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COMPARATIVE ANALYSIS OF DIFFERENT TRUSS TYPE RAILWAY STEEL BRIDGE

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Abstract-The structural efficiency and economic feasibility of railway steel bridges are critical considerations in infrastructure development. This study presents a comparative analysis of four different truss type railway steel bridges which are Howe Truss Bridge, Warren Truss Bridge, Pratt Truss Bridge, and K-type Truss Bridge. These truss bridges are designed and analysed using STAAD Pro under static railway load conditions. The primary objective of this research is to evaluate and compare the structural behaviour of these trusses based on key parameters such as Shear Force, Axial Force, Deflection, Steel Section Weight, and Cost. Finite Element Analysis (FEA) is employed in STAAD Pro to assess the response of each truss bridge to railway loadings, ensuring accurate computation of forces and deformations. The study determines the maximum and minimum values for each performance parameter, thus identifying the most efficient truss configuration. Furthermore, a cost analysis is conducted to determine the most economically viable design.

Index Terms- railway bridge; truss railway bridges; shear forces; axial forces; deflection; steel weight; optimizing truss design; structural analysis; bridge durability; structural configurations

1. Introduction

Railway bridges are essential for India's vast transportation network, enabling seamless connectivity across over 68,000 km of track. They facilitate smooth train operations over rivers, valleys, and other obstacles, reducing travel time and boosting economic activity. These bridges play a crucial role in cargo transportation, allowing the movement of essential goods like coal, iron ore, and agricultural products, which strengthens trade and national growth. They also improve accessibility for millions of people, connecting remote areas and promoting tourism, employment, and social integration. Additionally, well-constructed railway bridges enhance disaster resilience by ensuring connectivity during emergencies, improving overall quality of life. India has around 1,20,000 railway bridges, with over 20% being steel girder bridges. This includes 731 long-span open girders and 19,014 rolled steel joist or plate girders. Due to continuous train movement, these bridges experience repeated loadings, which weaken joint stiffness and make them more vulnerable to fatigue damage.

Railway bridges in India are designed following the Indian Railway Standards (IRS) Code of Practice, which specifies standard live loads. For Broad Gauge standard loadings, the longitudinal load for 20m spans is based on 25t Loading-2008, with a maximum axle load of 25.0t for locomotives. This study considers the 25.0t Loading-2008 standard for analysis.

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2. Methodology

Proposed steps are as follows:

1. Selection of truss configurations for analysis

2. Modelling of Truss Bridges

3. Load Calculations

5. Determination of results by analysis based on key parameters

6. Comparison of results

2.1 Selection of truss configuration for analysis

Trusses can be classified into various types based on the configuration of their members. In this study, a specific truss configuration was chosen. The different types of trusses classified by their member arrangements are Pratt Truss Bridge, Howe Truss Bridge, Warren Truss Bridge, K-Type Truss Bridge, Modified Warren Truss Bridge, Fink Truss Bridge.
Among the above types of truss bridge configurations, we selected Pratt, Howe, Warren and K-Type Truss configurations for analysis as these are the most commonly used in India.

2.2 Modelling of Truss Bridges

In this study, steel truss bridges are analyzed and optimized. Railway loading is considered as 336.73 kN axle load, and dead load is calculated and applied as per IS 875 Part-1. Four cases are compared:

I. Howe truss bridge with a 20m span.
II. Warren truss bridge with a 20m span.
III. Pratt truss bridge with a 20m span.
IV. K-type truss bridge with a 20m span.

Sr No	Description	Value
1	Length	20 m
2	X direction bays	10
3	Y direction bays	1
4	Height	4 m
5	Width	5 m
6	Railway track	Broad Gauge
7	Support type	Pinned Support

Table 1. Description of Structure

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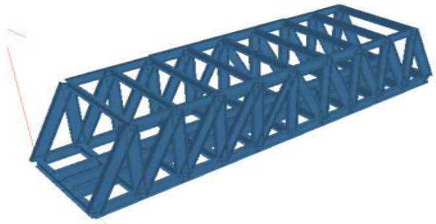

Fig 1. 3D view of Howe type Bridge

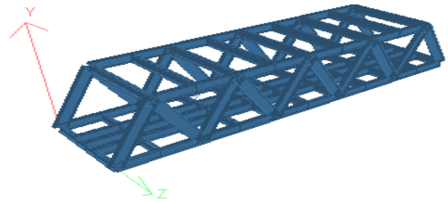

Fig 2. 3D view of Warren type Bridge

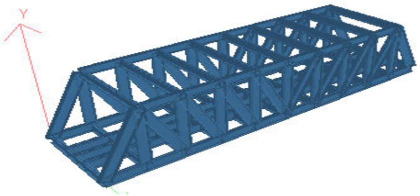

Fig 3. 3D view of Pratt type Bridge

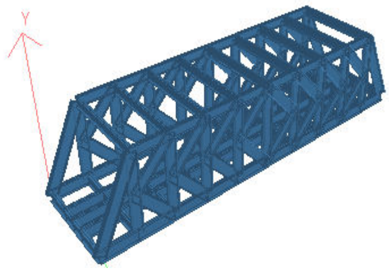

Fig 4. 3D view of K-type Bridge

2.3 Load Calculations

2.3.1 Dead Load

I. Self-Weight of truss

II. For design of ballasted deck bridges, a ballast cushion of 400mm for BG shall be considered

= Thickness x density of concrete x width of bridge

= 0.400 x 25 x 5

= 50 KN/m

III. Load of supporting slab

Slab thickness = 150 mm

Dead load of Slab = Thickness x density of concrete

Dead load of Slab = 0.150 x 25 = 3.75 KN/m

2.3.2 Moving Load

Axle load For Broad Gauge - 1676mm

Maximum axle load of 245.2 KN (25.0t) for the locomotives and a train load of 91.53 KN/m (9.33t/m)

Total Load of BG = Locomotive load + Train Load = 245.2 + 91.53 = 336.73 KN/m

3. Results and Discussion

3.2.1 Shear Force

Figure 8.1 shows the magnitude of maximum stress for different truss types. The analysis reveals that the K-type truss bridge experiences the highest shear force, while the Pratt truss bridge has the lowest shear force, leading to a more balanced section. As a result, the K-type truss bridge exhibits the most unbalanced forces, whereas the Pratt truss bridge has the least unbalanced forces under the same loading conditions.

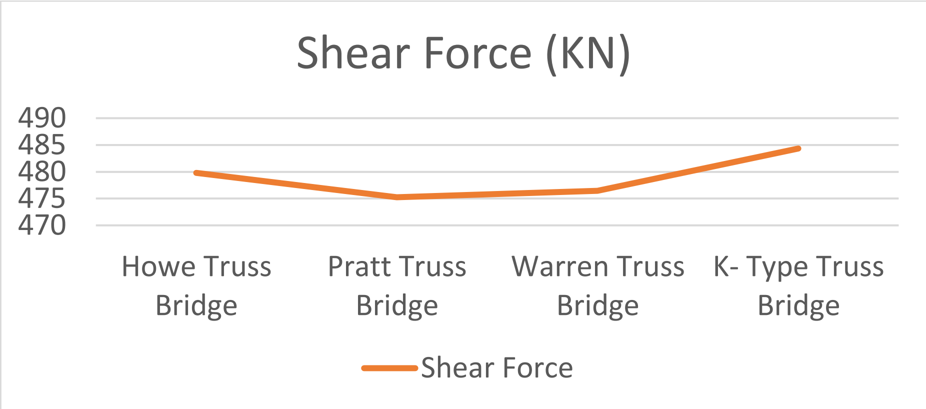

Fig 5. Shear Force in Truss Bridges

3.2.2 Axial Force

Figure 8.2 illustrates the magnitude of axial force for different truss types. The analysis shows that the Warren truss bridge experiences the highest axial force, while the Howe truss bridge has the lowest. This indicates that the Warren truss bridge distributes force more effectively compared to the other truss types.

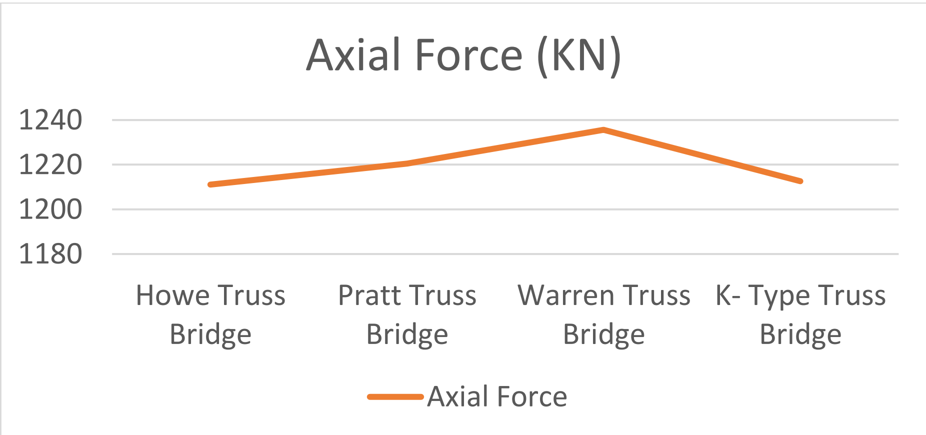

Fig 6. Axial Force in Truss Bridges

3.2.3 Deflection

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Magnitude of deflection for various forms of truss has been plotted in figure 8.3. It is determined that deflection is maximum in Pratt Truss Bridge and followed by Howe Truss Bridge whereas minimum in K-type Truss Bridge and Warren Truss Bridge suggests that the Pratt and Howe truss bridges will require more supports compared to the other types.

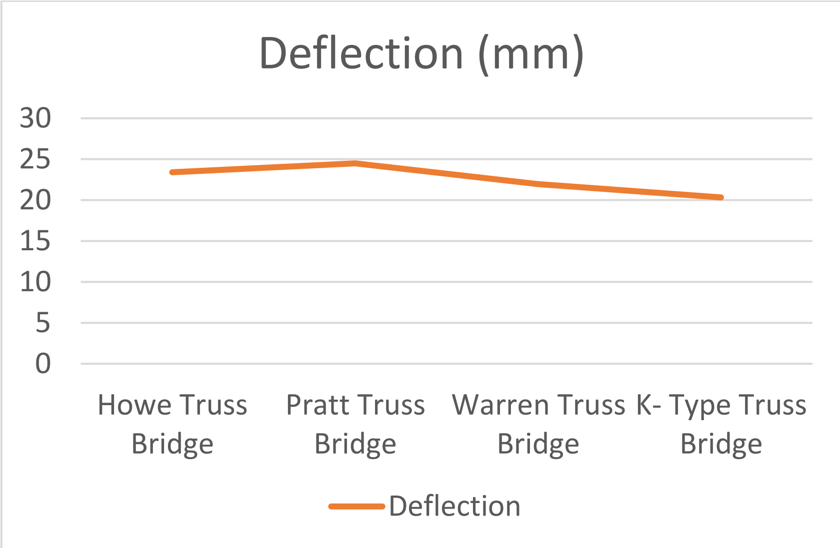

Fig 7. Deflection in Truss Bridges

3.2.4 Steel Section Weight

Figure 8.4 shows the steel section weights for different truss types. The analysis indicates that the Warren truss bridge is the most expensive under the same loading conditions, while the Howe truss bridge is the most economical among the options.

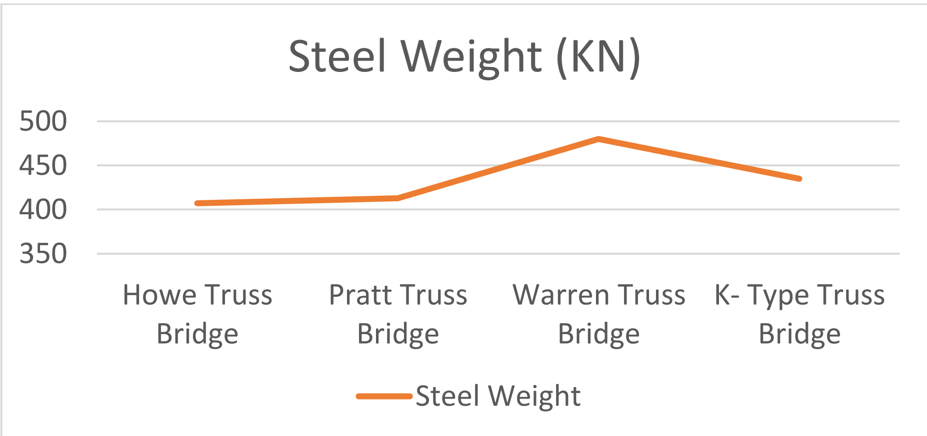

Fig 8. Steel Weight in Truss Bridges

3.2.5 Cost

The cost of a truss bridge structure primarily depends on the type of truss, material used, connections, site conditions, and quality of workmanship. The truss type varies based on design requirements, material costs, and connection types. Workmanship is influenced by factors such as site location, conditions, and structural specifications.

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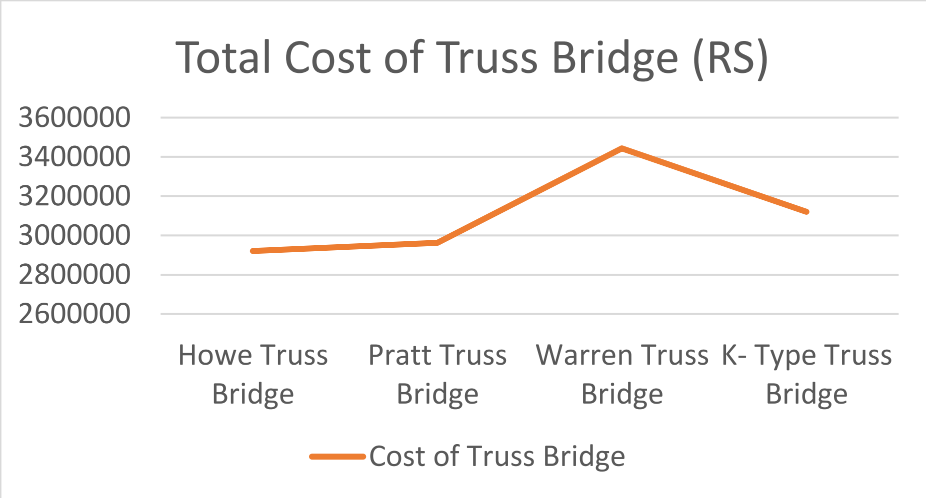

Fig 9. Comparison of truss bridge with respective cost

4. Conclusions

In this study, four types of truss bridges were analyzed using STAAD Pro software: Howe, Pratt, K-Type, and Warren truss bridges. Vehicle load cases (IRS 25T-2008 Loading), along with dead load and rail load, were considered for the analysis. The key observations and conclusions are:

1. Shear Force: Pratt and Warren truss bridges exhibit greater stability with lower shear forces, while the K-Type truss bridge shows the highest shear force.
2. Axial Force: Warren truss bridge experiences the highest axial force, whereas the Howe truss bridge shows the lowest.
3. Deflection: Maximum deflection occurs in the Pratt truss bridge, while the K-Type truss bridge has the least deflection.
4. Steel Structure Weight: Since India requires cost-effective designs, it is observed that the Howe truss bridge uses the least amount of construction material, making it the most economical with a weight of 407.12 Newtons.
5. Cost of Truss: Among the four types, the Howe truss bridge is the most economical for Broad Gauge railway applications under IRS 25T-2008 loading conditions. Comparison shows that the Warren Truss Bridge is most expensive, Howe Truss Bridge 15.3 %, Pratt Truss Bridge 14% and K-Type Truss Bridge 9 % cheaper than the Warren Truss Bridge. The most economical bridge is Howe Truss Bridge.

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