C. S., & Shek, P. N. (2012). Experimental investigation on wide-span cold-formed steel roof truss system. *Applied Mechanics and Materials*, 166-169. <https://doi.org/10.4028/www.scientific.net/AMM.166-169.1304>
- Nuryanto, N. (2021). Fungsi, Bentuk, dan Makna Atap Imah Panggung Sunda (Studi Perbandingan Atap Rumah di Kasepuhan Ciptagelar, Naga, dan Pulo). *Jurnal Arsitektur ZONASI*, 4(1). <https://doi.org/10.17509/jaz.v4i1.27718>

- Purwanto, L., Hermawan, & Sanjaya, R. (2006). Pengaruh Bentuk Atap Bangunan Tradisional di Jawa Tengah Untuk Peningkatan Kenyamanan (Sebuah pencarian model arsitektur tropis untuk aplikasi desain arsitektur). *DIMENSI (Jurnal Teknik Arsitektur)*, 34(2).
- Rafiq, M. A. (2014). Kelebihan dan kekurangan rangka atap baja dan kayu pada rumah. *Jurnal Teknik Sipil Fakultas Teknik Universitas Negeri Malang* .
- Sudarmadji. (2014). Analisa Sisi Positif Dan Negatif Pemilihan Bentuk Atap Berpenutup Genteng Untuk Rumah Tinggal. *PILAR*, 10(1).
- Suriani, E.-. (2024). Kajian Gaya Dalam Pada Konstruksi Rangka Batang (VAKWERK). *CLAPEYRON: Jurnal Ilmiah Teknik Sipil*, 4(2).
<https://doi.org/10.33387/clapeyron.v4i2.6487>
- Sutrisno, S., & Simanjuntak, J. A. (2017). Analisa Perencanaan Rangka Atap Baja Ringan Menggunakan Bahan Baja Ringan. *Educational Building*, 3(1).
<https://doi.org/10.24114/eb.v3i1.7440>
- Tampubolon, S. P. (2023). Perbandingan Hasil Analisa Perhitungan Rangka Kuda-Kuda Kayu Dengan Menggunakan SAP-2000 dan Metode Titik Buhul. *Praxis: Jurnal Sains, Teknologi, Masyarakat Dan Jejaring*, 5(1).
<https://doi.org/10.24167/praxis.v5i1.4443>
- Tampubolon, S. P., & Mulyani, A. S. (2021). Analysis and calculation of wooden framework structure by using Structural Analysis Program (SAP)-2000 and method of joint. *IOP Conference Series: Earth and Environmental Science*, 878(1). <https://doi.org/10.1088/1755-1315/878/1/012042>