



# Structural Response Evaluation of a Railway Station Footbridge Through Finite Element Analysis

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## **Abstract**

This study presents a finite element analysis of a pedestrian truss bridge located within a railway station, focusing on its structural performance under service loading conditions. The bridge, composed of steel L-section members and a steel deck, was modelled using ANSYS(ABACUS) to evaluate deformation behaviour, stress distribution, and overall stability. The analysis incorporated fixed and roller boundary conditions to simulate realistic support constraints and a uniformly distributed pedestrian load applied across the deck surface. The results indicate that the bridge exhibits stable deformation characteristics, with the maximum deflection occurring at the mid-span and remaining within permissible serviceability limits. The axial force distribution confirms efficient load transfer, with the top chords in compression and the bottom chords in tension, while the shear and bending moment patterns display typical behaviour for simply supported truss systems. Overall, the numerical results demonstrate that the design is structurally sound, ensuring adequate strength, stiffness, and safety for pedestrian usage within a railway environment.

**Keywords:** Finite Element Analysis, Truss Bridge, Pedestrian Bridge, Structural Performance, ANSYS(ABACUS)

## **1. Introduction:**

In recent years, the structural behaviour of pedestrian and small-span steel truss bridges has attracted significant research attention. Awaludin et al. (2023) investigated a cold-formed steel pedestrian bridge under static and dynamic loading and evaluated its deformation and modal response characteristics. Yan (2023) performed finite element modelling of a variable-height simply supported steel truss bridge and discussed geometry effects on stress distribution and stiffness. Shibeshi and Roth (2016) conducted field measurements and dynamic analysis of a steel truss railway bridge, combining experimental and numerical approaches to assess bridge performance. Qu et al. (2022) performed stability analysis of a simply supported steel truss bridge using ABAQUS, focusing on overall buckling behaviour. Hayashi et al. (2018) carried out experimental vibration monitoring and model updating of an FRP pedestrian truss bridge, validating finite element simulations through field data. Yang et al. (2023) presented finite element-based optimization of steel truss bridges, demonstrating high accuracy in predicting load responses. Vyas and Trivedi (2019) compared Pratt and lattice truss bridge types via FEM, highlighting differences in deformation and modal properties. Pan et al. (2022) analysed dynamic response and vibration control of a steel truss corridor pedestrian bridge using ABAQUS, addressing human-induced

vibration effects. Shinde et al. (2021) performed a comparative analysis of different truss configurations, concluding that material section and geometry significantly affect strength and stiffness.

Despite this extensive body of work, key limitations remain, particularly for pedestrian truss bridges with specific geometries and load environments such as railway stations. Many past studies have focused either on dynamic pedestrian or wind loading (Pan et al., 2022) or on field monitoring (Shibeshi and Roth, 2016) without integrating static, modal, and buckling assessments in a unified framework. Studies like that of Liyanage and Hidallana-Gamage (2021) explored lateral stability but only for variable-height trusses, while Vyas and Trivedi (2019) compared sectional types without investigating structural stability under sustained pedestrian loading. Liyanage and Hidallana-Gamage (2021) studied the lateral stability of variable-height steel truss pedestrian bridges in Sri Lanka, reporting buckling tendencies in specific configurations. Moreover, limited research has examined the structural performance of L-section truss members and steel deck configurations under realistic support conditions. This reveals a research gap in comprehensive finite element analyses of pedestrian truss bridges incorporating combined static, modal, and buckling behaviour to reflect real-world boundary and loading conditions.

The present study aims to address this gap by conducting a holistic finite element analysis of a pedestrian truss bridge composed of L-section members and a steel deck. The study integrates multiple analytical aspects, including deformation, stress, and stability behaviour, under service loading conditions typical of pedestrian environments. Through this approach, the research contributes a detailed understanding of the structural performance of pedestrian truss bridges in railway station applications and provides guidance for optimizing similar future designs.

## **2. Structure Selection**

### **2.1 Basic Parameter**

In this study, a pedestrian truss bridge with a span of 16 m, width of 2 m is analysed. The bridge is designed for pedestrian movement within a railway station. The main load-bearing system consists of steel L-sections with a leg length of 88.9 mm and a thickness of 6.5 mm, forming the truss framework. The bridge deck is a steel slab of 0.1 m thickness, providing the walking surface and additional stiffness to the structure. One end of the bridge is modelled as a fixed support, while the other is a roller (displacement-free) support to allow longitudinal expansion.

### **2.2 Material Properties**

The structural material used for the truss bridge is structural steel, chosen for its high strength, ductility, and ease of fabrication. The material properties adopted in the numerical model are summarized in Table 1. The concrete deck is modeled as a linear elastic material to simulate its contribution to the overall stiffness of the structure.

Table 1. Material properties of structural steel

Property	Value
Density	7850 kg/m <sup>3</sup>
Poisson's ratio	0.3
Young's modulus	2.0×10 <sup>5</sup> MPa
Strength coefficient	920 MPa
Tensile yield strength	2.5×10 <sup>8</sup> Pa
Compressive yield strength	2.5×10 <sup>8</sup> Pa

### 3. Modelling:

#### 3.2 Boundary Condition

Reference points were created at both support ends of the bridge and coupled to the lower edges of the truss base. The left end was modeled as a fixed support, restraining all degrees of freedom, while the right end was defined as a roller support to allow longitudinal displacement due to thermal effects.

A uniform pressure of 0.2 MPa was applied on the steel deck surface to simulate pedestrian and deck loads. In addition, a uniformly distributed pedestrian load was considered, assuming 25 persons, each weighing 80 kg, giving a total load of  $25 \times 80 \times 10 = 20,000$  N, evenly applied across the deck surface.

#### 3.3 Grid

The finite element model was discretized using beam and shell elements to represent the truss and deck components, respectively. The truss members, composed of steel L-sections, were modelled using beam elements to capture axial and bending behaviour, The shell elements (for the steel deck) typically have quadrilateral elements with sizes of 50 mm.

The final model contains 18,000 nodes and 17,200 elements. Finer meshing was adopted near the joints and support regions to improve accuracy in high-stress zones. The overall mesh configuration of the bridge model is shown in Figure 1.

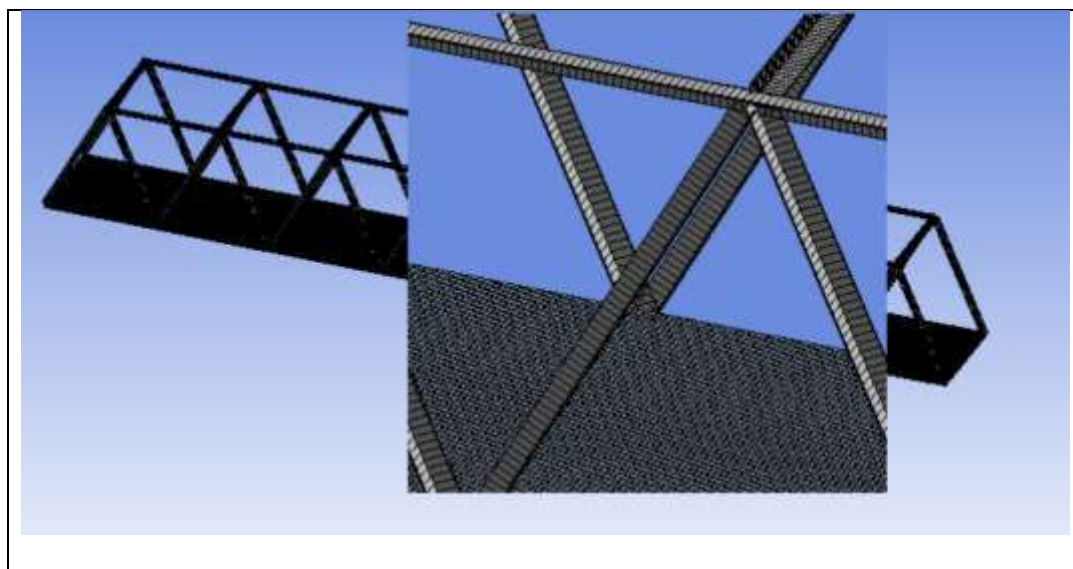


Figure 1: Mesh configuration of the bridge model

## **4. Analysis of calculation results**

### **4.1 Total Deformation**

The total deformation contour, shown in Figure 2(a) illustrates the deflection pattern of the bridge under the applied load. The maximum deformation occurs at the mid-span region of the deck, with a value of 7.5 mm, while the displacement near the supports remains negligible. This distribution follows the typical deformation shape of a simply supported truss bridge, where maximum vertical deflection develops at the centre of the span. The deformation pattern confirms adequate stiffness of the truss members, with no signs of excessive deflection that could compromise serviceability. The deformation response is primarily governed by the axial stiffness of the truss members, as bending deformation is minimal due to the efficient load-carrying configuration of the structure.

### **4.2 Axial Force Distribution**

The axial force diagram in Figure 2(b) presents the force distribution along the truss members in the longitudinal direction. The upper members primarily experience compressive forces, with peak values reaching about 210 kN, while the lower members are subjected to tensile forces of similar magnitude. The diagonal members exhibit alternating tensile and compressive stresses, indicating effective force transfer within the truss system. The magnitudes of axial forces are highest near the mid-span and

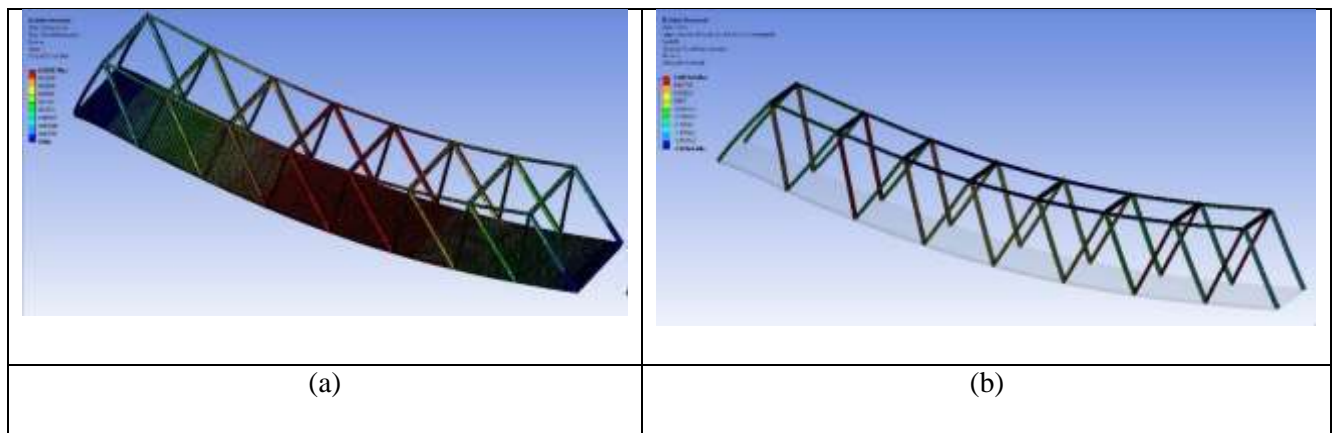
support junctions, consistent with theoretical expectations. The absence of any abrupt variations or reversals of force directions implies a stable and continuous stress path within the structural system.

#### **4.3 Bending Moment Distribution**

The bending moment contour shown in Figure 2(c) reveals that the maximum bending moment occurs at mid-span, Figure 2(e) shows approximately 34 kN·m, gradually reducing toward the supports. The bottom chord is mainly in tension, counteracting the compressive action in the top chord. The uniform and symmetric distribution of bending moments suggests a balanced load transfer mechanism and an efficient structural response. Localized bending at joint regions is minimal, reflecting adequate rigidity and joint continuity within the model. The moment distribution also demonstrates structural symmetry, implying that the boundary conditions and load applications are correctly defined.

#### **4.4 Shear Force Distribution**

The shear force diagram illustrated in Figure 2(d) displays the variation of shear stress along the bridge span. The maximum shear force develops near both supports, Figure 2(e) shows with a magnitude of approximately 40 kN, gradually decreasing toward the mid-span where the shear value approaches zero. The pattern confirms the expected shear behaviour of a simply supported truss structure, with diagonal members effectively channelling shear loads from the deck to the supports. The distribution pattern suggests that the truss configuration successfully resists shear effects without inducing local overstressing in the joints. The results confirm that the L-section members provide sufficient shear stiffness and that local connections can resist the induced shear stresses without failure.



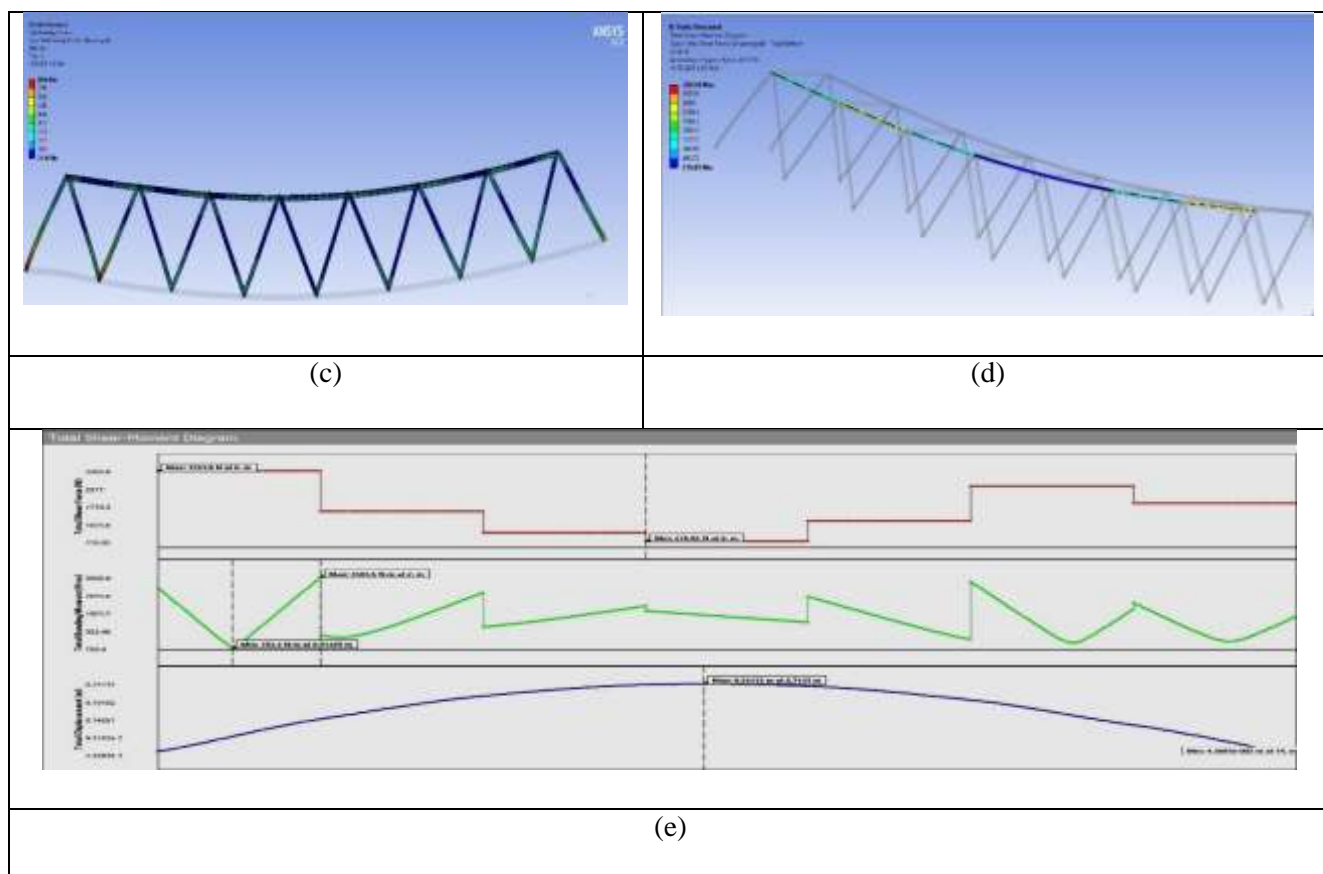


Figure 2: Diagram view of (a)Total Deformation (b) Axial Force Distribution (c)Bending Moment Distribution (d)Shear Force Distribution (e)Total shear moment diagram

## 5. Discussion

The analysis results demonstrate that the pedestrian truss bridge performs efficiently under service loading, exhibiting a uniform and stable structural response. The deformation pattern indicates adequate stiffness, with deflection behaviour typical of a simply supported truss system. The axial force distribution shows a well-defined load transfer mechanism, where the upper chords are in compression and the lower chords are in tension, ensuring structural balance and stability. The bending and shear distributions confirm that the truss effectively channels load from the deck to the supports without excessive stress concentration or distortion near the joints. Compared with previous studies on steel truss footbridges, the present model shows similar trends in load behaviour and stress patterns, confirming the reliability of the adopted configuration. These findings confirm that the structural response of the present model is consistent with established behaviour observed in previous studies. The efficient stress distribution and stable deformation pattern highlight the reliability of L-section trusses for small-span pedestrian bridges. This agreement with prior research by Gui et al. (2024) and

Piaolong et al. (2023) further validates the accuracy of the numerical analysis and modelling approach. The results also align with earlier findings that truss systems with properly connected members exhibit high efficiency in distributing applied loads and maintaining global stability under pedestrian-induced forces. Overall, the qualitative behaviour of the bridge verifies that the design satisfies performance requirements and demonstrates consistent agreement with established structural analysis outcomes reported in related research.

## **6. Conclusion and Recommendation:**

The numerical analysis of the pedestrian truss bridge for the railway station demonstrates that the structure performs effectively under the applied loading conditions, showing adequate stiffness, stability, and uniform stress distribution throughout its members. The deformation pattern confirms that the deflection is within acceptable service limits, while the axial, bending, and shear responses reflect a balanced and predictable load transfer mechanism typical of a well-designed truss bridge. The L-section members provide sufficient strength and rigidity, ensuring that the bridge can safely sustain pedestrian-induced loads without localized overstressing. The results are consistent with the findings of previous research on steel truss footbridges, validating both the modeling approach and structural configuration. It is recommended that future studies incorporate dynamic effects such as vibrations induced by nearby train operations and long-term fatigue behavior to further enhance design reliability. Experimental validation through physical testing could also strengthen the correlation between numerical predictions and real structural performance.

## **References:**

1. Awaludin, A., Susilowati, H., & Satyarno, I. (2023). Dynamic and static behavior of cold-formed steel pedestrian bridges. *Civil Engineering Dimension*, 25(1), 13–22. Petra Christian University.
2. Gui, Y., Chen, Z., Li, J., & Peng, Y. (2024). Computational analysis of a steel truss footbridge. *Sichuan Construction*, 44(2), 142–144.
3. Hayashi, K., Brownjohn, J. M. W., & Mufti, A. (2018). Monitoring and model updating of an FRP pedestrian truss bridge. *Engineering Structures*, 172, 475–487.
4. Liyanage, K., & Hidallana-Gamage, H. (2021). *Stability of variable height pedestrian truss bridges* (Undergraduate thesis). University of Moratuwa, Sri Lanka.
5. Pan, J., Li, Q., & Liu, Z. (2022). Dynamic response and vibration reduction of a steel truss corridor pedestrian bridge using ABAQUS. *Frontiers in Materials*, 9, Article 839265.
6. Piaolong, L., Chen, J., & Zhao, F. (2023). Welding residual stress elimination technique in the top chord of main truss of steel truss bridge. *Buildings*, 13(5), 1267.

7. Qu, Z., Chen, L., & Zhao, W. (2022). Stability analysis of simply supported steel truss bridges based on ABAQUS. *Highlights in Science, Engineering and Technology*, 55, 8250–8258.
8. Shibeshi, B., & Roth, M. (2016). *Dynamic analysis of a steel truss railway bridge* (Master's thesis). University of Pretoria, South Africa.
9. Shinde, S., Patil, V., & Kulkarni, R. (2021). Comparative analysis of truss bridges of different types. *International Journal of Engineering Research and Technology*, 10(5), 104–110.
10. Vyas, D., & Trivedi, A. (2019). Comparative analysis of Pratt and lattice truss bridges using finite element method. *International Journal of Times Engineering and Science*, 7(3), 2294–2300.
11. Yan, Y. (2023). Analysis of variable-height simply supported steel truss bridge using finite element method. *Journal of World Architecture*, 6(2), 98–106.
12. Yang, Y., Liu, S., & Li, X. (2023). Finite element analysis and optimization of steel truss bridges. *Advances in Civil Engineering*, 2023, 1–10.