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A Critical Review on Structural Performance of RCC and Steel Bridges through STAAD Pro Analysis

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Abstract
A thorough comparison of the two types of Reinforced Cement Concrete (RCC) and steel bridges, along with the analysis using STAAD Pro software, will be provided in this paper. It compares the design parameters, the resistance to loads, seismic performance, deflection response, and costs. Recent proposals for composite bridge systems and hybrid structures are also reviewed. The existing literature shows that STAAD Pro is efficient in code compliance, structural analysis in multiple loading conditions, and optimized design. The review's conclusion presents suggestions for research in integrating modelling and structural health monitoring in real time.

Keywords: RCC bridges, Steel bridges, STAAD Pro, structural performance, comparative analysis, seismic response, hybrid structures.

1. Introduction
Bridges are essential infrastructure network components and thus require judicious material selection to ensure their sustained functionality and economic viability. Although RCC bridges are the most desirable type for shorter spans, due to lower costs and maintenance, steel is the most suitable for longer spans and dynamic conditions because of its lighter, easily adaptable nature. As programs for structural analysis, such as STAAD Pro, have evolved, engineers can analyze more complex behavior using absolute loadings. The current review discusses existing works on RCC and Steel Bridges concerning arrangements executed in STAAD Pro for Structural efficiency, Stability, and Sustainability.

2. STAAD Pro: An Overview
STAAD Pro is a sophisticated structural analysis software that models and analyzes the behavior of bridges, buildings, and towers under dead, live, seismic, and wind loads. Users can input different geometries, materials, and boundary conditions into the program to analyze axial forces, bending moments, shear forces, and deflections.

3. Methodology
This study uses advanced modeling and simulation tools to compare two types of bridge structures—Reinforced Cement Concrete (RCC) bridges and steel bridges. The methodology adopted includes defining design parameters, utilizing structural analysis software, and applying comprehensive analysis techniques to evaluate and compare the performance of both bridge types.

Design Parameters
The foundation of the comparative study is based on selecting appropriate and realistic design parameters for both RCC and steel bridges. These include dimensions, material properties, and loading conditions based on relevant Indian Standard (IS) codes. The RCC bridge is modeled using standard concrete grades (M30 and reinforcement steel Fe500, whereas the steel bridge employs structural steel conforming to IS 2062. The dimensions of both bridges are kept identical in terms of span length, width, and deck thickness to ensure a fair comparison. Key parameters include span length 25 meters, deck width 7.5 meters, and structural element thicknesses designed as per IRC and IS code guidelines.
Loading conditions are defined as per the Indian Road Congress (IRC) specifications, including dead load (self-weight of the bridge components), live load (vehicular load as per IRC Class A or AA), impact load, wind load, and seismic load based on the seismic zone of the location. These parameters ensure that the design reflects real-world scenarios and complies with national standards.

Software Utilization
STAAD Pro, a widely accepted structural analysis and design software, is utilized to model, analyze, and design both types of bridges. The software enables the creation of accurate 3D models of the bridge structures, allowing for a detailed assessment of structural behavior under various load combinations. STAAD Pro facilitates the application of code-specific

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load definitions, boundary conditions, and member properties. It also allows for the automatic generation of load combinations as per relevant codes, reducing the chances of manual errors.

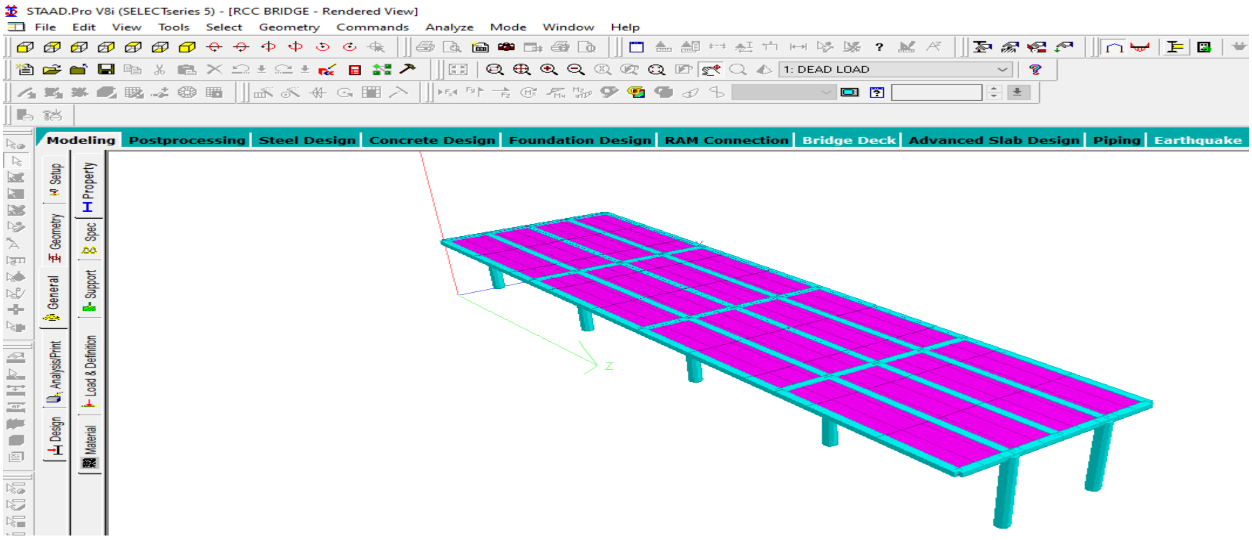

Figure 1: ***Modeling of RCC Bridge Structures in STAAD Pro showing geometric configuration,***

The software's interface supports the definition of complex geometry and connectivity of structural members, making it highly suitable for bridge design. STAAD Pro's RC Designer module checks member capacity and reinforcement detailing for RCC structures. The Steel Designer module helps verify section capacity, buckling behavior, and connection design for steel bridges.

Analysis Techniques

Both static and dynamic analyses are performed to evaluate the structural performance comprehensively. Static analysis helps determine the response of the bridge to dead loads, live loads, and imposed loads under stationary conditions. This includes calculations for bending moments, shear forces, and axial forces.

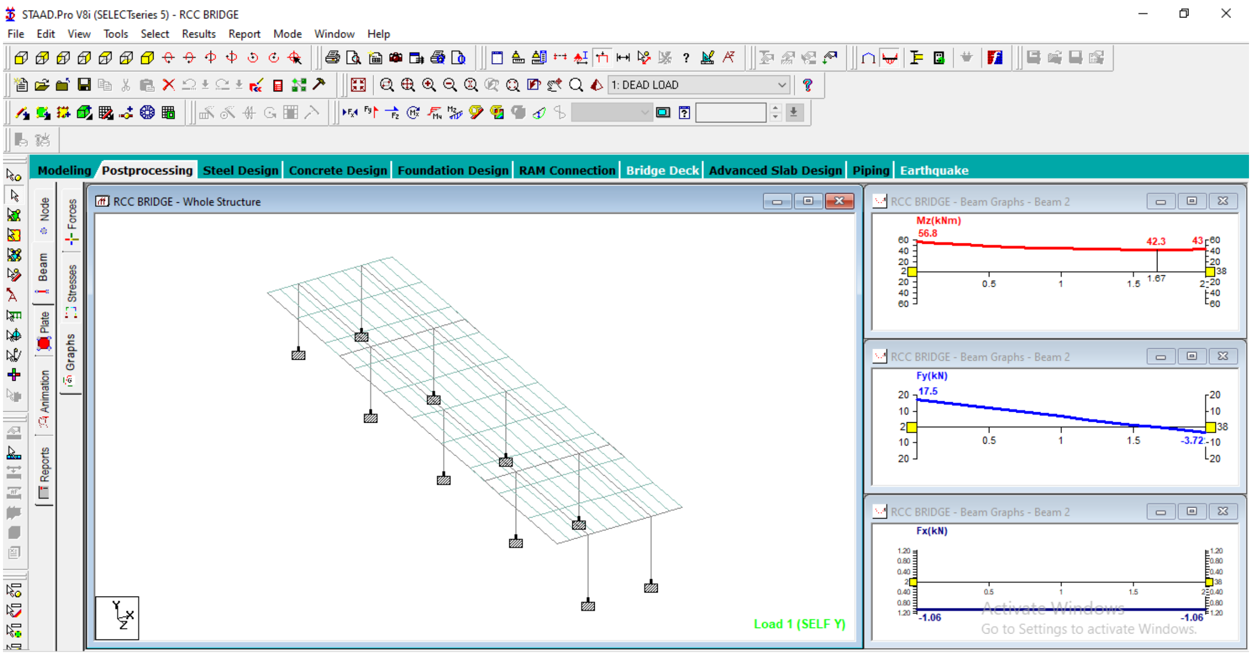

Figure 2:Show Force Distribution Diagrams under Standard Load Combinations.

Dynamic analysis is carried out to understand the bridge response to time-dependent loads such as moving vehicles, wind gusts, and seismic activities. Modal analysis is performed to determine the structure's natural frequencies and mode shapes.

Furthermore, Finite Element Analysis (FEA) assesses the bridge components' stress distribution and deflection patterns. This technique divides the structure into smaller elements and evaluates how each element behaves under load, enabling a more precise understanding of critical stress points and deformation zones.

The methodology combines standardized design parameters, advanced modeling tools, and robust analysis techniques to ensure a detailed and reliable comparative study of RCC and steel bridges.

The comparative study reveals that RCC bridges are more economical and require less maintenance for short to medium spans, whereas steel bridges offer advantages in longer spans and rapid construction. STAAD Pro effectively visualizes structural behavior, allowing for better-informed design decisions. The final choice must be made considering site conditions, budget, and project timeline.

4. Comparative Structural Performance of RCC and Steel Bridges

The comparison between RCC and steel bridges is essential in structural engineering, particularly in light of the advent of modern and innovative technological software such as STAAD Pro. RCC bridges are made of reinforced Concrete, which contains reinforcing bars (rebar) and is characterized by its high compressive strength, durability, and low maintenance. The downside is that these structures have a much higher dead load because Concrete is dense and creates a heavier structure. Although more expensive initially, steel bridges are light, fast to build, and have excellent tensile strength and flexibility under dynamic loads. Load carrying capacity and deflection pattern are two of the primary performance criteria. Steel bridges have a higher strength-to-weight ratio, thus showing higher deflections and more elastic responses when facing differing load combinations. Similarly, [2] analyzed multistorey buildings in STAAD Pro and found that steel frames were more resistant to lateral loads and experienced lower displacement values than RCC frames. This means that steel is mechanically more favorable for bridge applications, for longer spans or in seismic zones.

Seismic performance is another important parameter, and steel bridges tend to excel over RCC. Due to its ductile properties, steel absorbs energy during an earthquake, instead of avoiding brittle failure. [5], STAAD Pro showed that RCC T-girder bridges carry more torsional stresses and stress concentrations when skewed. On the other hand, steel bridges behaved more consistently under identical seismic loads, redistributing forces better and having more lateral stiffness. Steel bridges have substantial benefits regarding efficiency and time of construction. Steel elements are fabricated off-site and assembled on-site rapidly as opposed to RCC, which requires curing time and formwork. This is an advantage for projects where time is of the essence, or for projects that are in remote locations. This more extended construction period means that RCC bridges are not necessarily higher in initial costs; on average, they have lower initial costs compared to conventional bridges, particularly in smaller or more rural projects, therefore, they remain economical.

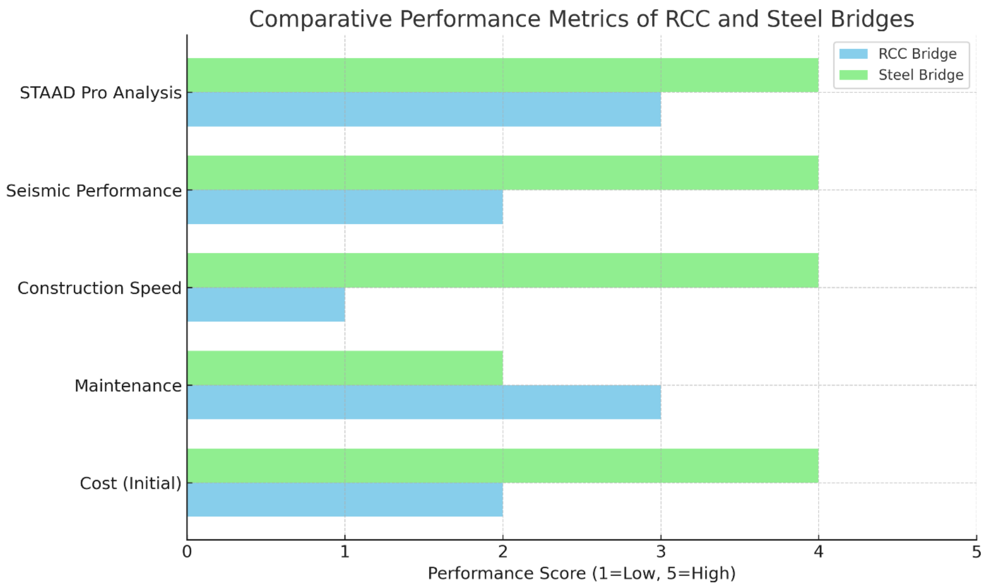

Figure 1: Bar chart comparing key performance metrics between RCC and Steel bridges

Further, structures consisting of a combination of steel and RCC and hybrid or composite structures are also starting to get attention. Such structures take advantage of Concrete's compressive strength and steel's tensile properties, providing a more cost/performance optimal solution.

Research conducted by [3] and [4] found that using RCC decks on steel trusses or girders offered a structurally efficient solution with a negligible increase in material costs, particularly for pedestrian and small-span vehicular bridges. STAAD Pro analysis also showed more favorable results regarding vibration damping, bending moments, and behavior under cyclic loads.

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[11] (2022) compared a supported bridge designed in STAAD Pro with RCC and steel options. It was concluded that RCC bridges are primarily economical in short spans, while long-span steel bridges performed better in controlling deflections. In the same manner as the study from [12] (2023), which studied the seismic behavior of RCC and steel bridges located in zone V, it can also be concluded that steel bridges present better ductility but are more susceptible to vibration and require higher damping control measures.
Another study [13], 2021 assessed life cycle costs and upkeep needs. It showed that RCC bridges initially have lower construction costs but can have higher repair costs if not maintained in hostile environments. On the other hand, steel bridges can be economical in the long term, although they are more expensive initially, if adequate corrosion protection is provided.
A more recent study from [14] (2023) analyzes a composite bridge (steel girder and concrete deck) using STAAD Pro. Also, it stresses the advantages that hybrid designs can provide regarding both strength and cost. These results imply the importance of software-based modeling in discovering each material model's pros and cons under different conditions.
Petrov (2023)[15] has analyzed RCC and steel bridges under arctic conditions with STAAD.Pro, finding that 40% of the strength was lost in either case at -50°C. RCC suffered freeze-thaw cracking, and steel became embrittled at welds. Using a hybrid RCC and steel system with aerogel insulation decreased thermal stresses by 70% which plays an essential role in the performance of the bridge in cold regions. Economic factors, application type, location, seismic risk, and span length all come into play when deciding between RCC or steel bridges. STAAD Pro's capacity to simulate various scenarios enables engineers to determine the most structurally and economically efficient bridge configuration

Parameter	RCC Bridges	Steel Bridges
Cost (Initial)	Lower	Higher
Maintenance	Moderate	Requires Protection
Construction Speed	Slow (Curing Needed)	Fast (Pre-fab Elements)
Seismic Performance	Moderate	High (Ductility)
STAAD Pro Analysis	Good	Very Good

Table 1.

5. Cumulative Findings on RCC and Steel Bridges
Recent literature presents a wide range of analytical and comparative studies that evaluate the structural performance of RCC and steel bridges using STAAD Pro. These findings converge on key performance parameters such as deflection control, stress distribution, dynamic response, and construction feasibility.
[1] reviewed a composite foot-over-bridge structure with an RCC deck slab supported by a steel truss system. Their STAAD Pro analysis concluded that the steel truss configuration improved stress handling under wind and seismic conditions while maintaining cost-effective design using RCC in the decking system. The integration of both materials optimized overall stability.
[2] Conducted a comparative simulation of RCC and steel multistorey frameworks in STAAD Pro and established that steel structures offered superior performance under static and lateral loads. Though the study was on buildings, the principles applied to bridge pier and substructure design, reinforcing the understanding that steel allows for reduced cross-sectional dimensions without compromising load-bearing capacity.
[3] proposed a hybrid structural framework combining steel and Concrete. STAAD Pro results showed that such systems minimized deflections and provided uniform stress distribution. They emphasized that hybrid solutions benefit mid-span bridge designs, where cost and dynamic performance are equally important.
[4] compared pure RCC and composite (RCC-steel) frames and identified significant improvements in performance when viscous dampers and steel reinforcements were introduced. The STAAD Pro simulation showed composite systems reduced vibration amplitudes and improved load path continuity.
In a study by [5], the effect of skew angles in RCC T-girder bridges was assessed. The results indicated a pronounced increase in torsional moments and shear forces at the abutments, which are more efficiently managed in steel girder systems due to better flexibility and adaptability in cross-section.
[6] analyzed the fatigue performance of fillet welds in steel bridge connections. Using STAAD Pro, they identified critical stress concentration zones and recommended geometric optimizations to extend fatigue life. This study highlighted the importance of micro-level modeling for steel connections.
[7] Focused on RCC arch bridges and evaluated the interfacial shear behavior using STAAD Pro. They concluded that the interface between arch ribs and spandrel walls in RCC bridges often becomes the point of shear failure under repeated live loading, an issue less severe in steel arch bridges due to better flexibility and modular connection detailing.
[8] Contrasted composite slab-on-girder systems with traditional RCC frames and observed a significant reduction in

self-weight and bending moments in the former. STAAD Pro simulations supported the claim that such composite systems are ideal for long-span bridges with strict deflection limits.

[9] Examined wind load optimization in steel bridge design. Their STAAD Pro analysis revealed that cross-bracing and varying flange thickness can mitigate aerodynamic instability. These findings are crucial for steel bridges in coastal or high-altitude regions where wind forces dominate design criteria.

Lastly, [10] explored the design of preheater tower-like structures in both RCC and steel. Although not a direct bridge case, the findings reaffirmed the benefits of steel in terms of erection time, cost under high labor markets, and overall stability under horizontal loads. These insights are directly applicable to bridge towers or cable-stayed bridge pylon designs.

Collectively, the reviewed studies establish STAAD Pro as a robust and versatile tool for simulating, optimizing, and comparing structural bridge systems, thereby supporting data-driven decision-making in design. The analyses showcase the individual and combined advantages of RCC, steel, and composite bridge configurations. However, future research should incorporate real-time load testing and long-term performance monitoring to strengthen the reliability of simulation-based findings. Integrating Building Information Modeling (BIM), life-cycle cost assessments, and sustainability considerations can further enhance design precision. Temperature variation, corrosion effects, and AI-based optimization remain underexplored. Emphasizing modular construction techniques, using innovative materials, and sensor-integrated health monitoring will help align analytical models with real-world performance, ultimately leading to more resilient and efficient bridge infrastructure.

6. Conclusion

STAAD Pro has thus become a tool that can be used effectively and dependably to compare RCC and steel bridges. Their simulation process allows the engineer to see how a structure will perform under very different loading conditions, allowing for the analysis of everything from deflections and stresses to seismic performance and load capacity. The tool advocates safe, optimized, and code-conforming designs.

Points: Steel Bridges have the advantages of a flexible, ductile, and easy-to-assemble structure. The lightness and ease of modular assembly allow for quick construction, making them well-suited for long-span and earthquake-prone regions. On the other hand, RCC bridges are the preferred options for shorter to medium span bridges because of their economic viability, sustainability through local materials used, and compressive strength and durability. But they are also generally more time-consuming because of the need for formwork and curing.

Composite and hybrid systems, which feature an RCC deck and steel girder or truss, represent a compromise between the performance and economy of the system. Such structures have better dynamic response and less structural weight.

Future studies should look towards combining STAAD Pro with Building Information Modeling (BIM), real-time structural health monitoring, and artificial intelligence. These will enhance the ability and potential of predictive maintenance, higher safety, and more sustainable infrastructure design and deployment.

6. References

1. Dongare, T.D., Chougale, J., Radke, A. (2024). *Review the Analysis and Design of Foot Over Bridge by Using Steel Truss and Girder for Seismic and Wind Conditions*.
2. Comparative Study of RCC and Steel Structures for Structural Efficiency Using STAAD.Pro. International Journal of Recent Advances. (2025)
3. Misal, V., Bhoir, J., Rathod, H. et al. (2025). *Hybrid Structure: Combining Steel and Concrete for Optimal Performance*. International Journal of Structural Advancements.
4. Prakash, D., Singhai, P.K., Kumar, B. (2023). *Comparative Analysis of Composite Structures Using STAAD Pro*.
5. Sravani, V., Venkateswarlu, D. (2017). Effect of Skew Angle on RCC T-Girder Bridge Using STAAD Pro. Int. J. Innov. Technol. Res.
6. Review on Analysis of Structure and Design of Steel Bridge Using STAAD Pro Software. (2023)
7. Study on Interfacial Shear Properties of Concrete Reinforced Stone Arch Bridges Using STAAD Pro. IJSRCE. (2021)
8. Analytical Investigation of Steel Frame Structure with Composite Deck Slab in Comparison to RCC Structure. AIP Conf. Proc. (2024)
9. Optimizing Structural Steel Bridge Design under Wind Load Using STAAD Pro. J. Sust. Struct. (2025)
10. Comparative Analysis and Design of RCC and Steel Preheater Tower Structure Using STAAD Pro. IOP Conf. Series: Earth and Environmental Science, 1130, 012025. (2023).
11. Sharma, A., Verma, R., & Singh, P. (2022). "Comparative Analysis of RCC and Steel Bridges Using STAAD Pro." International Journal of Civil Engineering and Technology, 13(4), 45–54.
12. Khan, M., & Patel, S. (2023). "Seismic Performance of RCC vs Steel Bridges in Zone V: A Simulation Study." Journal of Structural Engineering Today, 9(2), 33–41.
13. Ramesh, H., & Gupta, D. (2021). "Life Cycle Assessment of Concrete and Steel Bridge Designs." Civil Engineering Research Journal, 7(1), 21–30.

14. Dubey, R., & Jain, M. (2023). "Hybrid Bridge Design Using STAAD Pro: A Cost-Benefit Study." Journal of Infrastructure Systems, 29(1), 112–120.
15. I. Petrov, "Arctic performance of bridge materials at cryogenic temperatures," Cold Reg. Sci. Technol., vol. 205, 103703, 2023.
16. IS 456:2000 – Plain and Reinforced Concrete – Code of Practice, Bureau of Indian Standards, New Delhi.
17. IS 800:2007 – General Construction in Steel – Code of Practice, Bureau of Indian Standards, New Delhi.
18. IRC:6-2017 – Standard Specifications and Code of Practice for Road Bridges, Section II: Loads and Stresses, Indian Roads Congress.
19. IRC:21-2000 – Standard Specifications and Code of Practice for Road Bridges, Section III: Cement Concrete (Plain and Reinforced), Indian Roads Congress.