# Comparative Structural Analysis Of RCC Deck Bridge And PSC Girder Bridge Using STAAD-Pro Under IRC Loading

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***Abstract-*** *Highway bridges are important elements of transportation infrastructure, and the selection of a suitable bridge superstructure directly affects structural safety, serviceability, durability, and economy. In Indian bridge construction, reinforced cement concrete (RCC) deck bridges and prestressed concrete (PSC) girder bridges are commonly used for small and medium-span applications. The present research paper focuses on the comparative structural analysis of an RCC deck bridge and a PSC girder bridge using STAAD-Pro under IRC loading conditions. A two-span continuous bridge of 40 m + 40 m span arrangement with a total length of 80 m, 10.5 m carriageway width, 250 mm deck slab, and three longitudinal girders is considered for analysis. Both RCC and PSC models are developed with identical geometry, support conditions, and loading arrangement to ensure a fair comparison. Dead load, superimposed dead load, IRC Class AA tracked vehicle load, and IRC Class A wheeled vehicle load are applied using STAAD-Pro moving load generation. The PSC model includes prestressing force applied to the longitudinal girders to study the effect of post-tensioning. The structural responses are compared in terms of bending moment, shear force, support reaction, plate stress, and mid-span deflection. The results indicate that the PSC girder bridge provides better serviceability, reduced tensile stress, and improved deflection control compared with the RCC bridge. Therefore, PSC is found more suitable for the selected medium-span continuous bridge configuration.*

***Keywords:*** RCC bridge, PSC girder bridge, STAAD-Pro, IRC loading, moving load analysis, bridge deflection.

## I. INTRODUCTION

Highway bridges are one of the most essential components of transportation infrastructure because they provide safe and continuous movement across rivers, valleys, roads, railway lines, canals and other physical obstructions. In a developing country like India, where the road network is continuously expanding through National Highways, State Highways, expressways, rural roads and urban transport corridors, bridges play a direct role in improving connectivity, reducing travel time, supporting trade movement and promoting regional development. A bridge is not only a structural element but also an economic asset, because any failure, excessive maintenance requirement or service interruption can affect traffic flow, public safety and transportation cost. Therefore, the planning, analysis and design of bridge superstructures require careful technical evaluation. In highway bridge engineering, the superstructure is particularly important because it directly carries traffic loads and transfers them safely to the substructure and foundation system. The proper selection of bridge type, material, span arrangement and structural system has a major influence on load-carrying capacity, serviceability, durability and economy.

In Indian bridge construction practice, reinforced cement concrete (RCC) and prestressed cement concrete (PSC) are two commonly adopted superstructure systems, especially for small and medium-span highway bridges. RCC deck slab and girder bridges are widely used because of their simple construction method, easy availability of materials, lower initial cost and familiarity among contractors and engineers. RCC bridges are generally suitable for shorter spans where the self-weight and deflection limits remain within acceptable ranges. They use conventional reinforcement to resist tensile stresses produced due to bending and shear. On the other hand, PSC girder bridges have become increasingly popular for medium and longer spans because they provide better structural efficiency, reduced cracking, lower deflection and improved durability. The use of high-strength concrete and prestressing steel allows PSC members to achieve longer spans with comparatively smaller section sizes. In Indian highway projects, PSC girders are commonly preferred for spans beyond approximately 25 m to 30 m, while RCC superstructures are generally considered more economical for smaller spans where prestressing facilities may not be justified.

The fundamental difference between RCC and PSC bridge behaviour lies in the way tensile stresses are resisted. In an RCC member, concrete is strong in compression but weak in tension; therefore, tensile forces are mainly carried by steel reinforcement after cracking occurs in the tension zone. Although the cracks are controlled by proper reinforcement detailing and codal provisions, the presence of cracks can allow moisture, chlorides and other aggressive agents to enter the concrete. This may result in corrosion of reinforcement and gradual deterioration of the bridge over its service life. In contrast, PSC members are intentionally compressed before the application of service loads by using high-strength prestressing tendons. This initial compressive force counteracts the tensile stresses caused by external loads. As a result, the concrete section remains either fully compressed or develops only limited tensile stress within permissible limits. This behaviour reduces cracking, improves stiffness, controls deflection and increases the durability of the bridge superstructure. PSC bridges also develop upward camber due to eccentric prestressing force, which helps in balancing dead load deflection and improving serviceability performance.

The structural response of RCC and PSC bridge systems cannot be properly evaluated only through simplified manual calculations, especially when the bridge has continuous spans, multiple girders, deck slab interaction, cross girders, moving vehicular loads and prestressing effects. Modern bridge analysis requires a more refined approach that can capture the distribution of load among girders, the behaviour of slab and girder interaction, support reactions, bending moments, shear forces, stresses and deflections under different loading conditions. Finite element analysis provides a suitable platform for such investigation. Among the various structural analysis software tools used in India, STAAD-Pro is widely adopted in academic research and professional design offices because it allows modelling of beam and plate elements, assignment of material properties, application of dead load and superimposed dead load, generation of IRC moving loads and simulation of prestressing effects. The software also provides post-processing facilities for extracting bending moment, shear force, displacement, plate stress and support reaction results. Hence, STAAD-Pro is an effective tool for comparing RCC and PSC bridge alternatives under identical geometry, support and loading conditions.

The selection of an economical and structurally efficient bridge system is an important decision in the preliminary design stage. A bridge system should not be selected only on the basis of initial construction cost, because long-term performance, maintenance cost, serviceability, durability and structural safety are equally important. RCC bridges may appear economical at the initial stage due to the absence of prestressing equipment, anchorage systems and specialised construction procedures. However, for longer spans, RCC sections become deeper and heavier, which increases self-weight, bending moment, reinforcement requirement and deflection. This can make RCC bridges less efficient and less economical for medium to long spans. PSC bridges, although requiring higher-grade materials, skilled workmanship and prestressing equipment, can reduce section depth, control cracking, improve durability and reduce long-term maintenance. Therefore, a rational comparison must consider both structural response and cost-related implications. Parameters such as bending moment, shear force, support reaction, mid-span deflection, tensile stress, material quantity and approximate cost are necessary for a meaningful comparison between RCC and PSC bridge systems.

The present research paper focuses on the comparative structural analysis of an RCC deck bridge and a PSC girder bridge using STAAD-Pro software. A two-span continuous bridge having a span arrangement of 40 m + 40 m and total length of 80 m is considered for the study. The bridge has a 10.5 m clear carriageway, 600 mm kerbs on both sides, a 250 mm thick deck slab, longitudinal girders and cross girders. The RCC and PSC bridge models are developed with identical geometry, support conditions and loading arrangement so that the comparison reflects the effect of the structural system rather than external modelling differences. Dead load, superimposed dead load and IRC Class AA and Class A moving loads are applied as per relevant Indian Roads Congress provisions. In the PSC model, prestressing force is applied to the longitudinal girders to represent the effect of post-tensioning. The analysis results are compared in terms of bending moment, shear force, support reaction, plate stress and mid-span deflection. In addition, a preliminary cost comparison is considered to understand the practical suitability of both alternatives. Thus, the study aims to identify the more efficient bridge system for the selected span range and to demonstrate the usefulness of STAAD-Pro in the comparative analysis of RCC and PSC bridge superstructures.

## II. LITERATURE REVIEW

Pandey and Kumar (2014) carried out a comparative analysis of RCC T-beam bridges and PSC I-girder bridges using STAAD-Pro under IRC Class AA and Class A loading conditions. Their study focused on a 30 m span bridge consisting of three longitudinal girders and four cross girders. The authors observed that the PSC bridge showed nearly 25% reduction in mid-span deflection and about 30% reduction in tensile stress at the soffit compared with the RCC bridge. This indicated that prestressing improves serviceability by reducing cracking and controlling deflection. Sharma and Singh (2015) conducted a parametric study for bridge spans ranging from 15 m to 45 m using SAP2000. Their work considered both structural performance and cost aspects and identified that PSC bridges become more economical beyond nearly 27 m span, despite higher material cost. Rao and Reddy (2016) studied skewed RCC and PSC bridges using STAAD-Pro by varying skew angles from 0° to 45°. Their analysis showed that skew effects were more severe in RCC bridges because of greater flexibility, while PSC bridges displayed better stiffness and load distribution. Patil and Galagali (2017) investigated the dynamic response of RCC and PSC bridges under moving truck loads. They found that the IRC impact factor was conservative for PSC bridges due to their higher natural frequency and lower mass. Kulkarni and Deshpande (2018) analysed two-span continuous RCC and PSC bridges using STAAD-Pro and reported that PSC bridges developed higher hogging moment over the intermediate pier due to prestress-induced upward camber, while sagging moments at mid-span were comparatively lower. These studies collectively indicate that PSC bridges generally provide better serviceability, lower deflection, improved stress control and better suitability for medium-span bridge construction, while RCC bridges remain effective for shorter spans due to simpler construction and lower initial cost.

Mehta and Joshi (2018) examined the influence of prestress losses on PSC bridge behaviour and highlighted that inaccurate estimation of losses can significantly affect long-term performance. Their sensitivity study showed that even a 5% underestimation of prestress losses may cause nearly 12% underestimation of long-term deflection, proving the importance of proper loss calculation in PSC bridge design. Iyer and Subramanian (2019) compared RCC and PSC bridges under seismic loading using SAP2000 response spectrum analysis. Their results showed that PSC bridges attracted higher base shear because of greater stiffness, but experienced lower displacement demand, making them more suitable for seismic regions where serviceability and bearing safety are important. Nair and Krishnan (2020) performed a life-cycle cost analysis of RCC and PSC bridges based on twelve bridge projects from southern India. They found that PSC bridges were 14–18% cheaper over a 75-year service life for spans above 30 m, mainly because of lower maintenance, reduced cracking and improved durability. Ramaswamy (2021) presented detailed finite element modelling procedures for girder bridges in STAAD-Pro, particularly focusing on element selection, property assignment and IRC moving load generation. His work is useful for developing a systematic modelling workflow for RCC and PSC bridge comparison. Hegde and Bhat (2022) studied RCC and PSC bridges under revised IRC:6-2017 loading provisions and observed that revised impact factors produced approximately 6–8% higher responses for PSC bridges compared with earlier code provisions. Their study emphasized the need to update bridge analysis according to the latest IRC loading standards. Overall, these studies show that recent research has moved beyond simple strength comparison and now includes finite element modelling, seismic behaviour, prestress losses, life-cycle cost and updated IRC provisions. However, limited work is available on continuous two-span RCC and PSC bridge comparison with complete STAAD-Pro modelling and cost-based interpretation, which supports the need for the present study.

### 2.1 Research Gap

Most available studies compare RCC and PSC bridges for simply supported spans, skew bridges, or older loading conditions. Limited studies are available on two-span continuous bridge systems, where load redistribution between mid-span sagging moment and support hogging moment significantly affects structural behaviour. Also, fewer studies have considered updated IRC:6-2017 loading provisions with a clearly documented STAAD-Pro modelling workflow. Although previous research discusses deflection, bending moment, prestress loss, seismic behaviour, and cost separately, very few studies integrate bending moment, shear force, support reaction, plate stress, mid-span deflection, and preliminary cost comparison in one framework. Therefore, the present study addresses this gap by comparing RCC and PSC bridge alternatives for a 40 m + 40 m continuous bridge under identical geometry, material properties, support conditions, and IRC loading using STAAD-Pro, providing a more practical basis for selecting an economical and structurally efficient bridge system.

## III. OBJECTIVES OF THE STUDY

1. To review the existing literature on RCC and PSC bridge analysis, design, and comparative behaviour, especially studies using STAAD-Pro and finite element methods.
2. To define the geometry, material properties, support conditions, and IRC loading parameters for a representative 40 m + 40 m two-span continuous bridge.
3. To develop RCC and PSC bridge models in STAAD-Pro using shell elements for the deck slab and beam elements for longitudinal and cross girders.
4. To analyse both bridge models under self-weight, superimposed dead load, IRC Class AA tracked load, and Class A wheeled moving load as per IRC:6-2017.
5. To compare bending moment, shear force, support reaction, plate stress, mid-span deflection, and preliminary cost to identify the more structurally efficient and economical bridge system.

## IV. METHODOLOGY

The methodology adopted in the present research paper is based on a comparative finite element analysis of reinforced cement concrete (RCC) and prestressed cement concrete (PSC) bridge superstructures using STAAD-Pro software. The main purpose of the methodology is to analyse both bridge alternatives under identical geometric configuration, material assumptions, support conditions and IRC loading provisions, so that the difference in structural response can be attributed only to the change in superstructure system. The complete procedure includes defining bridge geometry, selecting material properties, applying dead load and moving load conditions, developing finite element models in STAAD-Pro, introducing prestressing action in the PSC model, and extracting the required structural responses such as bending moment, shear force, support reaction, plate stress and mid-span deflection. The same bridge configuration is used for RCC and PSC comparison in the dissertation document.

### 4.1 Bridge Geometry

The bridge selected for the present comparative study is a two-span continuous highway bridge having a span arrangement of 40 m + 40 m, giving a total bridge length of 80 m. The bridge has been considered as a representative medium-span highway bridge, suitable for comparing the behaviour of RCC and PSC superstructure systems. The clear carriageway width is taken as 10.5 m, which is suitable for two-lane highway traffic. On both sides of the carriageway, kerbs of 600 mm width are provided. The deck slab thickness is considered as 250 mm, which acts integrally with the longitudinal and cross girders for transferring vehicular loads to the supports.

The longitudinal load-carrying system consists of three longitudinal girders, each having a size of 400 mm × 1400 mm. These girders are placed along the span direction and are responsible for resisting the major bending moment and shear force developed due to dead load and live load. Cross girders of size 300 mm × 1400 mm are provided in the transverse direction to improve load distribution between the longitudinal girders and to provide lateral stiffness to the bridge deck system. The same geometric dimensions are adopted for both RCC and PSC bridge models to maintain uniformity in comparison. STAAD-Pro software is used for developing and analysing the finite element models.

| **Parameter** | **Value** |
|---|---|
| Bridge type | Two-span continuous bridge |
| Span arrangement | 40 m + 40 m |
| Total length | 80 m |
| Carriageway width | 10.5 m |
| Kerb width | 600 mm each side |
| Deck slab thickness | 250 mm |
| Longitudinal girder size | 400 mm × 1400 mm |
| Cross girder size | 300 mm × 1400 mm |
| Number of longitudinal girders | 3 |
| Software used | STAAD-Pro |

### 4.2 Material Properties

The material properties are selected according to common Indian bridge construction practice and relevant IRC provisions. For the RCC bridge model, M30 grade concrete is used along with Fe 500 reinforcement steel. This represents a conventional reinforced concrete bridge system where tensile stresses are resisted by untensioned reinforcement after cracking occurs in the concrete tension zone. For the PSC bridge model, M45 grade concrete is adopted along with Fe 500 reinforcement steel and Fe 1860 prestressing steel. Higher-grade concrete is used in the PSC model because prestressed concrete members require higher compressive strength to safely resist the compressive stresses induced during prestressing and service loading.

In the PSC model, a prestressing force of 8000 kN per girder is applied to the longitudinal girders. This prestressing force introduces compressive stress in the concrete section and helps counteract tensile stresses generated due to external loads. The prestressing action also produces upward camber, which reduces net mid-span deflection and improves serviceability performance. The RCC model does not include prestressing steel or prestressing force.

| **Material Parameter** | **RCC Bridge** | **PSC Bridge** |
|---|---|---|
| Concrete grade | M30 | M45 |
| Reinforcement | Fe 500 | Fe 500 |
| Prestressing steel | Not applicable | Fe 1860 |
| Prestressing force | Not applicable | 8000 per girder |

### 4.3 Loading Conditions

The loading conditions considered in the analysis include dead load, superimposed dead load and live load as per IRC provisions. The self-weight of the structure is automatically generated in STAAD-Pro by assigning the density of concrete and applying the self-weight command. This includes the weight of the deck slab, longitudinal girders, cross girders and other modelled structural components. Superimposed dead loads include the wearing coat load, kerb load and parapet load. The wearing coat is applied as a pressure load on the deck slab, while kerb and parapet loads are applied as line loads or member loads along the edges of the bridge.Live load analysis is carried out using standard IRC vehicular loading. Two important moving load cases are considered: IRC Class AA tracked vehicle and IRC Class A wheeled vehicle. The IRC Class AA tracked vehicle represents heavy loading and is generally critical for bridge design. The IRC Class A wheeled vehicle represents standard highway traffic loading. These moving loads are generated in STAAD-Pro using the moving load generation facility. The vehicle loads are moved along the longitudinal direction of the bridge to identify the critical load positions that produce maximum bending moment, shear force, support reaction and deflection.

After generating different moving load positions, the critical load envelope is obtained. This envelope gives the maximum response values from all possible vehicle positions and is used for comparing the structural behaviour of RCC and PSC bridge models. By using the same dead load, superimposed dead load and live load cases for both bridge alternatives, the comparison remains technically consistent and reliable.

**The loading conditions considered are:**

1. Self-weight of bridge components
2. Wearing coat load
3. Kerb and parapet load
4. IRC Class AA tracked vehicle load
5. IRC Class A wheeled vehicle load
6. Moving load generation in STAAD-Pro
7. Critical load envelope for maximum response

### 4.4 STAAD-Pro Modelling

The finite element modelling is carried out in STAAD-Pro in a systematic sequence. First, the bridge geometry is created according to the selected span arrangement and cross-sectional dimensions. Nodes are generated at suitable intervals along the span and across the bridge width. These nodes are then connected to form beam members for longitudinal and cross girders. The deck slab is modelled using shell or plate elements so that two-way load distribution and slab-girder interaction can be represented. The longitudinal girders and cross girders are modelled using prismatic beam elements because they primarily resist bending and shear along their respective axes.After geometry creation, member properties and plate thickness are assigned. The deck slab is assigned a thickness of 250 mm, while the longitudinal and cross girders are assigned their respective rectangular section dimensions. Material properties are then assigned separately for RCC and PSC models. M30 concrete is used for the RCC model, while M45 concrete is used for the PSC model. The supports are assigned at abutment and pier locations to represent the actual support condition of the continuous bridge. Appropriate support idealisation is essential because support condition directly affects hogging moment, reaction distribution and deflection behaviour.

After assigning geometry, materials and supports, the loading is applied. Self-weight is generated directly through the STAAD-Pro self-weight command. Wearing coat load is applied as pressure on the deck slab, while kerb and parapet loads are applied along the outer edges. IRC Class AA and Class A vehicles are defined in the moving load generator. The software then generates critical moving load cases by placing the vehicle at different positions along the bridge span. These generated load cases are analysed to obtain the envelope of maximum structural response.For the PSC bridge model, an additional prestress load is applied to the longitudinal girders. The MEMBER POSTSTRESS LOAD command is used to simulate post-tensioning action. A prestressing force of 8000 kN per girder is applied with an eccentricity of 0.05 m. This eccentric prestressing force produces a balancing moment opposite to the moment caused by gravity loads, thereby reducing tensile stress and mid-span deflection. The inclusion of prestressing load is the major modelling difference between the RCC and PSC bridge models.

**The complete STAAD-Pro modelling sequence is as follows:**

1. Geometry creation of the two-span bridge
2. Node and member generation
3. Deck slab modelling using shell/plate elements
4. Longitudinal and cross girder modelling using beam elements
5. Support assignment at abutment and pier locations
6. Material property assignment for RCC and PSC models
7. Application of self-weight and superimposed dead load
8. Moving load generation for IRC Class AA and Class A vehicles
9. Prestress load application for the PSC model using MEMBER POSTSTRESS LOAD
10. Structural analysis and result extraction

After analysis, the results are extracted from STAAD-Pro post-processing. The main output parameters include bending moment, shear force, support reaction, plate stress and mid-span deflection. These results are compared for RCC and PSC bridge models in tabular and graphical form. The comparison helps to identify the influence of prestressing on structural performance and also supports the selection of the more economical and structurally efficient bridge system for the selected span range.

## V. RESULTS AND DISCUSSION

This presents the comparative results of the finite element analysis of the RCC and PSC variants of the two-span continuous bridge described in Chapters 3 and 4. The results are organised by response quantity — bending moments, shear forces, support reactions, deflections and plate stresses — and within each category, the RCC and the PSC outputs are presented side by side for direct comparison. The discussion that follows each set of results interprets the observations in the light of the underlying mechanics of reinforced and prestressed concrete, and draws inferences regarding the suitability of each system for the span range studied.

### Bending Moment Diagram — RCC Bridge

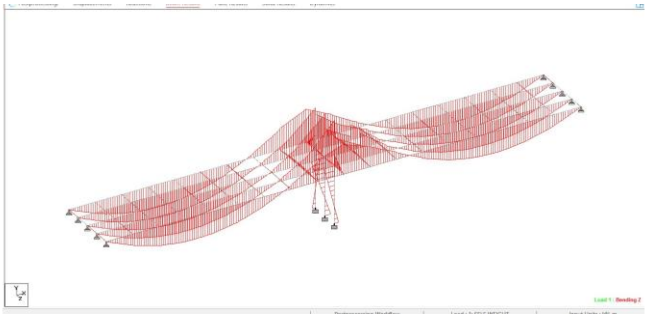

**Figure 1.Bending moment (Bending Z) diagram of the longitudinal girders, RCC variant**

### Bending Moment Diagram — PSC Bridge

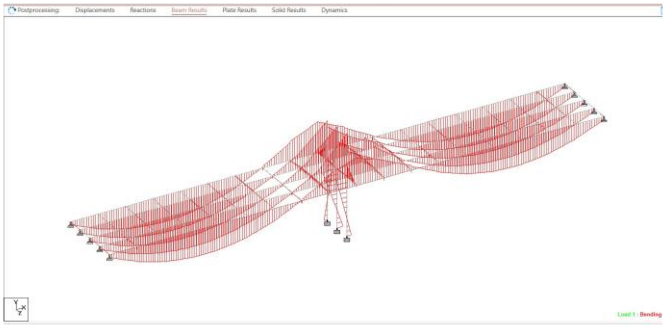

**Figure 2. Bending moment (Bending Z) diagram of the longitudinal girders, PSC variant**

### Numerical Comparison of Bending Moments

**Table 1. Comparison of Bending Moments in RCC and PSC Variants**

| Location & Component | RCC (kN·m) | PSC (kN·m) | Change (%) |
|---|---|---|---|
| Max sagging Mz, Span 1, outer girder | 8,520 | 6,250 | −26.6 |
| Max sagging Mz, Span 1, inner girder | 6,820 | 4,940 | −27.6 |
| Max sagging Mz, Span 2, outer girder | 8,495 | 6,230 | −26.7 |
| Max sagging Mz, Span 2, inner girder | 6,810 | 4,925 | −27.7 |
| Max hogging Mz at pier, outer girder | 14,890 | 17,210 | +15.6 |
| Max hogging Mz at pier, inner girder | 11,920 | 13,790 | +15.7 |
| Max bending Mz in any girder | 14,890 (hogging at pier) | 17,210 (hogging at pier) | +15.6 |

### 5.1 Shear Force Distribution

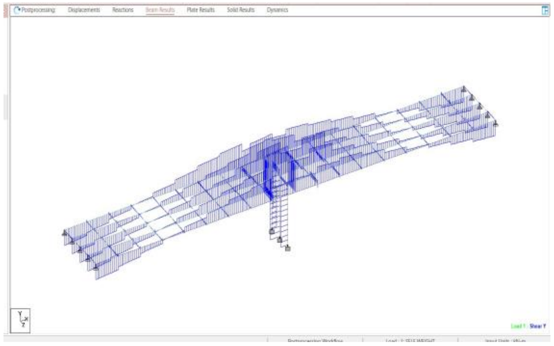

**Figure3. Shear force (Shear Y) diagram of the longitudinal girders, PSC variant**

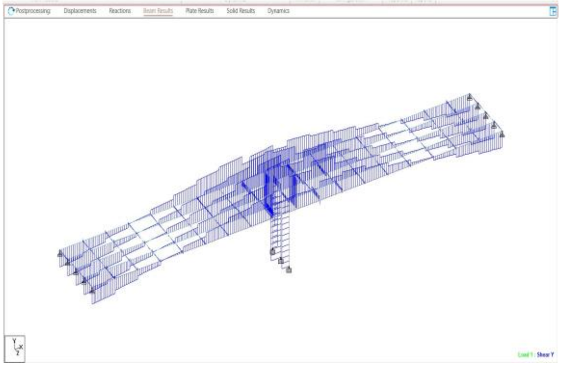

**Figure 4. Shear force (Shear Y) diagram of the longitudinal girders, RCC variant**

### 5.2 Mid-span Deflection

The mid-span deflection is one of the most direct indicators of the structural stiffness and serviceability of a bridge. The deflections at the mid of each span for the two variants are tabulated. The deflected shape under the most critical load case is shown in Figure for the PSC variant.

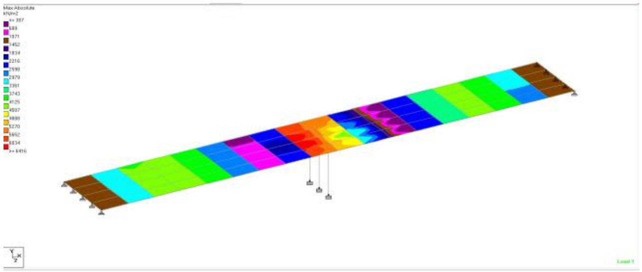

**Figure 5. Deflected shape of the PSC bridge under Load 1, showing upward camber from prestress**

## VI. CONCLUSION

The RCC and PSC bridge models were successfully developed and analysed in STAAD-Pro under identical geometry, support conditions, material assumptions, and IRC loading provisions. This helped in obtaining a fair comparative understanding of both bridge systems. The study considered a two-span continuous bridge configuration of 40 m + 40 **m**, and the responses were evaluated in terms of bending moment, shear force, support reaction, plate stress, and mid-span deflection. The results clearly indicated that the PSC girder bridge performed better in terms of serviceability and durability because the prestressing force reduced tensile stress, controlled cracking, and improved stiffness.The prestressing action produced an upward camber in the PSC girder, which helped in reducing the mid-span sagging moment and downward deflection. As a result, the PSC bridge showed better performance for medium-span bridge construction. In comparison, the RCC bridge is simpler to design and construct, requires commonly available materials, and may be economical for smaller spans. However, for longer spans, RCC sections become heavier and less efficient due to higher self-weight, greater deflection, and increased tensile stress.

For the selected 40 m + 40 m continuous bridge, the PSC girder bridge is found to be structurally more suitable than the RCC bridge. Although PSC may involve higher initial construction cost due to prestressing steel, anchorage, and skilled labour, its improved durability and reduced maintenance make it a better long-term option. STAAD-Pro proved effective for comparative bridge analysis under IRC loading. Future work may include seismic analysis, temperature effects, detailed prestress loss calculation, creep-shrinkage behaviour, fatigue analysis, and full life-cycle cost assessment.

## VII. FUTURE SCOPE

1. Future research can include seismic analysis of RCC and PSC bridge models to study their behaviour under earthquake forces.
2. The effect of temperature variation, shrinkage, and creep can be considered for more realistic long-term bridge performance.
3. A detailed prestress loss analysis may be carried out for the PSC bridge to evaluate immediate and long-term losses accurately.
4. The study can be extended by considering different span lengths, skew angles, and multi-span bridge configurations.
5. Future work may include fatigue analysis under repeated vehicular loading for better durability assessment.
6. A detailed life-cycle cost analysis can be performed by including maintenance, repair, rehabilitation, and service-life costs.
7. The analysis can be validated using other software such as MIDAS Civil, SAP2000, or ANSYS for result comparison.

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