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Trussed Bridges

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Abstract

Trussed railway bridges offer a unique structural advantage by efficiently distributing the load between the truss members and the girder. In such designs, a significant portion of the load is carried by the truss members, which reduces the stress on the bridge girder itself. As a result, the girder in a trussed bridge can be constructed with a reduced thickness compared to bridges that lack a truss system. This optimization not only minimizes the use of materials for the girder but also contributes to the overall cost-effectiveness of the structure. Another critical advantage of trussed bridges is their ability to span longer distances, making them particularly suitable for large-scale infrastructure projects such as railway bridges crossing rivers, valleys, or other challenging terrains. The combination of trusses and girders enhances the overall stability and durability of the bridge while maintaining efficiency in material use. Trussed systems are also highly adaptable, as they can be designed to withstand dynamic loads, such as those imposed by passing trains, ensuring safety and reliability under variable conditions. Additionally, the modular nature of trussed bridges facilitates easier construction and maintenance. The individual components of the truss can be prefabricated and assembled on-site, reducing construction time and labor costs. Furthermore, their design enables them to resist deformation and stress concentration, ensuring a longer service life compared to other bridge types without trusses. Overall, trussed railway bridges represent an ideal balance between structural integrity, material efficiency, and adaptability for diverse engineering challenges. Their capacity to bear heavy loads over long spans makes them a preferred choice for modern railway bridge design, ensuring safety, sustainability, and economic viability in infrastructure development.

Keywords: Railway bridge girders, trussed bridge structures, long-span bridges, load distribution, structural efficiency

INTRODUCTION

In trussed bridge designs, the load from the passing train or any applied force is not solely carried by the girder but is distributed among the various members of the truss system. The primary function of the truss is to divide the load into smaller forces, reducing the burden placed directly on the girder and allowing for a more efficient use of materials. This principle is particularly important in railway bridges, where the loads imposed by trains are significant and dynamic. The main focus of this analysis is to examine the deflection at the middle node of the truss system, which is where the maximum deflection typically occurs [1–3].

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The middle node was chosen for analysis because it is positioned farthest from the supports, making it the point of maximum displacement under load. This is a common characteristic in many structural systems, as the largest deflections are generally observed at the mid-span of a bridge or structure. By calculating the deflection at this critical point, engineers can determine whether the bridge will perform safely under the expected operational conditions, particularly with heavy loads carried by trains [4–6].

Deflection is a critical factor in bridge design because excessive bending or movement can compromise the structural integrity and safety of bridges. The deflection value at the middle node of the truss was compared with the permissible deflection, which is typically determined based on the span and type of material used for the bridge. If the calculated deflection exceeds the permissible value, the bridge needs to be reinforced or redesigned. Thus, calculating and comparing deflection against permissible limits is an essential step in ensuring that a bridge remains safe for long-term use [7–9].

Moreover, a properly designed trussed bridge accommodates the load efficiently and reduces material costs. The girder thickness can be reduced by distributing the load among the truss members, thereby optimizing the overall construction budget. This efficiency is particularly important when designing large-scale infrastructure such as railway bridges that must span long distances while supporting high traffic volumes.

LITERATURE REVIEW: TRUSSED BRIDGE DESIGN AND ANALYSIS

Overview of Trussed Bridges

Trussed bridges are widely recognized for their structural efficiency, consisting of interconnected triangles that distribute loads in a manner that minimizes material usage while maintaining strength. Historically, trussed bridges have been essential for long-span applications, particularly in railway and highway systems. The primary advantage of trussed bridges is their ability to provide greater load-bearing capacity with less material compared to traditional solid beam designs. Over time, engineering advancements have improved their design, incorporating better materials and more precise construction techniques [10–12].

Trussed structures offer multiple benefits such as reduced weight, cost-effectiveness, and the ability to span long distances. These factors make them suitable for challenging construction environments where conventional materials or beam designs are less efficient or cost prohibitive.

Load Distribution in Trussed Bridges

In a trussed bridge, the applied load is shared between the truss and bridge girder members. This distributed load helps to reduce the thickness of the girder required in the design, thereby reducing material costs. Trusses transfer forces through their triangular shape, which ensures that the load is spread across several members. As a result, each member of the truss bears a smaller portion of the total load than a solid beam structure [13, 14].

Effective load distribution in trussed bridges is essential for maximizing the efficiency of the structure and minimizing costs. The use of computational tools has enhanced the ability to model and analyze the distribution of loads across the truss, leading to optimized designs that improve both performance and material usage.

Deflection and Stress Considerations

Deflection is an important factor for evaluating the performance of a bridge. In trussed bridges, the mid-span of the girder and nodes of the trusses are the key locations for deflection analysis. The deflection at these points provides insight into how the structure behaves under applied loads. The bending moment (BM) at the center of the bridge plays a crucial role in determining the stress levels in both the truss members and the girder. In many designs, it is essential to ensure that the deflection remains within allowable limits to maintain the functionality and safety of the bridge [15–18].

Stress calculations, using principles such as the bending equation, help to ensure that the material strength is not exceeded. For example, it is important to calculate the maximum bending moment and the associated stress to verify the feasibility of the design. Properly calculating and managing deflection and stress ensures that the structure can bear the expected loads without experiencing failure or excessive movement [19].

Designing Trusses for Longer Spans

Trussed bridges are particularly advantageous for longer spans, where the weight of the solid beams is prohibitive. Unlike solid beam designs, which may become overly large or costly for long spans, trussed bridges efficiently manage large loads while maintaining their stability. The inherent flexibility of trussed designs allows greater span lengths with reduced material usage, which is why trussed bridges are commonly used in railways, highways, and other large-scale construction projects.

Recent developments in materials science have further enhanced the ability of trussed bridges to span greater distances. The use of high-strength materials has led to lighter, more durable trusses capable of supporting greater loads while reducing the overall weight of the structure.

Advances in Computational Tools

Advancements in computational tools have significantly affected the design process of trussed bridges. Software, such as finite element analysis (FEA), enables engineers to simulate the behavior of a truss under various loading conditions. This simulation provides detailed insights into the distribution of forces and potential points of failure, helping engineers optimize the design before construction begins. In addition, computational methods allow for the analysis of more complex truss designs, such as hybrid trusses that combine traditional elements with modern materials or innovative configurations. These tools enable engineers to fine-tune the truss performance, making it more efficient, safer, and easier to construct.

Stress and Deflection Limits

One of the most critical factors in trussed bridge design is ensuring that the stress and deflection of the bridge remain within acceptable limits. Engineers can ensure the long-term stability and safety of the structure by calculating the permissible stress of the materials used in the truss and ensuring that the deflection does not exceed predefined limits. Stress analysis accounts for both the internal forces within the truss members and the external loads acting on the structure.

Deflection, on the other hand, must be controlled to ensure that excessive movement does not occur, which could lead to structural failure or unsafe conditions for the vehicles using the bridge. Designers often set permissible deflection limits as a fraction of the span length to ensure that the bridge can accommodate loads without excessive bending or movement.

RESULTS AND DISCUSSION

As shown in the Figures 1 and 2, the unique design of the trussed bridge allows for more efficient load distribution. In this system, half of the total load is applied by the truss members, while the remaining load is supported by the girder. This results in a design that requires less material for the girder because it is subjected to only half of the load that would otherwise be carried in a traditional non-trussed design. The ability to reduce the girder's material requirements helps lower the overall cost of the bridge while maintaining its structural integrity (Figure 1).

This Figures 1 and 2 visually demonstrates how the load is divided between the truss and girder. The truss members play a critical role in bearing a significant portion of the applied load, preventing the girder from experiencing excessive stress, and reducing the thickness required for the girder. This not only saves material but also contributes to a more cost-effective and lightweight design. The design of the truss system ensures that the load is transferred efficiently and uniformly across the structure, thereby enhancing the overall stability and safety of the bridge Figure 2.

To further analyze the structural integrity, we calculated the maximum BM at the mid-span of the girder. The maximum BM at mid-span was calculated using the following formula:

$$200\times10-50\times10-100\times6-100\times2=700 \text{ kg-m}$$

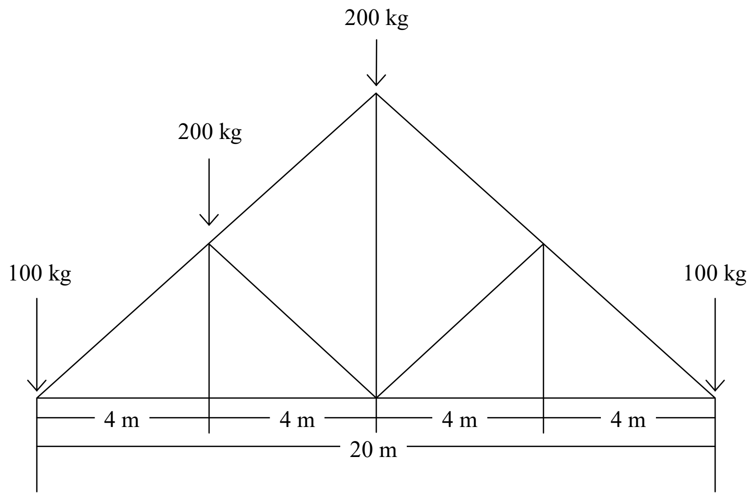

Figure 1. Trussed bridge.

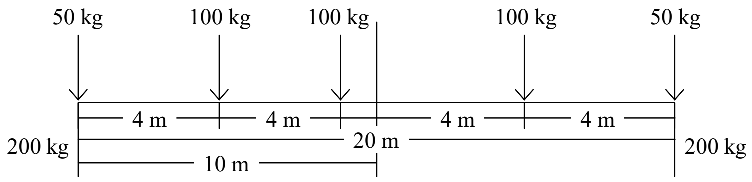

Figure 2. The load is divided between the truss and the girder.

This calculation provides insight into the bending stresses acting on the girder at the critical point of mid-span. The bending equation was then applied to calculate the permissible stress in the truss material, which was assumed to be 100 N/mm^2. With this information, we can determine the dimensions of the girder required to withstand the bending stresses.

The calculation for the required girder dimensions is as follows:

$$8333d2=7000000 \Rightarrow d2=840 \Rightarrow d=30 \text{ cm}$$

Thus, the girder is designed with dimensions of $b \times d = 400\ \text{mm} \times 500\ \text{mm}$, ensuring that it could withstand the calculated maximum bending moment without exceeding the allowable stress limit of the material. This careful calculation ensures that the girder remains stable and capable of supporting the imposed loads.

The deflection at the mid-span of the girder was calculated to be 10 mm, which is an essential aspect of the analysis. This deflection value was then compared to the permissible deflection, which is typically set to 25 mm for this particular span. Because the calculated deflection of 10 mm was significantly lower than the permissible value of 25 mm, the design was deemed satisfactory and within acceptable limits.

Permissible deflection serves as an important safety measure, ensuring that the bridge remains structurally sound and that there is no excessive bending that could affect the stability of the structure over time. If the deflection exceeds the permissible value, it suggests that the bridge might be prone to excessive movement, which could lead to fatigue, discomfort for passengers, or even failure in extreme cases. Therefore, maintaining the deflection within these limits is crucial for the longevity and safety of bridges.

The maximum deflection at the mid-span of the girder must be determined. Maximum BM at mid-span of girder.

$200 \times 10 - 50 \times 10 - 100 \times 6 - 100 \times 2$

Maximum BM = 700 kg-m
Using bending equation:

$\frac{M}{Z} = f$

- Permissible stress of material of truss = 100 N/mm^2 taken

  $\frac{700 \times 10 \times 1000}{\frac{1}{12} \times 500 \times d_3 \times \frac{2}{d}} = 100$

- Hence
  8333 d^2 = 7000000
  d^2 = 840
  d = 30 cm taken
  Hence, b × d = 400 mm × 500 mm was used as the girder of the bridge.
  $\delta = \frac{fl^2}{6ED}$ [for concentration load],

- Hence deflection $\delta = \frac{100 \times (10 \times 1000)^2}{2 \times 10^5 \times 500} = \frac{10000000000}{1000 \times 10^5}$ = 10 mm

- Permissible deflection $= \frac{Span}{800} = \frac{20 \times 1000}{800} = 25\ mm$

  Deflection 10 mm < 25 mm
  Hence O.K.

CONCLUSION

In conclusion, the design of the trussed bridge was highly effective in distributing the load between the truss and girder. By doing so, the girder can be constructed with reduced thickness, leading to material savings and cost efficiency without compromising the structural integrity of the bridge. The deflection analysis confirmed that the design was safe and that the calculated deflection fell well within the permissible limit. This ensures that the bridge functions safely under the expected loads and over the long term. The trussed bridge design, with its efficient load distribution and minimal material usage, offers an optimal solution for large-span railway bridges that balance both cost-effectiveness and safety.

Using advanced structural analysis techniques, engineers can continue to refine and optimize bridge designs to accommodate modern infrastructure needs. This not only helps to reduce the environmental impact by minimizing material use but also ensures the safety and durability of critical transportation networks.

Notation

b = Width of girder in mm.
d = Depth of girder in mm
M = Bending moment in kg-m.
I = Moment of inertia in m^4.
Z = Sectional modules in m^3.

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