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Design and Construction of Lightweight Steel Roof Structure for Kaleles Sapi Kerapan Sumenep

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Abstract: The need for efficient and environmentally friendly building construction demands innovation in material selection and structural design, including the use of lightweight steel roofs. This study aims to design a lightweight steel roof structure adopting the Kaleles Sapi Kerapan design in Sumenep that safely withstands loads, efficiently uses materials, and supports solar panel integration as an alternative energy source. The methodology includes literature study, geometry and material data collection, and numerical modeling using SAP2000 v22.0.0 Ultimate software with linear static analysis according to SNI 7971:2013. Loads analyzed include dead load, live load, and wind load with various combinations. Simulation results indicate the roof frame design has strength ratios below 1 and is therefore safe. The total material requirements include C75 trusses, battens, braces, screws, spandek sheets, and ridge elements in measured quantities. This lightweight steel roof design is structurally feasible, economical, and supports sustainable building concepts.

Keywords: Design, Roof, Lightweight Steel, Keleles Sapi Kerapan.

1. Introduction

Based on data from the Ministry of Public Works and Housing of the Republic of Indonesia, the annual housing demand is approximately 800,000 units [1]. To meet this demand, the Ministry of PUPR launched the One Million Houses Program. In 2016, this program successfully constructed 805,000 houses, including 570,000 units for Low-Income Communities (MBR) and 240,000 non-MBR houses [2].

Achieving such ambitious housing targets requires efficient construction processes to prevent project delays [3]. Material selection is critical to project success, influencing durability, maintenance, customer satisfaction, production systems, lifecycle, usage, environmental impact, and cost [4]. Over the last decade, lightweight steel roofing has emerged as a notable innovation in construction projects. It offers superior quality compared to traditional wooden roofs [5], while requiring fewer resources in terms of cost and installation time [6], [7].

Lightweight steel refers to high-quality, light, and thin steel, with strength comparable to conventional steel. Currently, cold-formed steel (commonly abbreviated as CFS or BCD) is widely used and preferred for designing roof framing in residential and commercial buildings [8]. This facilitates engineering innovation through computational programs for analysis and design. Many high-rise buildings require constructions designed to withstand specific forces and loads [9]

The diversity of roof frame designs presents challenges for planners. Selection needs to balance economy, aesthetics, ease of implementation, and structural strength against applied loads [9]. Therefore, designing a lightweight steel roof frame that is not only efficient but also supports functionality and building aesthetics is essential. This study aims to design a lightweight steel roof frame capable of adequately resisting loads, with efficient material use and cost effectiveness, while integrating solar panels as an alternative electricity-saving measure. Accordingly, the lightweight steel roof design for the Kaleles Sapi Kerapan building in Sumenep is expected to provide civil engineers with a robust, economical, and environmentally friendly construction alternative. Furthermore, this research contributes to advancing knowledge in construction engineering, particularly in modern roof frame design.

Figure 1. *Design of the Kaleles Sapi Kerapan Roof Frame*

2. Literature Review

2.1. Design Theory

Planning serves as a guideline for project implementation to ensure that the project is completed within optimal time and cost according to the intended objectives. Managing project activities is the responsibility of management to optimize the use of all available resources [10]. The roof is a primary component that protects a building from solar radiation. In energy-efficient buildings, heat entering through the roof must be minimized to maintain cooler indoor temperatures [11]. The roof frame structure is a critical part of building construction that requires careful design to ensure strength and serviceability [12]. In the assembly of lightweight steel roof frames, the spacing between trusses is a decisive factor: the greater the load to be supported, the smaller the required truss spacing (Salmon, 2000).

2.2. Roof Structural System

The roof structural system is the main supporting framework that carries the roof covering and all loads above it. It consists of interconnected elements that distribute loads evenly to guarantee stability and strength of the roof. Trusses are central components comprising horizontal beams (resisting tension) and vertical posts (resisting compression) that support purlins or rafters and roof covering, and must withstand temperature variations, weather, horizontal forces, and fire [13]. The ridge beam is the apex of the roof that ties trusses together and generally runs parallel to the length of the roof frame [14]. Purlins function as transverse beams connecting trusses and serve as supports for rafters and hip rafters, while rafters rest on purlins and provide support for battens. Battens, the smallest profile members running perpendicular over rafters, hold the roof covering in place and reinforce the structural system. Finally, the roof covering, as the outermost element, protects the building from external weather such as wind and rain and completes the overall functionality of the roofing system [14].

2.3. Lightweight Steel Roof Frame Elements

Building structural elements form part of a system that transmits loads from the building to the ground [15]; In lightweight steel roof frames, these elements are composed of members assembled to form a planar frame, typically constituting a single triangle or a series of triangular combinations. The naming of these elements refers to the scheme shown in Figure 2.

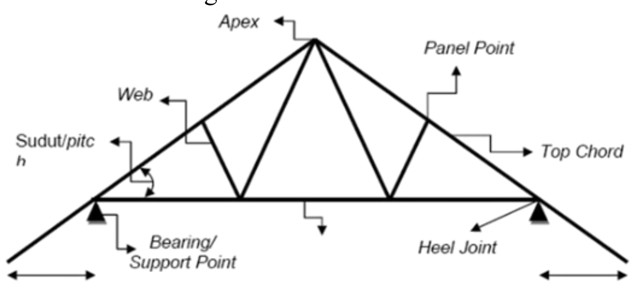

Figure 2. *Naming of Members on the Roof Frame*

The uppermost point of the truss is called the apex, while the heel joint is the node where the upper and lower main chords meet. A panel point refers to a node where multiple elements converge, and bearing or support points are locations where the truss is supported by at least two points, often selected from panel points above supports like columns or ring beams. Additionally, pitch denotes the roof slope angle; overhang refers to the extension of the upper main chord beyond the support; clear span is the horizontal distance between the inner edges of the supports, while span denotes the horizontal distance between the axes of supports. The upper main members are called top chords, the lower main members are bottom chords, and interior members of the truss are called webs. These terms are used to standardize member and joint identification in the planning and analysis of roof frames [16].

3. Methodology

This study employs a literature review approach combined with numerical modeling. Geometrical and material data were collected from literature sources and manufacturer datasheets. Load cases and load combinations refer to Indonesian National

Standard SNI 7971:2013 and relevant SNI codes. The structural model was created and analyzed using SAP2000 v22.0.0 Ultimate software, utilizing beam elements to represent the roof frame. The analysis included linear static analysis for primary load combinations and a sensitivity study varying rafter spacing, profile selection, and solar panel integration. Model results were verified by manual calculations on critical elements, and the final design was evaluated based on strength, deflection, and material usage analysis.

Table 1. Main Truss Loading

Profile	Cross Sectional Area (m^2)	Density (Kg/m^3)	Unit Weight (Kg/m)	
Main Frame (C75)	0,00011700	7850	0,91845	Kg/m^1
Batten	0,00005941	7850	0,466398 43	Kg/m^1
Spandek			5,2	Kg/m^2

4. Result and Discuson

4.1. Loading and Load Combination

The loads applied in the truss structural analysis are dead load (DL), live load (LL), and wind load (W) with the following combinations:

1. Load Combination 1 1.4D
2. Load Combination 2 1.2D+1.6L
3. Load Combination 3 1.2D+1.0W+L

4.1. Main Truss Loading

The spacing of the main trusses in this study is 865 mm.

Table 1. Main Truss Loading

Profile	Cross Sectional Area (m^2)	Density (Kg/m^3)	Unit Weight (Kg/m)	
Main Frame (C75)	0,00011700	7850	0,91845	Kg/m^1
Batten	0,00005941	7850	0,46639843	Kg/m^1
Spandek			5,2	Kg/m^2

4.1.1. Dead Load

Dead load refers to the permanent load that is always present and does not change over time. This load includes the weight of the structure itself and all fixed elements attached to it.

Table 2. Dead Load on the Main Truss

Load Code	Cross Sentional Area (m^2)	Unit	Weight (N)
P1	**1,7846**	**Kg**	**17,85 N**
a) Purlin	2*(0.466*0.865)/2	0.4034 Kg	
b) Spandek	(0.431*0.865*5.2)/2	0.9693 Kg	
c) Joint	0.3*1.373	0.4118 Kg	
P2	**3,4434**	**Kg**	**34,43 N**
a) Purlin	1*(0.466*0.865)	0.4034 Kg	
b) Purlin	(0.466*0.865)/2	0.4034 Kg	
c) Sapndek	(0.431*0.865*5.2)/2	0.9693 Kg	
d) Spandek	(0.388*0.865*5.2)/2	0.8726 Kg	
e) Joint	0.3*2.649	0.7946 Kg	
P3	**3,9756**	**Kg**	**39,76 N**
a) Purlin	1*(0.466*0.865)	0.4034 Kg	
b) Purlin	1*(0.466*0.865)	0.4034 Kg	
c) Spandek	(0.388*0.865*5.2)/2	0.8726 Kg	
d) Sapndek	(0.613*0.865*5.2)/2	1.3786 Kg	
e) Spandek	0.3*3.058	0.9174 Kg	
P4	**5,6662**	**Kg**	**56,66 N**
a) Purlin	1*(0.466*0.865)	0.4034 Kg	
b) Purlin	1*(0.466*0.865)	0.4034 Kg	
c) Upper Beam	1*(0.918*0.865)	0.7945 Kg	
d) Spandek	(0.613*0.865*5.2)/2	1.3786 Kg	
e) Spandek	(0.613*0.865*5.2)/2	1.3786 Kg	
f) Joint	0.3*4.359	1.3076 Kg	

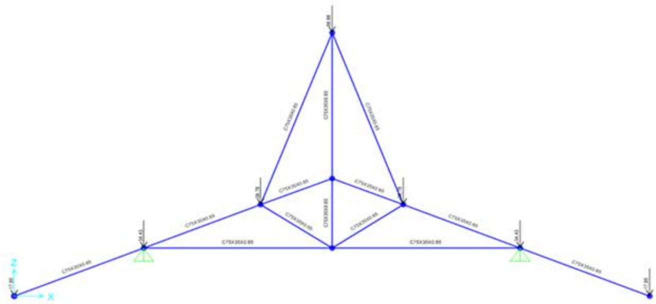

Figure 3. *Dead Load on the Main Truss*

4.1.2. Live Load on The Main Truss

Live load refers to a non-permanent load that can move or vary in magnitude over time. In this study, an additional live load of 100 Kg (equivalent to 1000 N) was added to loads P2 through P4.

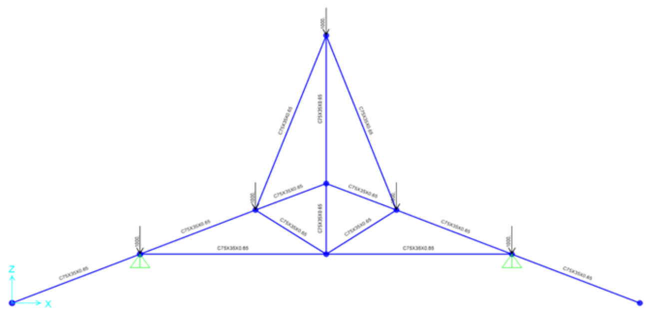

Figure 4. *Live Load on the Main Truss*

4.1.3. Normal Wind Load Condition

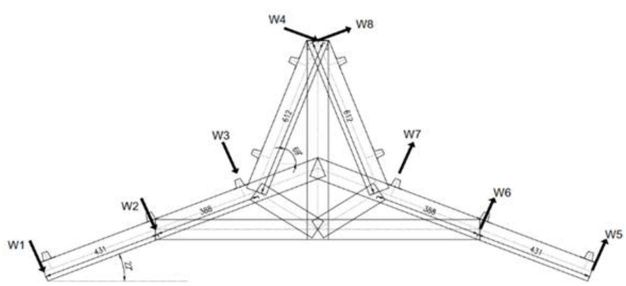

Figure 5. *Normal Wind Load Condition*

The normal wind load is taken as a minimum of 25 kg/m^2

The wind pressure coefficient is expressed as 0.02α – 0.4, where α is the roof slope angle in degrees

For example

α = 22 → = 0.02*22-0.4 = 0.04

α = 69 → = 0.02*69-0.4 = 0.98

Table 3. *Normal Wind Load on the Main Trusses*

Load Code	Cross Sectional Area (m^2)	Unit	Weight (N)
W1	0.431*0.865*0.04*25/2	0,186 Kg	1,86 N
W2a	0.431*0.865*0.04*25/2	0,186 Kg	1,86 N
W2b	0.431*0.865*0.04*25/2	0,186 Kg	1,86 N
W3a	0.431*0.865*0.04*25/2	0,186 Kg	1,86 N
W3b	0.613*0.865*0.98*25/2	6,496 Kg	64,96 N
W4	0.613*0.865*0.98*25/2	6,496 Kg	64,96 N

4.1.4. Suction Wind Coefficient

The suction wind coefficient used in this study is -0.4.

Table 4. *Suction Wind Coefficient on the Main Truss*

Load Code	Cross Sectional Area (m^2)	Unit	Weight (N)
W5	0.431*0.865*(-0.4)*25/2	-1,184 Kg	-18,64 N
W6a	0.431*0.865*(-0.4)*25/2	-1,184 Kg	-18,64 N
W6b	0.388*0.865*(-0.4)*25/2	-1,678 Kg	-16,78 N
W7a	0.388*0.865*(-0.4)*25/2	-1,678 Kg	-16,78 N
W7b	0.613*0.865*(-0.4)*25/2	-2,651 Kg	-26,51 N
W8	0.613*0.865*(-0.4)*25/2	-2,651 Kg	-26,51 N

4.1.5. Wind Load in Sap2000

Table 5. *Wind Load in SAP2000*

Code		Load (N)	α	W x Cos α (N)		W x Sin α (N)	
Wind Pressure							
W1	W1	1.86	22	1,728	1,728	0.698	0,698
W2	W2a	1.86	22	1,728	3,284	0.698	1,327
	W2b	1.68	22	1,556		0.629	
W3	W3a	1.68	22	1,556	24,834	0.629	61,269
	W3b	64.96	69	23,278		60.641	
W4	W4	64.96	69	23,278	23,278	60.641	60,641
Wind Suction							
W5	W5	-18,64	22	-17,287	-17,287	-6,983	-6,983
W6	W6a	-18,64	22	-17,287	-32,842	-6,983	-13,269
	W6b	-16,78	22	-15,559		-6,286	
W7	W5	-18,64	22	-17,287	-25,060	-6,286	-31,038
	W6a	-18,64	22	-17,287		-24,751	
W8	W6b	-16,78	22	-15,559	-9,501	-24,751	-24,751

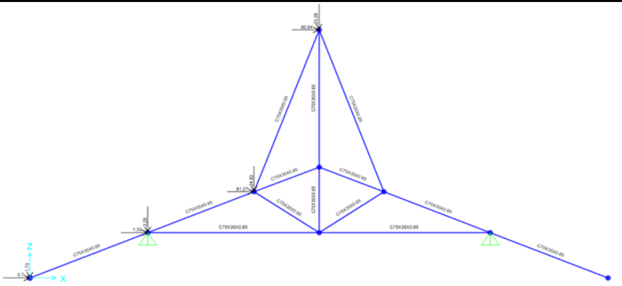

Figure 6. *Wind Pressure Load on Main Truss*

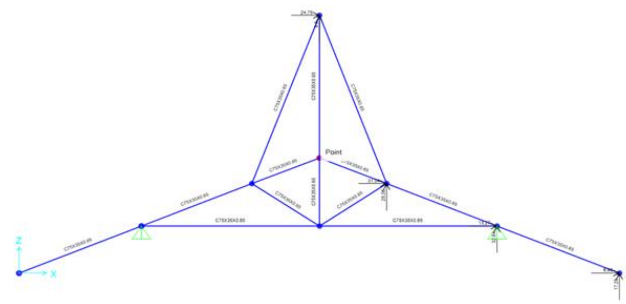

Figure 7. *Wind Section Load on Main Truss*

4.2. Rear Truss Loading

The spacing between rear trusses in this study is 765 mm.

Table 6. *Rear Truss Loading*

Profile	Cross Sectional Area (m^2)	Density (Kg/m^3)	Unit Weight (Kg/m)
Main Frame (C75)	0,00011700	7850	0,91845 Kg/m^1
Batten	0,00005941	7850	0,46639843 Kg/m^1
Spandek			5,2 Kg/m^2

4.2.1. Dead Load

Table 7. *Dead Load in Rear Truss Loading*

Load Code	Cross Sentional Area (m^2)	Unit	Weight (N)
P1	**1,7846**	**Kg**	**15,86 N**
a) Purlin	2*(0.466*0.765)/2	0.3568 Kg	
b) Spandek	(0.434*0.765*5.2)/2	0.8632 Kg	
c) Joint	0.3*1.22	0.3660 Kg	
P2	**3,4434**	**Kg**	**1069,40 N**
a) Purlin	1*(0.466*0.765)	0.3568 Kg	
b) Purlin	1*(0.466*0.765)/2	0.1784Kg	
c) Spandek	(0.434*0.765*5.2)/2	0.8632 Kg	
d) Spandek	(0.434*0.765*5.2)/2	0.8632 Kg	
e) Solar Panel	80	80,0 Kg	
f) Joint			
P3	**3,9756**	**Kg**	**36,22 N**
a) Purlin	2*(0.466*0.765)/2	0.3568 Kg	
b) Upper Beam	1*(0.918*0.765)	0.7026 Kg	
c) Spandek	(0.434*0.765*5.2)/2	1.7265 Kg	
d) Joint	00.3*2.786	0.8358 Kg	

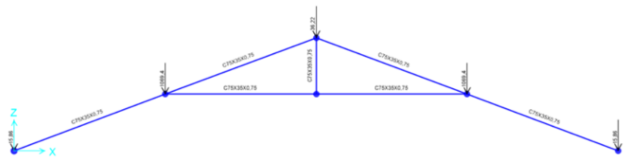

Figure 8. *Dead Load Distribution*

4.2.2. Live Load on the Reae Truss

In this study, an additional live load of 100 Kg (equivalent to 1000 N) was added to loads P2 through P4.

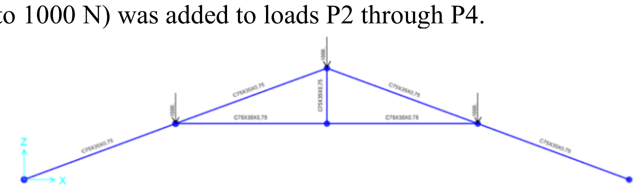

Figure 9. *Live Load on the Rear Trusses*

4.2.3. Normal Wind Load

The normal wind load is taken as a minimum of 25 kg/m².

The wind pressure coefficient is defined by the equation 0.02α−0.4, where α is the roof slope angle.

For example:

α = 20 → = 0,02*20,4-0,4 = 0,04

Table 8. *Normal Wind Load on Rear Trusses*

Load Code	Cross Sectional Area (m^2)	Unit	Weight (N)
W1	0.434*0.765*0.008*25/2	0,033Kg	0,33 N
W2a	0.434*0.765*0.008*25/2	0,033Kg	0,33 N
W2b	0.434*0.765*0.008*25/2	0,033Kg	0,33 N
W3	0.434*0.765*0.008*25/2	0,033Kg	0,33 N

4.2.4. Suction Wind Coefficient

The suction wind coefficient used in this study is -0.4.

Table 9. *Suction Wind Coefficients on Rear Trusses*

Load Code	Cross Sectional Area (m^2)	Unit	Weight (N)
W4	0.434*0.765*(-0.4)*25/2	-1,660 Kg	-16,60 N
W5a	0.434*0.765*(-0.4)*25/2	-1,660 Kg	-16,60 N
W5b	0.434*0.765*(-0.4)*25/2	-1,660 Kg	-16,60 N
W6	0.434*0.765*(-0.4)*25/2	-1,660 Kg	-16,60 N

4.2.5. Wind Load in Sap2000

Table 10. *Wind Loads Applied in SAP2000*

Code		Load (N)	α	W x Cos α (N)		W x Sin α (N)	
Wind Pressure							
W1	W1	0,33	20	0,311	0,311	0.116	0,116
W2	W2a	0,33	20	0,311	0,622	0.116	0,231
	W2b	0,33	20	0,311		0.116	
W3	W3	0,33	20	0,311	0,311	0.116	0,116
Wind Suction							
W4	W4	-16,60	20	-15,559	-15,559	-5,786	-5,786
W5	W5a	-16,60	20	-15,559	-31,119	-5,786	-11,573
	W5b	-16,60	20	-15,559		-5,786	
W6	W6	-16,60	20	-15,559	-15,559	-5,786	-5,786

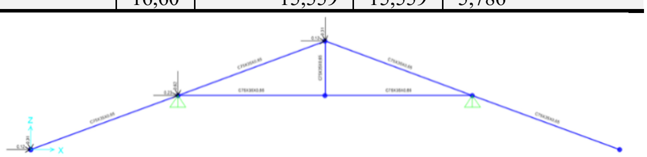

Figure 10. *Wind Pressure Load on Rear Trusses*

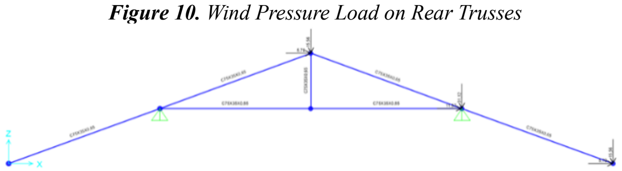

Figure 11. *Wind Suction Load on Rear Trusses*

4.2.6. Structural Analysis Results Using SAP2000

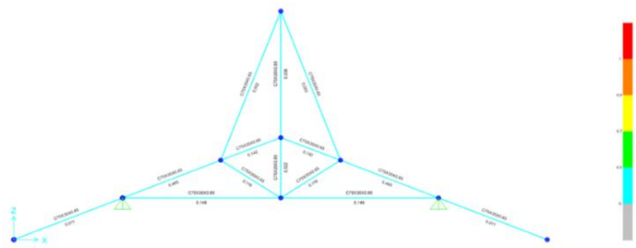

Figure 12. *Strength Ratio of the Main Truss Frame*

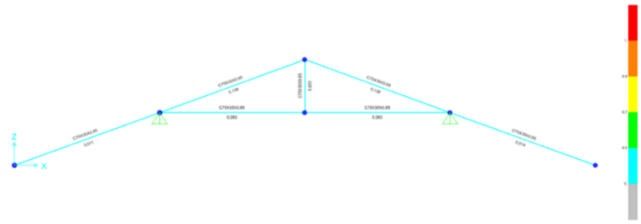

Figure 13. *Strength Ratio of the Rear Truss Frame*

4.2.7. Material Requirements

The material used in this study is lightweight steel shaped as a "C" profile, made from alloy steel plates with a thickness of 0.65 mm. The mechanical properties of the lightweight steel are as follows:

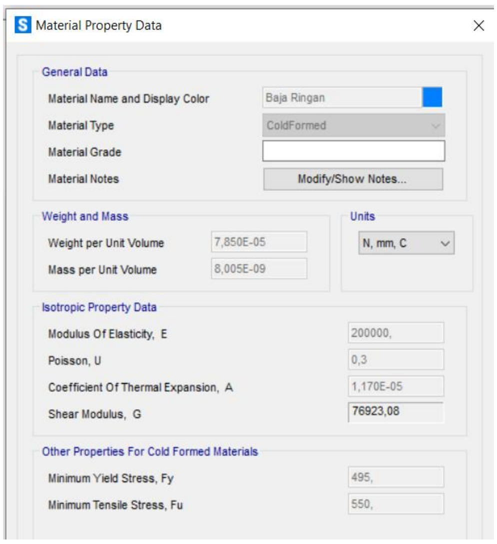

Figure 14. *Material Quality Display*

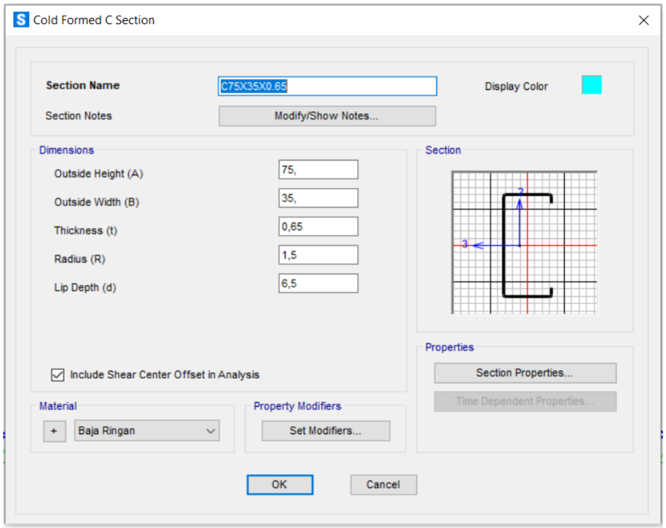

Figure 15. *Material Profile Dimensions*

Based on the structural analysis results, the total material required is summarized in the table below

Table 11. *Material Requirements*

Item	Length	Unit
Main Truss	4,39	Pieces
Batten	7,69	Pieces
L Braced Brace	0,40	Pieces
Hip Rafter	1,21	Pieces
Screw Bolt C 10 x 16 x 16	360	Pieces
Screw Bolt C 12 x 14 x 20	234	Pieces
Spandek Sheet	5,41	Sheets
Ridge Beam	16,73	Units

5. Conclusion

Based on the research and discussion, the following conclusions can be drawn:

1. The structural design calculations of the lightweight steel roof frame "Kaleles Sapi Kerapan" using SAP2000 V22.0.0 Ultimate are safe, with strength ratios for all members below 1, indicating structural safety.
2. The total material requirements for the lightweight steel roof are as follows:
   a. Main truss bars C 75.35.0.65 = 4.39 pieces
   b. Batten bars 30.20.0.45 = 7.69 pieces
   c. L-braced braces = 0.40 pieces
   d. Hip rafters C 75.35.0.65 = 1.21 pieces
   e. Screw bolts C 10 x 16 x 16 = 360 pcs
   f. Screw bolts C 12 x 14 x 20 = 234 pcs
   g. Spandek roofing sheets = 5.41 sheets

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References

[1] Dinas Pekerjaan Umum dan Tata Ruang, "Data Perumahan BPS Harus Dijadikan Acuan," Dinas Pekerjaan Umum dan Tata Ruang Kabupaten Buleleng.

[2] R. Gofur and I. E. Jumiati, "Analisis Kebijakan Program Sejuta Rumah: Sebuah Tinjauan Literatur," *Adm. J. Ilm. Adm. Publik dan Pembang.*, vol. 12, no. 2, pp. 113–120, 2021, doi: 10.23960/administratio.v12i2.230.

[3] H. Hassan, J. B. Mangare, and P. A. K. Pratasis, "Faktor-Faktor Penyebab Keterlambatan pada Proyek Konstruksi dan Alternatif Penyelesaiannya (Studi Kasus: Di Manado Town Square III)," *J. Sipil Statik*, vol. 4, no. 11, pp. 657–664, 2016.

[4] M. R. Cabral and P. Blanchet, "Prioritizing Indicators for Material Selection in Prefabricated Wooden Construction," *Buildings*, vol. 14, no. 1, p. 63, Dec. 2023, doi: 10.3390/buildings14010063.

[5] M. H. Zulfiar and F. Kusumawardana, "Risiko Kerugian Mutu Pekerjaan Konstruksi Pada Pembangunan Gedung Sekolah 4 Lantai," *Bull. Civ. Eng.*, vol. 4, no. 1, pp. 7–12, Feb. 2024, doi: 10.18196/bce.v4i1.21901.

[6] D. Oktarina and A. Darmawan, "Analisa Perbandingan Rangka Atap Baja Ringan dan Rangka Atap Kayu dari Segi Analisis Struktur dan Anggaran Biaya," *J. Konstr.*, vol. 7, no. 1, pp. 27–36, 2015.

[7] S. A. Rahayu and D. F. Manalu, "ANALISIS PERBANDINGAN RANGKA ATAP BAJA RINGAN DENGAN RANGKA ATAP KAYU TERHADAP MUTU, BIAYA DAN WAKTU," *FROPIL (Forum Prof. Tek. Sipil)*, vol. 3, no. 2, pp. 116–130, 2015.

[8] W. Wuryanti, "Kapasitas Rangka Atap Baja Canai Dingin Dengan Berbagai Model Geometris Dalam Memikul Beban Statis," *J. Permukim.*, vol. 13, no. 2, p. 90, Apr. 2019, doi: 10.31815/jp.2018.13.90-103.

[9] H. Purwanto, "Analisis Efisiensi Konstruksi Rangka Atap Baja Ringan," *J. Deform.*, vol. 2, no. 1, pp. 26–36, 2017, doi: 10.31851/deformasi.v2i1.2817.

[10] G. Hartati, D. Suryadi, and A. Maskur, "ANALISIS PERENCANAAN DAN PENJADWALAN PROYEK PEMBANGUNAN RUMAH SEDERHANA MENGGUNAKAN NETWORK PLANNING DI DESA SUKAHURIP KECAMATAN CISAGA KABUPATEN CIAMIS," *J. Media Teknol.*, vol. 10, no. 01, pp. 29–39, Sep. 2023, doi: 10.25157/jmt.v10i01.3322.

[11] M. Y. N. Budhyowati, "Kajian Konstruksi Atap Bangunan Hemat Energi," *J. Tek. Sipil Terap.*, vol. 4, no. 2, p. 45, Sep. 2022, doi: 10.47600/jtst.v4i2.434.

[12] M. Iman, L. O. Nelfia, and E. H. Manurung, "STEEL ROOF STRUCTURE STRENGTH ANALYSIS USING 2D

FINITE ELEMENT METHOD," *Indones. J. Constr. Eng. Sustain. Dev.*, vol. 6, no. 2, Dec. 2023, doi: 10.25105/cesd.v6i2.18894.

[13] M. N. La Ola, H. Purnama, M. Makmur, and D. Mandeno, "Analisis Numerik Kuda-Kuda Baja Ringan terhadap Lendutan dan Efisiensi pada Berbagai Konfigurasi Struktur," *MEDIA Konstr.*, vol. 10, no. 2, pp. 215–224, Jul. 2025, doi: 10.33772/jmk.v10i2.125.

[14] A. G. Djafar, R. Rahmayanti, W. Saputra, and A. Kaharu, "CONSTRUCTION ANALYSIS OF HOUSING'S ROOF IN GORONTALO CITY," *J. Build. Archit.*, vol. 1, no. 1, pp. 10–15, Feb. 2023, doi: 10.56190/jba.v1i1.6.

[15] B. A. R. R., "Perbandingan Desain Elemen Struktur Pada Bangunan Gedung Secara Manual dan Dengan Software RSAP 2022," *J. Qua Tek.*, vol. 13, no. 1, pp. 46–60, Mar. 2023, doi: 10.35457/quateknika.v13i1.2660.

[16] H. Husnah, N. E. Darfia, and F. Hidayat, "ANALISIS STRUKTUR RANGKA BAJA RINGAN DAN BAJA BERAT (WF) DENGAN METODE BRICSCAD DAN METODE ELEMEN HINGGA," *Siklus J. Tek. Sipil*, vol. 5, no. 2, pp. 87–96, Oct. 2019, doi: 10.31849/siklus.v5i2.3232.