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Comparative Analysis of Steel and Timber Truss Structural Strength in Shophouse Buildings using the Structure Analysis Program Method

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Abstract

Wood and steel trusses are two types of materials commonly used in building roof structures, each with its own advantages and disadvantages in terms of strength, durability, cost, aesthetics, and other aspects. This study examines steel and wood trusses from the aspect of strength by designing both types of trusses and then determining the quality of wood and steel materials for analysis using a structural analysis program. The truss design has a span of 18 m with a roof slope of 30°, and the trusses are spaced 2 m apart. The total area of the shop-house building is 12 m × 18 m = 216 m², with a height of 4 m. The truss material uses steel with a grade of BJ 37, while the wood is grade A. The structure of the shop-house uses concrete with a strength of 25 MPa. The dead load consists of a uniform load of 50 kg/m² for the trusses and 150 kg/m² for the shop-house. The live load for the roof (liveroof) is 50 kg/m², while the live load for the shop-house floor is a uniform load of 100 kg/m². The load combination used in the analysis is 1.2D + 1.6L + 0.5Lr. The analysis results show that the bending moment, shear force, and axial force of the steel truss are greater than those of the wood truss because the self-weight of the steel truss is higher than that of the wood truss. The deflection of both steel and wood trusses remains within the allowable limit of 0.3, indicating that the deflections are safe. Based on the structural design check, both steel and wood trusses are safe to use.

Introduction

A truss is one of the main structural elements in a roof framing system, functioning as the primary support that bears the overall roof load (Qin & Stewart, 2019; Gupta & Limkatanyoo, 2008). In building construction, the truss plays a vital role by transmitting and distributing all roof loads both dead loads such as the weight of tiles, ceilings, and roof frames, and live loads such as wind, rain, and maintenance activities to the lower structural elements like columns and supporting walls. Without a strong and stable truss system, the roof structure would be unable to maintain its stability, potentially leading to deformation or even structural failure that could endanger building occupants (Krentowski, 2021; Tüfekci et al., 2020).

Therefore, the planning and design of trusses represent one of the most critical aspects of structural engineering (Paryati, 2025). In the construction field, trusses can be made from various materials, including wood, steel, reinforced concrete, or a combination of these. The selection of truss materials depends on several key factors, such as the architectural design of

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the building, climatic and environmental conditions, soil bearing capacity, availability of materials at the project site, and the owner's budget.

Additionally, considerations such as strength, load resistance, ease of installation, and structural service life also influence the material choice. The two most commonly used materials for truss construction in Indonesia are wood and steel, each with its own advantages and limitations (Ariani et al., 2015; Octavia et al., 2019). Wooden trusses have long been the most widely used type, particularly in traditional and residential buildings. Wood offers several benefits, including its lightweight nature, ease of shaping, local availability in tropical regions like Indonesia, and its natural, warm aesthetic appeal.

Furthermore, wood has good vibration-damping properties and adequate tensile and compressive strength when sourced from strong types such as class I or II woods (for example, teak, ironwood, and merbau). However, wood also has several weaknesses it is vulnerable to termite attacks, humidity changes, decay, and dimensional limitations due to natural conditions. Moreover, the availability of high-quality hardwood has decreased due to environmental concerns and logging restrictions, leading to increased costs for strong timber materials (Ikhsan et al., 2024; Mulyadi et al., 2020).

Conversely, steel trusses have become an increasingly popular alternative in the modern era, especially for commercial, industrial, and low- to mid-rise residential buildings (Khan et al., 2023; Tenório et al., 2024; Hassan & Saeed, 2024). Steel offers very high tensile and compressive strength, uniformity, and can be mass-produced with consistent quality. It is also relatively lighter than concrete, resistant to termites and fungi, and allows for longer roof spans without requiring many intermediate supports. Another advantage is the ease of connection through bolts, welding, or knock-down systems, which makes installation faster and more efficient.

However, steel also has drawbacks it is prone to corrosion if not properly coated and requires regular maintenance, especially in humid or coastal areas. In terms of cost, steel trusses usually require a higher initial investment than wood, but they offer a longer service life (Abdullah et al., 2024; Pipinato, 2018; Abed et al., 2022). Given these advantages and disadvantages, the choice between steel and wooden trusses must balance structural strength, cost efficiency, ease of construction, and sustainability. Balasbaneh et al. (2022) said that, In the Indonesian context where climate and socioeconomic conditions vary widely a comparative study between steel and wooden trusses is highly relevant.

Such studies help planners, project implementers, and the public choose the most appropriate structural material according to local needs and conditions without compromising safety and efficiency (Fitriyanti & Ismawati, 2024; Yansiku et al., 2025). This study specifically examines the structural strength comparison between steel and wooden trusses. The analysis is conducted by designing truss models from both materials applied to a one-story shophouse (ruko) building. The selection of a one-story shophouse as the research object is based on the fact that this type of building is commonly found in both urban and suburban areas of Indonesia and serves a dual function as a business place and residence.

Roof structures in shophouses generally have wide spans, requiring strong and efficient truss systems (Ali & Moon, 2018). Through the design and structural analysis of steel and wooden trusses, this study aims to provide a comprehensive comparison of the strength, material efficiency, and structural performance of both materials (Aproga et al., 2025; Hermawan et al., 2023). The analysis in this study uses a Structural Analysis Program a software tool for calculating and simulating structural behavior under various load types. With this software, loads acting on the trusses such as dead loads, live loads, and wind loads can be modeled more accurately and realistically (Arditama & Rasidi, 2021).

The calculation results are then used to evaluate internal forces (compression, tension, and bending moments) and determine whether the structural design meets safety criteria as required by building design standards (for example, SNI 1729:2020 for steel structures and SNI 7973:2013 for wooden structures). Thus, this research is not only theoretical but also practical, integrating structural engineering principles with modern analytical technology (Huang et al., 2025; Tenório et al., 2024).

The main benefit of this study is to provide deeper insight into the strength comparison between steel and wooden trusses, particularly when applied to simple structures like one-story shophouses. For civil engineering students, the findings may serve as an academic reference that helps them understand the mechanical characteristics of both materials and their implications for structural design (Siron et al., 2021). For practitioners and building planners, the results can be a useful consideration in selecting the most efficient material in terms of strength, cost, and long-term maintenance. For the general public, this study is expected to provide useful knowledge for making construction decisions especially when choosing safe, economical, and sustainable roofing materials (Cudicio & i Gardella, 2024).

Furthermore, this research contributes to improving material resource efficiency in the construction sector. In the context of sustainable development, material selection must consider not only technical and economic aspects but also environmental factors. Excessive wood usage may harm forest ecosystems, while inefficient steel use may increase carbon emissions during production (Hromada et al., 2024; Lippke et al., 2011; Punhagui & John, 2022). Therefore, comparing these two materials helps determine the more eco-friendly option according to green construction principles. Studies like this are essential to support the vision of infrastructure development that is not only strong and safe but also environmentally conscious and oriented toward long-term sustainability (Parthasarathy et al., 2021; Adshead et al., 2019; Pandit et al., 2017; Malekpour et al., 2015; Oyebode et al., 2025).

Additionally, comparing steel and wooden trusses is relevant in the context of adapting to climate change and increasingly frequent extreme weather conditions. The roof structure is the most exposed part of a building to heat, rain, and wind; thus, its strength and durability against weather variations are crucial (Prati et al., 2022). Steel trusses may perform better in high-rainfall areas due to their resistance to decay, while wooden trusses may be more suitable in rural regions with low corrosion risks and abundant local wood resources. This analysis is expected to provide a scientific basis for adapting roof structural designs according to Indonesia's diverse geographical and environmental conditions (Adekunle et al., 2024).

In conclusion, this study not only focuses on strength comparison but also encompasses broader considerations of structural efficiency, sustainability, and practical relevance in modern construction. Through a program-based structural analysis approach, the results are expected to be more objective and accurate, serving as a valuable reference for both technical and academic decision-making.

Overall, this study aims to answer a fundamental question: which truss type steel or wood demonstrates better structural performance when applied to a one-story shophouse building? The answer is expected to enrich structural engineering knowledge and make a tangible contribution to the design of efficient, safe, and sustainable buildings.

Methods

This study employs a structural analysis method, which aims to assess the strength and stability of roof trusses under applied loads. The analysis utilizes the Structure Analysis Program, a civil engineering software used to calculate internal forces (such as moments, shear forces, and axial forces) and deformations in the structure due to specific load combinations. Through this method, an accurate depiction of the structural behavior of trusses made from two different materials steel and wood can be obtained, enabling an objective comparison in terms of strength and structural efficiency. The data used in this study include truss design, material specifications, and loads acting on the roof frame system. The analyzed truss design is applied to a one-story shop-house (ruko) building, chosen due to its common structural form and widespread use in the field. Data regarding building dimensions, roof type, and supporting systems (such as ring beams and columns) are also considered to ensure that the analytical model represents real field conditions. In general, this research consists of several main stages carried out systematically and sequentially, from the initial phase to the final stage of the study. The research flow, originally presented in a diagram, can be described narratively as follows. The first stage begins with "Start," marking the initiation of the research. At this stage, the researcher defines the objectives and scope of the study, namely to compare the strength of steel and wooden trusses in supporting roof loads on a one-story shop-house. Problem identification and limitation setting are also conducted to keep the research focused. The research limitations include: (1) analysis is focused solely on the roof truss system without considering full interaction with other structural elements such as floor beams; (2) loads are determined based on Indonesian load regulations; and (3) materials are limited to common steel profiles and Class I structural timber.

The second stage is a literature review. This stage involves gathering information and theories relevant to the planning and analysis of truss structures. The literature sources include national standards such as SNI 1727:2020 (Minimum Design Loads for Buildings and Other Structures), SNI 1729:2020 (Steel Structure Design for Buildings), and SNI 7973:2013 (Wood Structure Design). Additional references, including civil engineering textbooks, scientific journals, and previous studies, are also used to strengthen the theoretical foundation and design references. The results of this stage serve as the basis for determining analytical approaches, calculation parameters, and design assumptions. The third stage is preliminary design or pre-elementary design. In this phase, initial designs of steel and wooden trusses are created based on building dimensions and roof functional requirements. The preliminary design includes determining the truss type (e.g., simple triangular or Pratt truss), span length, height, and type of joint used. The initial member dimensions are estimated based on load assumptions and material properties. The goal of this stage is to produce an initial design to be further tested in the structural analysis phase. If the design later fails to meet strength and safety criteria, it will be revised and returned to this stage for adjustment.

The fourth stage is structural analysis the core of the research process. At this stage, the designed trusses are inputted into the Structure Analysis Program to simulate loading conditions. The purpose is to identify how the structure behaves under various loads. The analyzed loads include dead loads (self-weight of the truss structure and all roof system components such as tiles, battens, rafters, and supporting elements), live loads (temporary loads such as maintenance workers and rainwater accumulation), and wind loads, calculated based on wind direction and intensity in accordance with SNI 1727:2020. Through this analysis, the truss's ability to resist and distribute loads safely can be evaluated, forming the basis for conclusions about its strength and stability. The analysis program then calculates the structure's response to load combinations, including compression, tension, bending moments, and deflections in each truss member. These results determine whether the chosen member sizes and configurations meet strength and stability requirements. If the analysis results indicate that the design does not meet safety criteria, the process returns to the pre-elementary design stage for modifications. If the structure satisfies all safety standards, the research proceeds to the next stage.

The fifth stage is final design. After comprehensive analysis and verification, the final steel and wooden truss designs are established, fulfilling requirements for strength, stiffness, and stability. The final design includes detailed member sizes, connection types (bolted, welded, or pegged), and an optimized configuration for both strength and material efficiency. At this stage, the design results are documented in the form of technical drawings and specification tables. The sixth stage is design checking. The purpose is to validate and evaluate the final designs of both truss types. This involves comparing the structural capacity against the maximum applied loads and analyzing material efficiency. Internal forces, maximum deflections, and safety factors between steel and wooden trusses are also compared to determine which material performs better for one-story shop-house structures in terms of strength and stability. The final stage involves drawing conclusions and providing recommendations. Based on analysis and design checking results, the researcher concludes the comparative strength performance between steel and wooden trusses and provides recommendations for the most suitable material under specific conditions. Suggestions for further research are also given, such as exploring cost efficiency, durability, or ease of construction in the field. The entire research process concludes at the “Finish” stage, indicating that all steps from data collection, design, analysis, to conclusion formulation have been systematically completed. A structured research methodology such as this is expected to produce analytical results that are accurate, measurable, and scientifically accountable. Consequently, the outcomes not only provide a comparative understanding of the strength between steel and wooden trusses but also offer practical insights for building designers and civil engineering students in comprehending efficient, safe, and standard-compliant roof structure design principles in Indonesia.

Results and Discussion

In this study, the design was created by combining the structure of a one-story shop-house (ruko) with both steel and wooden trusses, as follows:

Design and Materials

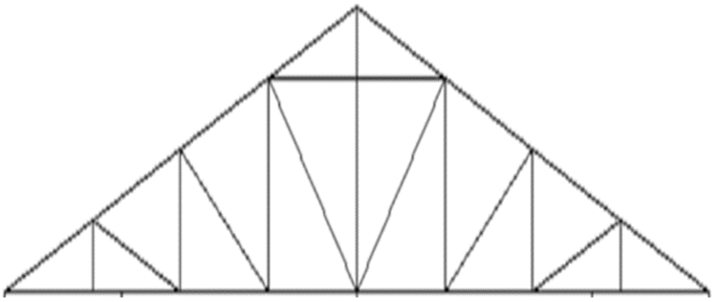

Figure 1. Truss Design

The truss span length is 18 m², roof slope is 30°, and the truss spacing is 2 m.

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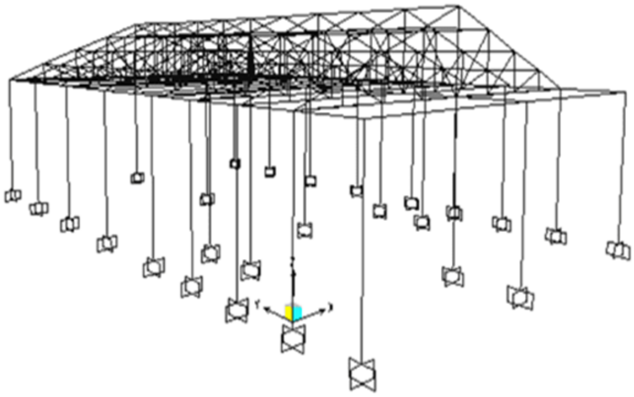

Figure 2. 3D Model of the Shop-House with Trusses

The shop-house building area is 12 m × 18 m = 216 m², with a column height of 4 m. The main column dimensions are 25 cm × 25 cm, the secondary column dimensions are 20 cm × 20 cm, and the ring beam dimensions are 15 cm × 20 cm. The concrete quality (Fc') is 25 MPa, with a unit weight of 2400 kg/m³, modulus of elasticity (E) of 23,500 MPa, and a Poisson's ratio of 0.2. For the steel truss, L-angle steel 45.45.6 is used, and for the purlins, C-channel steel C.75.45.1.6 with BJ 37 steel grade is applied. The unit weight of steel is 7,849 kg/m³, modulus of elasticity (E) is 200,000 MPa, Poisson's ratio is 0.3, minimum yield stress (Fy) is 240 MPa, and minimum tensile stress (Fu) is 370 MPa. For the wooden truss, Grade A timber with dimensions of 5/7 is used. The wood density is 450 kg/m³, modulus of elasticity (E) is 13,000 MPa, and Poisson's ratio is 0.3.

Loading

The uniform dead load for the roof tiles, ceiling, frame, and hangers is 50 kg/m², while the dead load for the shop-house structure (according to SNI) is 150 kg/m².

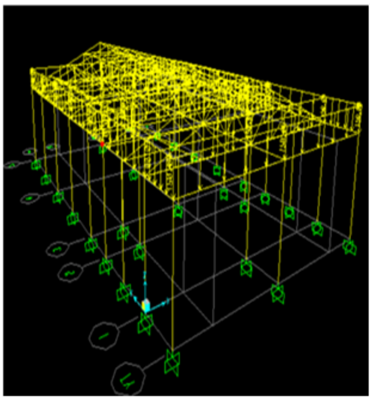

Figure 2. Dead Load on Truss

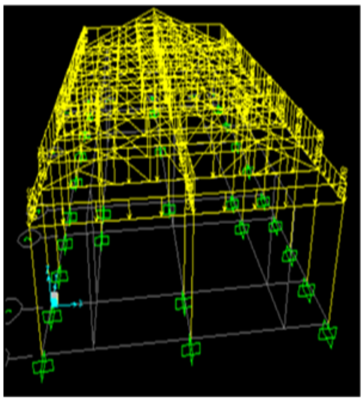

Figure 3. Live Load on Truss

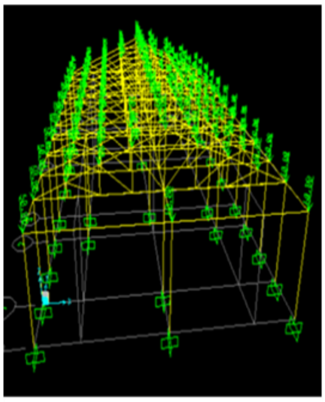

Figure 4. Liferoof Load

The live load on the shop-house floor is 100 kg/m², and the roof live load (liferoof) is 50 kg. The load combination used is 1.2D + 1.6L + 0.5Lr, where D = dead load, L = live load, and Lr = liferoof load.

Coordinate System and Structural Deflection

Structural analysis in this study uses the UCS (Universal Coordinate System) with active degrees of freedom in a 3D modeling system. Based on the analysis results from the structural analysis software, the truss deflections obtained are as follows:

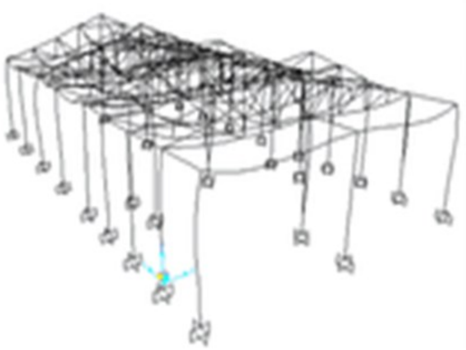

Figure 5. Deflection of Steel Truss

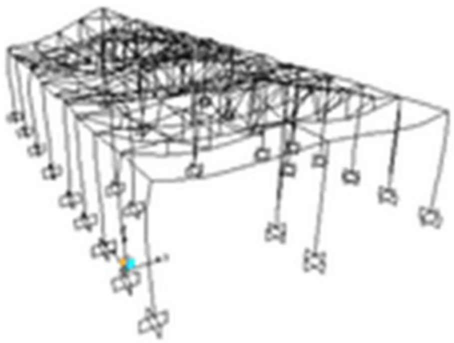

Figure 6. Deflection of Wooden Truss

According to SNI, the maximum allowable deflection limit for structures supporting ceilings or roofs is l/180 × 6 m = 0.03. The analysis results are presented as follows:

Table 1. Comparison of Deflection in Steel and Wooden Trusses

Joint	**Output Case**	**Steel Truss**			**Wooden Truss**		
		U1 (m)	**U2 (m)**	**U3 (m)**	**U1 (m)**	**U2 (m)**	**U3 (m)**
115	1.2D + 1.6L + 0.5(Lr or S or R)	-0.00001	-0.00045	-0.00308	-0.00011	0.00020	-0.00155
141	1.2D + 1.6L + 0.5(Lr or S or R)	-0.00013	-0.00027	-0.00190	0.00015	-0.00039	-0.00598

From the table above, it can be seen that the maximum deflection of the steel truss occurs at joint 115 with a value of 0.00308 m, while the maximum deflection of the wooden truss occurs at joint 141 with a value of 0.00598 m. Therefore, the deflection in the wooden truss is greater than that in the steel truss. However, both trusses remain safe since neither exceeds the allowable deflection limit of 0.03 m.

BMD (Bending Moment Diagram)

The forces resulting from the load combinations produce the following bending moments:

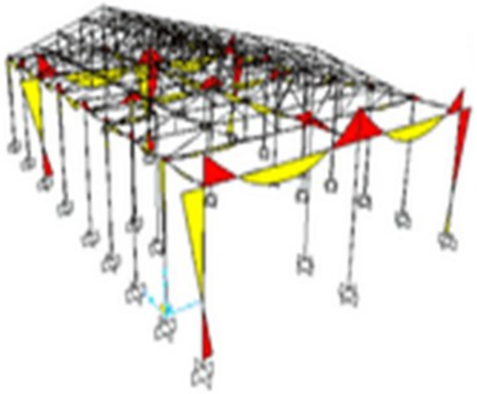

Figure 7. Filled Moment Diagram

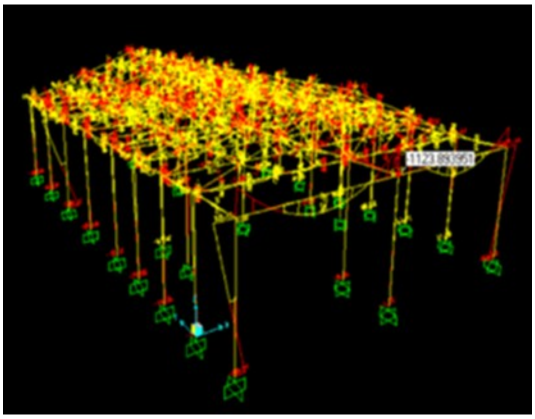

Figure 8. Moment Value Diagram

From the moment diagram above, the maximum bending moment in the shop structure with a steel truss is -1123.894 Kgm.

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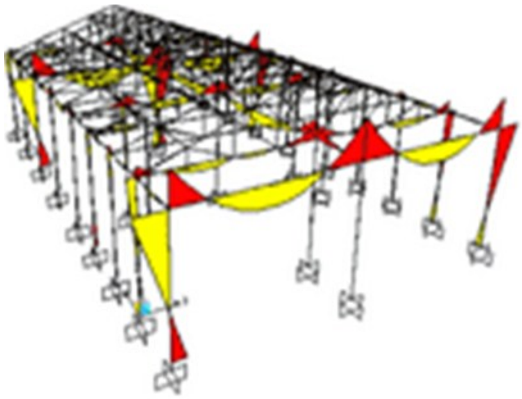

Figure 9. Filled Moment Diagram

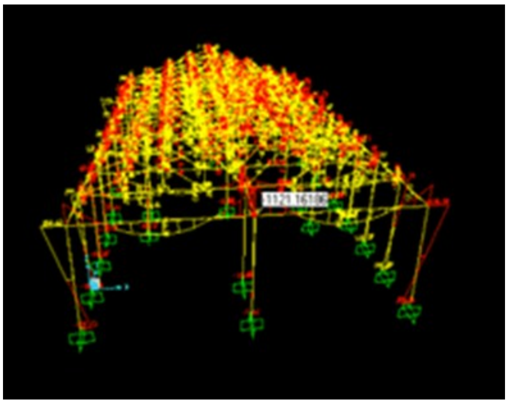

Figure 10. Moment Value Diagram

From the diagram above, the maximum bending moment in the shop structure with a wooden truss is -1121.162 Kgm. The bending moment in the steel truss is slightly greater than that in the the wooden truss, with a value of 1123.894 Kgm > 1121.162 Kgm.

SFD (Shear Force Diagram)

The shear forces acting perpendicular to the member axis are as follows:

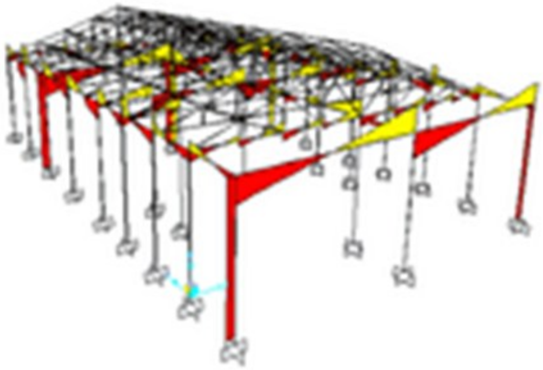

Figure 11. Filled Shear Diagram

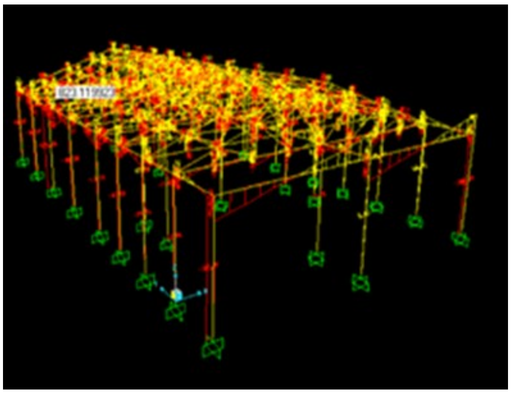

Figure 12. Shear Value Diagram

From the diagram above, the maximum shear force in the shop structure with a steel truss is 823.119 Kg.

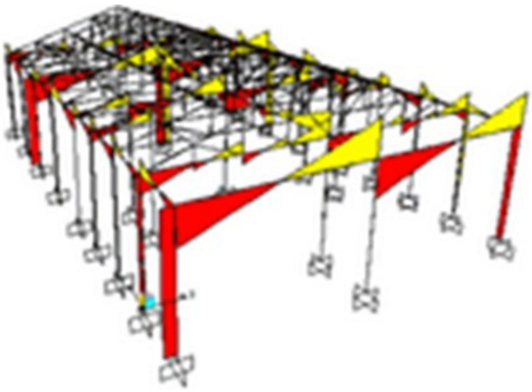

Figure 13. Filled Shear Diagram

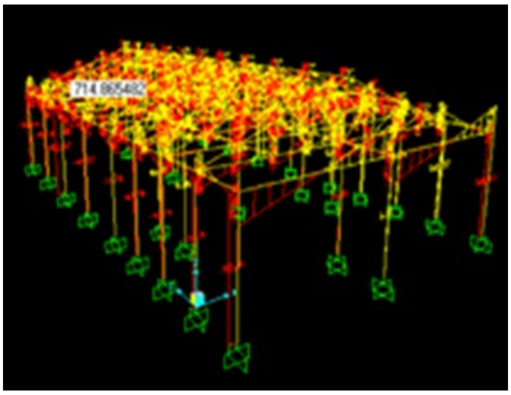

Figure 14. Shear Value Diagram

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From the shear force diagram above, it can be seen that the largest shear force value in the shophouse structure with wooden trusses reached 714.865 kg. This value indicates the magnitude of the shear force acting on the truss elements due to the load received from the roof and the structure above it. Meanwhile, in steel trusses, the shear force that occurs is greater, namely 823.119 kg. This shows that steel trusses have a higher shear force resistance capacity than wooden trusses. This difference is caused by differences in material properties, where steel has greater strength and stiffness than wood, so it is able to withstand greater loads without experiencing significant deformation. Thus, from the results of this shear force analysis, it can be concluded that steel trusses are superior in terms of shear force resistance capacity compared to wooden trusses, making them more suitable for buildings with relatively heavy roof loads.

NFD (Normal Force Diagram)

The normal forces due to compressive loads are illustrated as follows:

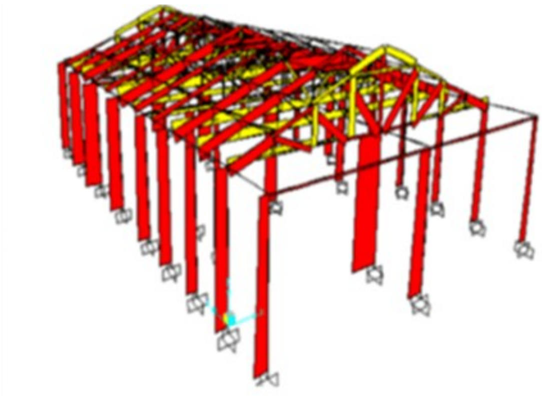

Figure 15. Filled Normal Diagram

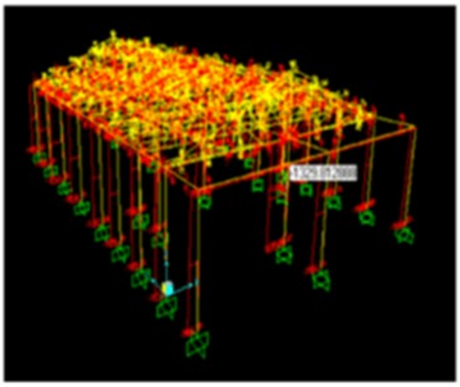

Figure 16. Normal Value Diagram

From the diagram above, the maximum normal force in the shop structure with a steel truss is 1329.813 Kg.

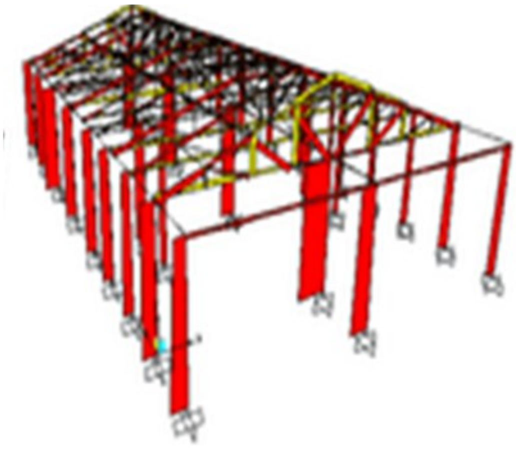

Figure 17. Filled Normal Diagram

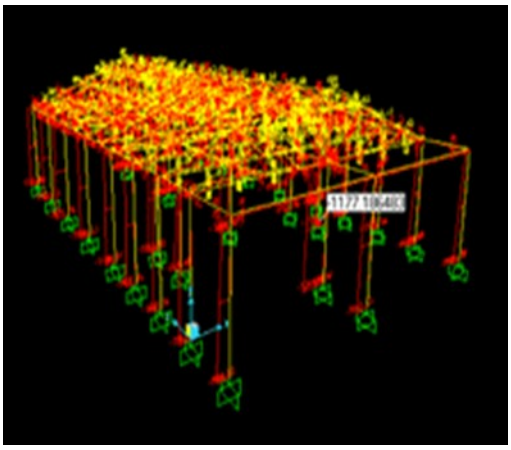

Figure 18. Normal Value Diagram

From the diagram above, the maximum normal force in the shop structure with a wooden truss is 1177.186 Kg. The compressive normal force in the steel truss is greater than that in the wooden truss, with a value of 1329.813 Kg > 1177.186 Kg.

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Assembled Joint Masses

The results of the vibration analysis are as follows:

Table 2. Assembled Joint Masses

Joint	Steel Truss (Kgf·s^2/m)			Wooden Truss (Kgf·s^2/m)		
	U1 (m)	U2 (m)	U3 (m)	U1 (m)	U2 (m)	U3 (m)
14	32.93995	32.93995	32.93995	32.66715695	32.66715695	32.66715695
15	81.98518	81.98518	81.98518	70.97224698	70.97224698	70.97224698
38	33.52827	33.52827	33.52827	33.5282684	33.5282684	33.5282684

From the table above, it can be seen that the mass at each joint when the building vibrates (in s^2/m) for the steel truss is 81.98518 Kgf·s^2/m, which is greater than that of the wooden truss structure (70.97225 Kgf·s^2/m).

Check Design Structure

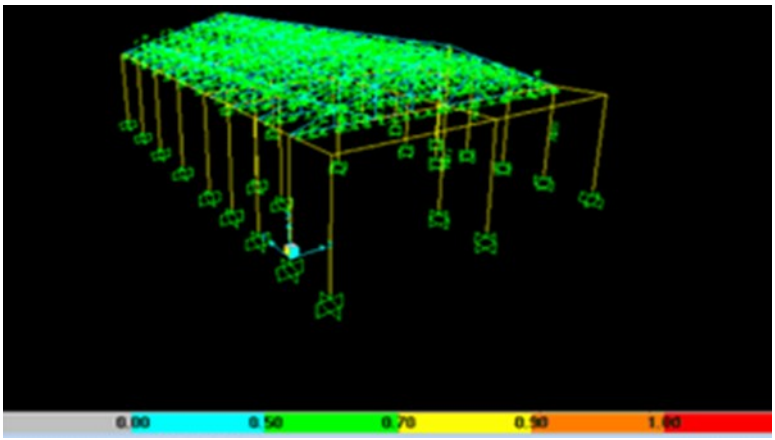

Figure 19. Check Design Structure

From the design check results, the steel structure is shown in blue color, indicating that it is safe. For the wooden structure, the application used does not yet support the wood design check system, but based on the analysis of the moment and deflection results, it can be concluded that the design of the wooden truss is also safe. In conclusion, both steel and grade A (quality 1) wood trusses are safe for use. Steel offers greater strength, while wood is lighter in weight.

Conclusion

Based on the results of the analysis and discussion, the following conclusions can be drawn, the truss structure has a span length of 18 meters with a roof slope of 30° and a spacing between trusses of 2 meters. The total area of the shop building is 12 m × 18 m = 216 m^2, with a building height of 4 meters. The truss materials used are BJ 37 grade steel for the steel truss and Grade A wood for the wooden truss. The main structure of the shop building uses reinforced concrete with a compressive strength of f'c = 25 MPa. The dead load consists of a uniform load on the truss of 50 kg/m^2 and on the shop floor of 150 kg/m^2. The live load used includes a concentrated live roof load of 50 kg/m^2, while the live load on the shop floor is a uniform load of 100 kg/m^2. The load combination used in the analysis is 1.2D + 1.6L + 0.5Lr. The analysis results indicate that the values of bending moment, shear force, and normal force in the steel truss structure are greater than those in the wooden truss, due to the higher self-weight of steel compared to wood. However, the deflection values of both trusses remain within the allowable limits, not exceeding the deflection limit of 0.03 m. Based on the check design structure results, both the BJ 37 steel truss and the Grade A wooden truss are considered safe for use. Therefore, both materials are suitable for application in shop building structures. Steel has the advantage of higher strength, while wood offers the benefit of being lighter in weight. It is recommended that the loading calculations be carried out in a more detailed and specific manner, particularly by specifying the exact type of wood used in the structure. Future analyses should also utilize structural analysis software that supports check structure with wood design features to obtain more accurate and reliable results for wooden trusses.

Suggestion

In addition, it is advisable to consider testing the design using lightweight steel trusses, as their self-weight is significantly lower than that of conventional steel. By using lightweight steel, the resulting internal forces can be reduced, thereby improving the overall stability and efficiency of the supporting structural system beneath the truss.

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