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Comparison of the Structural Strength of Steel and Timber Trusses in Shophouse Structures Using the Structural Analysis Program Method

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Abstract

Timber and steel are the two materials most frequently adopted for roof-truss construction, and each carries a distinct profile of strengths and drawbacks with respect to load capacity, durability, cost, and appearance. This paper evaluates the structural performance of steel and timber trusses by designing both configurations and assessing their material quality through computer-based structural analysis. The truss spans 18 m at a 30° roof pitch, with trusses spaced 2 m apart. The shophouse footprint totals 216 m² (12 m × 18 m) at a height of 4 m. Grade BJ 37 steel and Grade A timber were selected as the two truss materials, while the shophouse structure itself is built from 25 MPa concrete. A uniform dead load of 50 kg/m² was applied to the trusses and 150 kg/m² to the shophouse; the live roof load was set at 50 kg/m², and the shophouse floor live load at a uniform 100 kg/m². Load combinations followed 1.2D + 1.6L + 0.5Lr. The results show that bending moment, shear, and axial force are all higher in the steel truss than in the timber truss, a consequence of steel's greater self-weight. Deflections for both truss types stayed within the 0.03 m code limit, confirming that both designs are structurally sound. The design checks therefore indicate that steel and timber trusses alike are suitable for use in this application.

Keywords:

Steel Truss; Timber Truss; Structural Analysis Program; Bending Moment; Deflection

1.0 Introduction

Within a roof framing system, the truss functions as the principal load-bearing component, carrying the full weight of the roof assembly (Qin & Stewart, 2019; Gupta & Limkatanyoo, 2008). It gathers and transfers every load acting on a building's roof — dead loads such as tiling, ceiling finishes, and framing members, together with live loads arising from wind, rainfall, and maintenance activity — down to the columns and load-bearing walls beneath. A roof lacking a sound, stable truss system cannot maintain its geometry, risking deformation or outright structural collapse that endangers occupants (Krentowski, 2021; Tüfekci et al., 2020).

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For this reason, truss planning and design sit among the most consequential tasks in structural engineering practice (Paryati, 2025). Trusses may be fabricated from timber, steel, reinforced concrete, or hybrid combinations of these, and the choice of material hinges on several considerations: the building's architectural intent, prevailing climatic conditions, the bearing capacity of the underlying soil, local material availability, and the client's budget.

Additional considerations — strength, load-carrying capacity, ease of erection, and expected service life — likewise shape material selection. In Indonesia, timber and steel remain the two dominant truss materials, each offering its own set of trade-offs (Ariani et al., 2015; Octavia et al., 2019). Timber trusses have a long history of use, particularly in residential and vernacular construction, owing to timber's light weight, workability, ready availability across the tropics, and warm visual character.

Timber also damps vibration effectively and, when sourced from durable species such as teak, ironwood, or merbau (Class I or II timber), delivers adequate tensile and compressive capacity. Its shortcomings, however, include susceptibility to termite attack, sensitivity to moisture fluctuation, decay, and size constraints imposed by natural growth. Compounding this, the supply of high-grade hardwood has diminished under logging restrictions and environmental pressures, pushing up the price of durable timber (Ikhsan et al., 2024; Mulyadi et al., 2020).

Steel trusses, by contrast, have gained ground as a modern alternative, particularly for commercial, industrial, and low- to mid-rise residential projects (Khan et al., 2023; Tenório et al., 2024; Hassan & Saeed, 2024). Steel provides substantial tensile and compressive strength, dimensional consistency, and can be manufactured at scale with reliable quality. It is comparatively light relative to concrete, immune to termite and fungal attack, and permits longer clear spans with fewer intermediate supports. Bolted, welded, or knock-down connections also make steel trusses quicker and more straightforward to erect.

Steel's drawbacks include vulnerability to corrosion without adequate coating and the resulting need for ongoing maintenance, especially in humid or coastal climates. Steel trusses also typically demand a larger upfront outlay than timber, though this is offset by a longer service life (Abdullah et al., 2024; Pipinato, 2018; Abed et al., 2022). Weighing these trade-offs, a decision between steel and timber must balance structural performance, cost, constructability, and sustainability. As Balasbaneh et al. (2022) note, such comparisons are especially pertinent in Indonesia, where climate and socio-economic circumstances vary considerably from region to region.

Comparative studies of this kind assist planners, contractors, and the public in selecting truss materials suited to local conditions without sacrificing safety or efficiency (Fitriyanti & Ismawati, 2024; Yansiku et al., 2025). The present study focuses specifically on comparing the structural performance of steel and timber trusses, modelling both material options for a single-storey shophouse (ruko). A shophouse was chosen as the case-study building type because it is a familiar building form throughout Indonesia's urban and peri-urban areas, combining commercial and residential functions under one roof.

Because shophouse roofs typically span considerable widths, they demand truss systems that are both strong and efficient (Ali & Moon, 2018). By designing and analysing steel and timber truss options, this study seeks to compare the strength, material efficiency, and overall structural behaviour of the two materials (Aproga et al., 2025; Hermawan et al., 2023). Analysis was carried out using a structural analysis program — software capable of simulating structural response under a range of load types.

With such software, dead loads, live loads, and wind loads acting on the trusses can be modelled with greater realism and precision (Arditama & Rasidi, 2021). The resulting output was used to evaluate internal member forces — compression, tension, and bending moment — and to verify compliance with the relevant design codes, namely SNI 1729:2020 for steel structures and SNI 7973:2013 for timber structures. The work therefore combines theoretical structural-engineering principles with contemporary computational tools (Huang et al., 2025; Tenório et al., 2024).

This study's principal contribution lies in clarifying how steel and timber trusses compare in strength when applied to a straightforward structure such as a single-storey shophouse. For civil engineering students, the findings offer an academic reference point for understanding the mechanical behaviour of the two materials and its bearing on structural design (Siron et al., 2021). For practitioners and building planners, the results provide a practical basis for choosing the more efficient material in terms of strength, cost, and long-term upkeep. For the wider public, the study aims to inform decision-making around safe, economical, and sustainable roofing choices (Cudicio & i Gardella, 2024).

The work further speaks to resource efficiency within the construction sector. Sustainable material selection must weigh not only technical and cost factors but environmental ones as well — excessive timber harvesting can damage forest ecosystems, while inefficient steel use raises embodied carbon emissions (Hromada et al., 2024; Lippke et al., 2011; Punhagui & John, 2022). Comparing these two materials therefore helps identify the more environmentally sound choice under green-construction principles, supporting infrastructure that is strong, safe, and mindful of long-term sustainability (Parthasarathy et al., 2021; Adshead et al., 2019; Pandit et al., 2017; Malekpour et al., 2015; Oyebode et al., 2025).

The comparison also bears on climate adaptation, given the increasing frequency of extreme weather. The roof is the building element most exposed to sun, rain, and wind, making its strength and durability under changing weather conditions especially important (Prati et al., 2022). Steel trusses may hold an advantage in high-rainfall regions owing to their resistance to decay, whereas timber trusses may suit rural areas with lower corrosion risk and abundant local timber supply. The analysis aims to provide a scientific basis for tailoring roof-truss design to Indonesia's varied geography and climate (Adekunle et al., 2024).

In sum, this study extends beyond a simple strength comparison to encompass structural efficiency, sustainability, and practical relevance for contemporary construction. A software-based structural analysis approach is expected to yield more objective and accurate results, offering a useful reference for both technical and academic audiences.

Overall, the study addresses one central question: between steel and timber, which truss material delivers better structural performance in a single-storey shophouse application? The answer is intended to add to the body of structural-engineering knowledge and to inform the design of efficient, safe, and sustainable buildings.

2.0 Methods

This research applies a structural-analysis methodology to evaluate the strength and stability of roof trusses under design loads. A structural analysis program — civil-engineering software used to compute internal forces (moment, shear, and axial force) and deformation arising from specified load combinations — forms the analytical backbone of the study. This approach yields a detailed picture of how trusses built from two different materials, steel and timber, behave structurally, enabling an objective comparison of strength and efficiency between them. Inputs to the analysis include the truss design, material properties, and the loads acting on the roof frame.

The truss design examined here is applied to a single-storey shophouse (ruko), selected for its common structural form and prevalence in practice. Building dimensions, roof configuration, and supporting elements such as ring beams and columns were incorporated to keep the analytical model representative of real construction conditions. The research followed several sequential stages, described narratively below rather than through a flow diagram.

The process opens with a Start stage, in which the study's objectives and scope are defined — namely, comparing the load-carrying performance of steel and timber trusses supporting the roof of a single-storey shophouse. Problem identification and scope limitation were also carried out at this point to keep the research focused. Three boundaries were set: (1) the analysis addresses only the roof-truss system, without modelling full interaction with other structural elements such as floor beams; (2) loads follow Indonesian design regulations; and (3) materials are restricted to common steel profiles and Class I structural timber.

The second stage is a literature review, gathering the theory and standards relevant to truss planning and analysis. Sources consulted include 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), alongside civil-engineering textbooks, journal articles, and prior research, all of which underpin the analytical approach, calculation parameters, and design assumptions used later.

The third stage is preliminary (pre-elementary) design, during which initial steel and timber truss configurations are drafted based on the building's dimensions and roofing requirements. This stage fixes the truss type (for example, a simple triangular or Pratt configuration), span, height, and joint arrangement, with member sizes estimated from assumed loads and material properties. The intent is to produce a starting design that can subsequently be tested through structural analysis; designs that fail to satisfy strength and safety criteria are returned to this stage for revision.

The fourth stage — structural analysis — forms the heart of the research. Here the trial truss designs are entered into the structural analysis program to simulate their response under load. Loads modelled include dead loads (the self-weight of the truss and associated roof components such as tiles, battens, rafters, and hangers), live loads (temporary loads from maintenance activity or rainwater ponding), and wind loads calculated per SNI 1727:2020 for the relevant direction and intensity. This analysis establishes how safely each truss resists and redistributes load, providing the evidentiary basis for conclusions about strength and stability.

The software computes the structure's response to the specified load combinations, including compressive force, tensile force, bending moment, and deflection in every truss member, which are then checked against strength and stability requirements for the chosen member sizes and layout. Where a design fails to satisfy these criteria, the process loops back to the preliminary design stage for adjustment; once the structure meets all safety benchmarks, the study proceeds to the next stage.

The fifth stage is final design. Once analysis and verification are complete, finalized steel and timber truss designs — satisfying strength, stiffness, and stability requirements — are established, including detailed member sizes, connection type (bolted, welded, or pegged), and a configuration optimized for both strength and material efficiency. Results at this point are recorded as technical drawings and specification tables. The sixth stage, design checking, validates and evaluates the finished designs of both truss types by comparing structural capacity against the maximum applied loads and assessing material efficiency; internal forces, peak deflections, and safety factors are compared between steel and timber to determine which material performs better for this building type.

The final stage draws conclusions and formulates recommendations. Based on the analysis and design-check outcomes, the study concludes on the comparative structural performance of steel versus timber trusses and recommends the more suitable material for given conditions, while also suggesting avenues for further research — for instance, into cost efficiency, durability, or constructability. The process concludes at a Finish stage once every step, from data collection through design, analysis, and conclusion, has been completed systematically. Such a structured methodology is intended to yield results that are accurate, measurable, and scientifically defensible, offering both a comparative understanding of steel and timber truss strength and practical guidance for designers and engineering students on efficient, safe, code-compliant roof design in Indonesia.

3.0 Results and Discussion

The design developed in this study combines a single-storey shophouse (ruko) structure with both steel and timber truss options, as detailed below.

3.1 Design and Materials

The truss spans 18 m at a 30° roof pitch, with a 2 m spacing between adjacent trusses. The shophouse footprint measures 12 m × 18 m (216 m^2) with a column height of 4 m. Main columns measure 25 cm × 25 cm, secondary columns 20 cm × 20 cm, and the ring beam 15 cm × 20 cm. The concrete used has a compressive strength (f'c) of 25 MPa, a unit weight of 2,400 kg/m^3, a modulus of elasticity (E) of 23,500 MPa, and a Poisson's ratio of 0.2.

The steel truss uses L-angle profile 45.45.6, with C-channel profile C.75.45.1.6 for the purlins, both in BJ 37 grade steel. Steel properties used in the model are a unit weight of 7,849 kg/m^3, modulus of elasticity (E) of 200,000 MPa, Poisson's ratio of 0.3, minimum yield stress (Fy) of 240 MPa, and minimum tensile stress (Fu) of 370 MPa. The timber truss uses Grade A timber sized 5/7, with a density of 450 kg/m^3, modulus of elasticity (E) of 13,000 MPa, and Poisson's ratio of 0.3.

Loading

A uniform dead load of 50 kg/m² was applied for roof tiles, ceiling, framing, and hangers, while the shophouse structure itself carries a dead load of 150 kg/m² per SNI provisions. The shophouse floor live load is 100 kg/m², and the roof live load (liveroof) is 50 kg. The load combination adopted for analysis is 1.2D + 1.6L + 0.5Lr, where D denotes dead load, L denotes live load, and Lr denotes roof live load.

3.2 Coordinate System and Structural Deflection

The structural model uses a Universal Coordinate System (UCS) with active degrees of freedom in three dimensions. Per SNI, the maximum permissible deflection for roof- or ceiling-supporting members is l/180 × 6 m = 0.03 m. Table 1 summarizes the deflection results obtained from the analysis.

Joint	Output Case	Steel U1 (m)	Steel U2 (m)	Steel U3 (m)	Timber U1 (m)	Timber U2 (m)	Timber 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

Table 1. Comparison of Deflection in Steel and Timber Trusses

The results indicate that the steel truss reaches its maximum deflection at joint 115, at 0.00308 m, while the timber truss reaches its maximum at joint 141, at 0.00598 m. The timber truss therefore deflects more than the steel truss overall; nevertheless, both remain well within the 0.03 m code limit and are considered safe.

3.3 Bending Moment

Under the applied load combinations, the maximum bending moment recorded in the shophouse structure with a steel truss is -1123.894 kgm, while the maximum for the timber-truss configuration is -1121.162 kgm. The steel truss therefore carries a marginally higher bending moment than the timber truss (1123.894 kgm versus 1121.162 kgm).

3.4 Shear Force

Peak shear force acting perpendicular to member axes reaches 823.119 kg in the steel-truss structure, compared with 714.865 kg in the timber-truss structure. The steel truss therefore exhibits a higher capacity to resist shear than the timber truss, a difference attributable to steel's superior strength and stiffness, which allow it to sustain larger loads without significant deformation. This indicates that steel trusses are the stronger choice, in shear-resistance terms, for buildings subject to comparatively heavy roof loading.

3.5 Axial (Normal) Force

The maximum compressive axial force recorded in the steel-truss structure is 1329.813 kg, versus 1177.186 kg for the timber-truss structure. The compressive force carried by the steel truss thus exceeds that carried by the timber truss (1329.813 kg versus 1177.186 kg).

3.6 Assembled Joint Masses

Table 2 presents the joint masses obtained from the vibration analysis.

Joint	Steel U1 (Kgf·s²/m)	Steel U2 (Kgf·s²/m)	Steel U3 (Kgf·s²/m)	Timber U1 (Kgf·s²/m)	Timber U2 (Kgf·s²/m)	Timber U3 (Kgf·s²/m)
14	32.93995	32.93995	32.93995	32.66716	32.66716	32.66716
15	81.98518	81.98518	81.98518	70.97225	70.97225	70.97225
38	33.52827	33.52827	33.52827	33.52827	33.52827	33.52827

Table 2. Assembled Joint Masses

The table shows that, at joint 15, the vibrating mass associated with the steel truss (81.98518 Kgf·s²/m) exceeds that of the timber truss (70.97225 Kgf·s²/m), consistent with steel's greater self-weight.

3.7 Design Check

The design-check results classify the steel structure as safe (indicated in the analysis software by a blue color code). The software used does not yet support an automated design-check routine for timber; however, based on the bending-moment and deflection results obtained, the timber truss design can likewise be judged safe. Both the steel truss and the Grade A (quality 1) timber truss are therefore fit for use, with steel offering the greater strength and timber the lighter weight.

4.0 Conclusion

This study analyzed a truss structure spanning 18 m at a 30° roof pitch, with 2 m spacing between trusses, supporting a shophouse with a 216 m² footprint (12 m × 18 m) and a 4 m building height. BJ 37 grade steel and Grade A timber were used for the steel and timber truss options respectively, while the main shophouse structure was built from reinforced concrete with f'c = 25 MPa. Dead loads of 50 kg/m² (truss) and 150 kg/m² (shophouse floor) were applied, together with a concentrated roof live load of 50 kg/m² and a uniform floor live load of 100 kg/m², combined per 1.2D + 1.6L + 0.5Lr.

The results show that bending moment, shear force, and axial force are all greater in the steel truss than in the timber truss, reflecting steel's higher self-weight. Deflection in both truss types nonetheless remained within the 0.03 m code limit. Based on the design-check outcomes, both the BJ 37 steel truss and the Grade A timber truss are suitable for shophouse construction, with steel offering superior strength and timber offering a lighter overall structure. Future work should refine the load calculations further, specifying the exact timber species used, and should employ structural analysis software capable of automated timber design checks so as to obtain more reliable results for timber trusses

It would also be worthwhile to evaluate a lightweight (cold-formed) steel truss option, given its markedly lower self-weight relative to conventional hot-rolled steel. Adopting lightweight steel could reduce the resulting internal forces, improving the stability and overall efficiency of the structural system supporting the truss.

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