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Comparative Study of RCC & SRC Piers

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Abstract

Bridges are important component of civil infrastructure which serves as the links for growth of economy by providing the connectivity between the major destinations. The structural design of a bridge involves various consideration in which seismic loading also plays the vital role while designing. The seismic design of a bridge requires rigorous analysis to guarantee safety, resilience and sustainability. The bridges are typically built with Steel structure or with the Reinforced Cement Concrete (RCC), the usage of the composite materials for the large infrastructure is still under consideration. The other variations of the structural components are Concrete filled tubes (CFT) in which the concrete is encased with hollow steel tube and Steel Reinforced concrete (SRC) in which the structural steel is encased in concrete. In this present study, a typical Reinforced Cement Concrete (RCC) bridge is considered and is analyzed in CSI Bridge software after the validation. The pier system of the bridge is replaced with Steel Reinforced Concrete (SRC) and the results of the two structural systems are compared. The comparison is carried for the all-load combinations including the seismic load. The main comparison of the results is taken for the seismic analysis.

Keywords: Reinforced Cement Concrete (RCC), Steel Reinforced Concrete (SRC), CSI Bridge.

1.Introduction:

Bridge piers are one of the most important structural components in bridge engineering, as they support the superstructure and transfer loads safely to the foundation. They resist not only the vertical loads from the bridge deck but also horizontal forces caused by wind, braking, and seismic actions. RCC piers are composed of concrete reinforced with steel bars, where the concrete resists compressive stresses and the steel reinforcement resist tensile stresses. RCC has been widely used due to its ease of construction, good compressive strength, and durability. However, its main limitations are its low tensile strength and brittle failure behaviour under large lateral or seismic loads.

To overcome these limitations, SRC Bridge piers are one of the most important structural components in bridge engineering, as they support the superstructure and transfer loads safely to the foundation. They resist not only the vertical loads from the bridge deck but also horizontal forces caused by wind, braking, and seismic actions. piers (Steel Reinforced Concrete piers) have been developed as a composite structural system combining the advantages of both steel and concrete.

In SRC construction, a structural steel section—such as an I-section or box section—is embedded inside the reinforced concrete. This creates a composite action between the materials, where steel provides high tensile strength and ductility, while concrete contributes to compressive strength and stiffness. As a result, SRC piers exhibit higher load-carrying capacity, better energy dissipation, and superior seismic performance compared to RCC piers.

Structural engineering plays a vital role in ensuring the safety and resilience of infrastructure against natural hazards, particularly earthquakes. As a specialized branch of civil engineering, it focuses on designing structures that can withstand dynamic loads and maintain integrity during seismic events. Earthquakes pose unique challenges due to their unpredictable nature and the complex interaction between ground motion and structural response.

Structural engineers employ a combination of scientific understanding, engineering judgment, and design strategies to ensure buildings can withstand seismic forces. These principles are not just theoretical—they're embedded in building codes and validated through real-world performance.

The primary aim of this study is to evaluate and compare the structural performance of Reinforced Cement Concrete (RCC) and Steel Reinforced Concrete (SRC) piers with respect to their load-carrying capacity, pushover analysis, shear capacity, and spectrum analysis under seismic loading conditions.

1.1 Objectives

- ❖ To analyze the axial load, shear force, and bending moment distribution in RCC and SRC piers.
- ❖ To compare the demand–capacity (D/C) ratios and identify the critical sections influencing overall pier behaviour.

2.Literature Review

Hao Sun et al.

In this study, the seismic response of a two-span continuous girder bridge with CFST piers under multiple earthquakes is analyzed, thereby addressing a research gap in which attention is typically limited to single-event performance. A detailed finite element model incorporating advanced steel and confined concrete damage–plasticity formulations is developed, and seismic inputs are generated in accordance with the Endurance Time Analysis method. The results demonstrate that ETA is an efficient tool for evaluating sequential earthquake effects and that lateral deformation behavior depends strongly on the peak intensity ratio between consecutive events. As initial damage increases, the threshold intensity ratio needed to trigger further deterioration decreases, raising the likelihood of progressive structural damage.

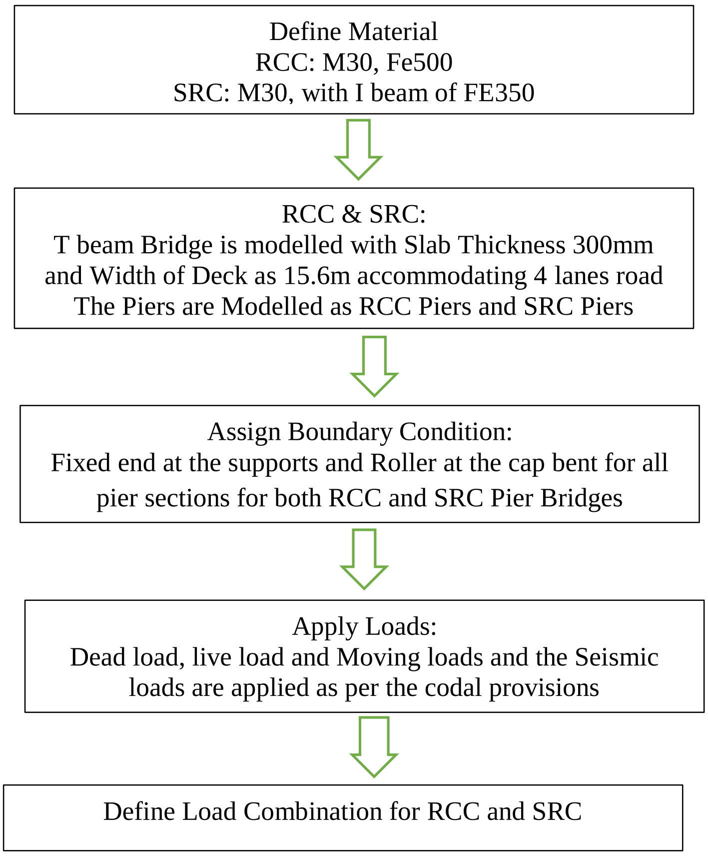
Lihan Xu et al.

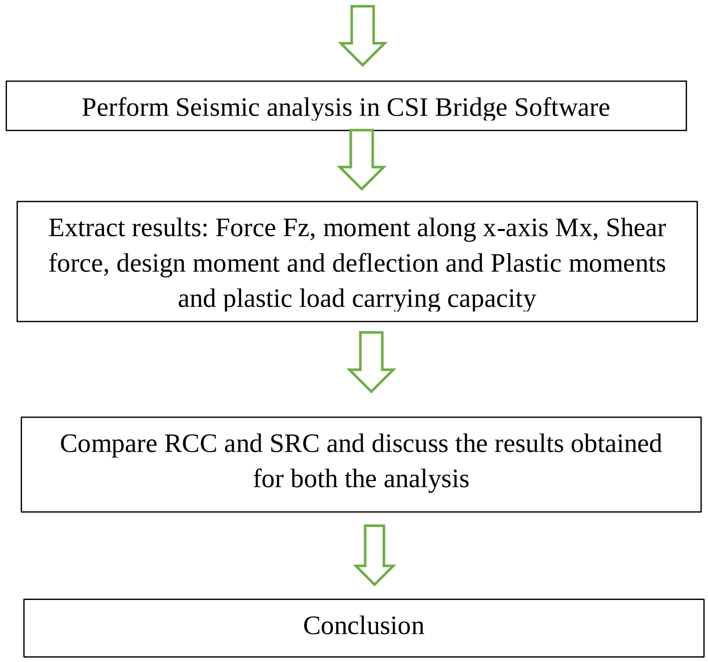
In this study, a static–dynamic sequence analysis method is developed to evaluate how stress accumulation during construction affects the seismic response of large-span CFST arch bridges, with nonlinear material, geometric, and boundary behaviours being incorporated. Stress buildup resulting from steel tube erection, concrete placement across multiple working faces, and time-dependent effects such as shrinkage and creep is modeled using this method. Comparative analyses between models with and without construction-induced stresses reveal significant differences in peak responses, response trends across earthquake intensities, and the locations of critical demand. Additional models isolating key construction factors show that ignoring these effects can lead to inaccurate estimates of elastic–plastic behaviour, demonstrating the necessity of incorporating construction-stage stresses in seismic analysis.

3.Methodology

CSI Bridge is a powerful software application developed by Computers and Structures, Inc. (CSI) for modelling, analysis, and design of bridge structures. It is widely used by civil and structural engineers for the efficient planning, simulation, and design of a wide range of bridge types, from simple highway overpasses to complex cable-stayed and suspension bridges. CSI Bridge is used for the modelling of the bridge components such as decks, piers, abutments, tendons and bearings with parametric control. The software allows to model for either template or user made based on the requirement. It has the option from modelling of geometry till the seismic analysis and can perform code based design checks in a unified environment reducing the errors

The methodology employs CSI Bridge software for detailed seismic analysis of Bridges with RCC and SRC Piers, adhering to IS 456:2000, IRC 6 and IS 1893:2016 standards. The Bridge of 72m length with 5 spans is analysed in the software. For IS 1893: 2016 zone V spectrum, importance factor 1.0, response reduction 5 for beams, soil type II is considered.





- Abutments and piers were modeled with the following parameters:
  - Pier height: 8 m
  - Foundation type: Isolated Foundation is modeled as Foundation springs.

3.1 Bridge Geometry details

RCC Piers

1. Total Span of the Bridge = 72m
2. Span details:

Table-1: Section Details of the RCC Bridge.

Span Name	(Start) Station	(End) Station	Length
Span 1	0	12.75	12.75
Span 2	12.75	28.25	15.50
Span 3	28.25	43.75	15.50
Span 4	43.75	59.25	15.50
Span 5	59.25	72.00	12.75

3. The Abutment section is of size = 3m x 2m
4. The Cap bent section is of size = 2m x 1.5m
5. No. of Column Supporting the Cap bent = 3
6. The Column/Pier is of Circular concrete section of Diameter = 1.2m

Table 2: Details of RCC Pier.

Column	Section	Distance (m)	Height (m)
1	RCC Pier	3.3	8
2	RCC Pier	7.3	8
3	RCC Pier	11.3	8

Frame Sections: The Frame sections are defined as the Abutment, Cap bent and RCC pier as per the requirements.

SRC Piers:

1.Total Span of the Bridge = 72m
2.Span details:

Table 3: Section Details of the SRC Bridge.

Span Name	(Start) Station	(End) Station	Length
Span 1	0	12.75	12.75
Span 2	12.75	28.25	15.50
Span 3	28.25	43.75	15.50
Span 4	43.75	59.25	15.50
Span 5	59.25	72.00	12.75

3.The Abutment section is of size = 3m x 2m
2 The Cap bent section is of size = 2m x 1.5m
3 The Pier is of Circular concrete section of Diameter = 0.8m
The Pier is designed using section designer and the details of the section properties used are shown below:

Figure 1: Cross Section details of SRC section.

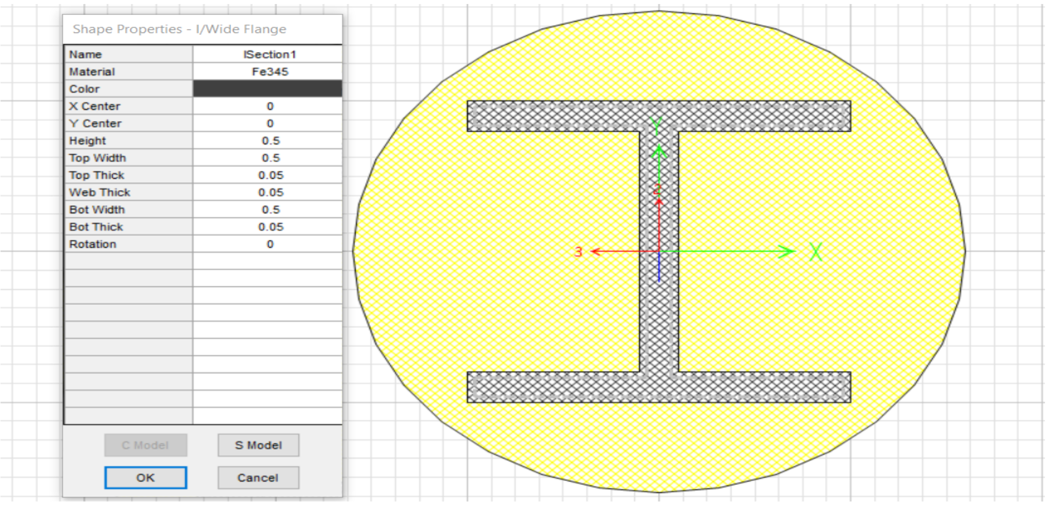


Table 4: Details of SRC Pier.

Column	**Section**	**Distance (m)**	**Height (m)**
1	SRC Pier	3.3	8.
2	SRC Pier	7.3	8.
3	SRC Pier	11.3	8.

4 Number of Pier supporting the Cap bent = 3
5 The Reinforcement in concrete section = I section of FE345
6 The Concrete grade used for the analysis = M30

Frame Sections: The Frame sections are defined as the Abutment, Cap bent and SRC pier as per the requirements.

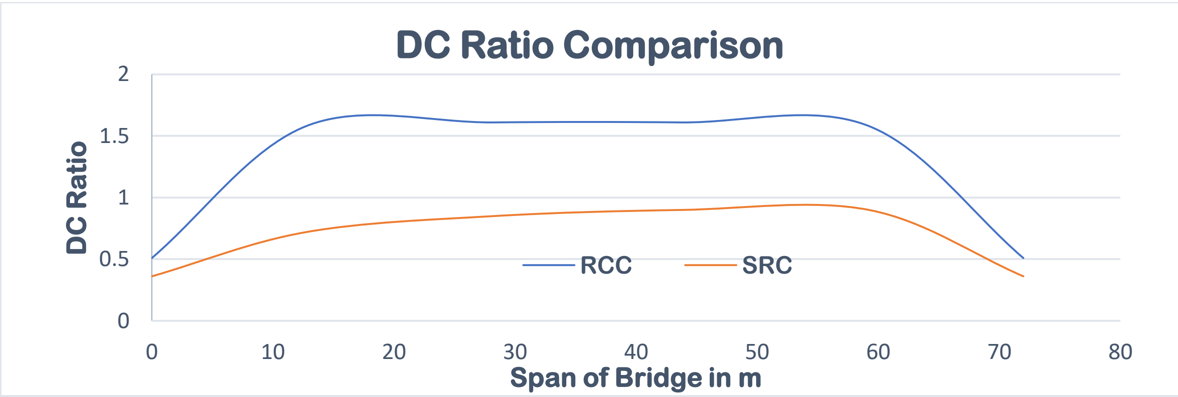
4.Results and Discussion:

4.1. Results of the Demand Capacity Ratio: A comparison of the Demand Capacity ratio for both the bridges are carried out by tabulating the DC ratio of both the bridge as well as graph is also represented.

Table 5: Comparison of DC ratio.

Span	***Station***	***DC Ratio***	
	m	***RCC***	***SRC***
Start Abutments	0	0.51	0.36
Span 2	12.75	1.58	0.72
Span 3	28.25	1.61	0.85
Span 4	43.75	1.61	0.9
Span 5	59.25	1.58	0.9
Span 1	72	0.51	0.36

Figure 2: Comparison of RCC and SRC Bridge for DC Ratio.



Discussions:

The above data represents the comparison of the Demand Capacity Ratio for RCC and SRC across all the spans. The DC Ratio less than 1.0 indicates that section is operating within safe limits, if values exceed 1.0 then structure operates in overstress and may face potential failure.

- For Span 1 and the end stations, both RCC and SRC bridges show low demand–capacity (DC) ratios, indicating minimal demand and greater stability in these regions due to lower loads or better support conditions.
- In the mid-spans (Spans 2 to 5) of the RCC bridge, the DC ratio ranges from 1.58 to 1.61, exceeding the safe threshold of 1.0.
- This suggests that the elements are overstressed and potentially unsafe under the applied loads.
- In contrast, the mid-spans of the SRC bridge (Spans 2 to 5) exhibit DC ratios ranging from 0.72 to 0.90, indicating that the elements remain within safe limits and below the critical threshold. The data clearly demonstrate that the SRC bridge performs better in terms of structural efficiency and safety compared to the RCC bridge.
- This enhanced performance can be attributed to the presence of the steel beam section in the SRC system, which significantly improves ductility, strength, and load distribution, resulting in more uniform DC ratios across the spans.

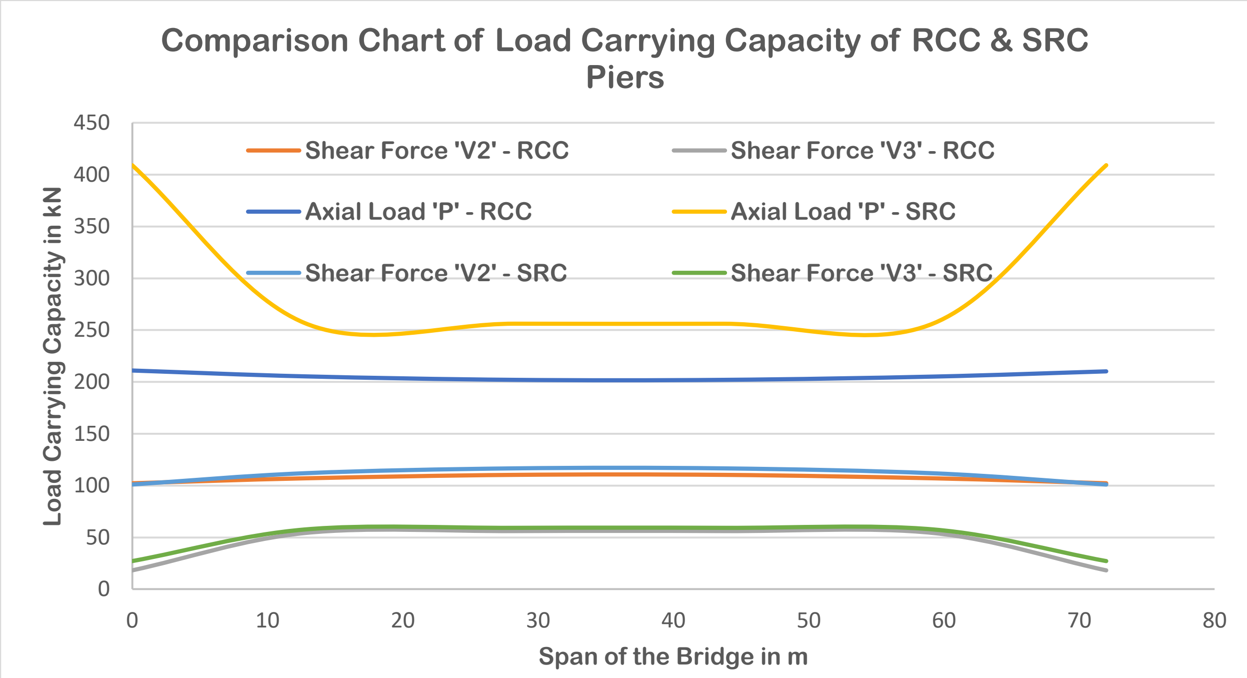
4.2 Comparison of Results of Analysis with respect to Load Carrying capacity:

A comparison of the Load carrying capacity in terms of Axial load compared for both the bridges by tabulating and graphical representation.

Table 6: Comparison of Load for both RCC and SRC Bridge.

Span Name	Station	Axial Load P, kN		Shear Force (V2)		Shear Force (V3)	
	m	RCC	SRC	RCC	SRC	RCC	SRC
Start Abutment	0	210.9	409.09	102.2	101.02	18.1	27.3
Span 2	12.75	205.4	256.91	106.9	111.88	54.3	57.73
Span 3	28.25	202.1	256.25	110.2	116.55	56.2	59.3
Span 4	43.75	202.1	256.21	110.2	116.52	56.2	59.3
Span 5	59.25	205.2	256.67	106.9	111.8	54.3	57.73
Span 1	72	210.1	409.09	102.2	100.97	18.1	27.3

Figure 3: Comparison of Load Carrying Capacity for RCC and SRC Bridge.



Comparison in terms of Axial Load Carrying capacity: The Fig 4.2 shows load carrying capacity of the Reinforced Cement Concrete and Steel Reinforced Concrete across all the spans.

- The RCC bridge carries axial loads ranging from 200 to 211 kN, indicating a uniform distribution of load capacity with a slight reduction at the central spans.
- In contrast, the SRC bridge carries higher loads at the ends or abutments, showing greater load concentration at the boundaries, while maintaining a relatively uniform load distribution across the mid-spans.
- The composite action between steel and concrete in the SRC bridge enhances its stiffness, thereby improving its overall load-carrying capacity compared to the RCC bridge section. Although the RCC bridge demonstrates smooth load transitions that help minimize stress concentration, it would require larger cross-sections to achieve performance levels comparable to those of the SRC bridge.

Comparison in terms of Shear force carrying capacity: The above table and data show the comparison of the Shear force comparison of the Reinforced Cement Concrete and Steel Reinforced Concrete across all the spans.

- The shear force (V2) for the RCC bridge shows a balanced load distribution across all spans, with values ranging between 102 and 111 kN.
- The maximum shear occurs at Spans 3 and 4; however, the values indicate a well-balanced load distribution resulting from the symmetrical nature of the sections.
- The SRC bridge exhibits higher shear force values compared to the RCC section, while maintaining a similar load distribution pattern.

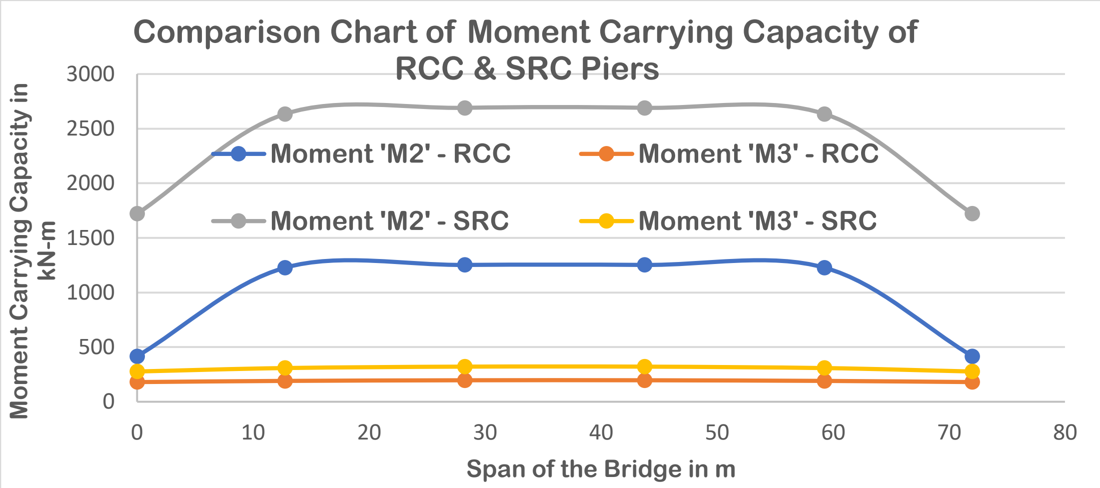
- This increase in shear capacity is attributed to the composite behaviour of the SRC system, where the combined action of steel and concrete enhances the overall shear force-carrying capacity compared to that of the RCC bridge.
- The shear force (V3) for the RCC bridge shows a balanced load distribution across the spans, with values ranging between 18 and 56 kN
- The maximum shear occurs at Spans 3 and 4, but the values indicate that the load distribution remains balanced due to the symmetrical nature of the sections.
- The SRC bridge exhibits higher shear force values compared to the RCC section, while maintaining a similar distribution pattern.
- This increase in shear capacity is a result of the composite behaviour of the SRC system, where the interaction between steel and concrete enhances the overall shear force-carrying capacity relative to that of the RCC bridge.

4.4 Comparison in terms of moment-carrying capacity: A comparative evaluation of the moment carrying capacity (M2 and M3) of the RCC and SRC bridges is presented in a tabulated format for clear and systematic assessment. The results obtained from the analysis are compared to highlight the differences in flexural performance between the two bridge systems. This comparison provides insight into the relative structural efficiency and moment resistance characteristics of RCC and SRC bridges under similar loading conditions.

Table 6: Comparison of Moment Carrying Capacity for both RCC and SRC Bridge.

Span Name	**Station**	**Moment (M2) KN-m**		**Moment (M3) in KN-m**	
	m	**RCC**	**SRC**	**RCC**	**SRC**
Start Abutment	0	415.8	1721.85	179.75	277.53
Span 2	12.75	1227.9	2634.5	190.77	308.95
Span 3	28.25	1252.8	2690.2	196.75	321.86
Span 4	43.75	1252.8	2690.2	196.71	321.78
Span 5	59.25	1227.9	2634.5	190.66	308.71
Span 1	72	415.8	1721.92	179.69	277.4

Figure 4: Comparison of Moment Carrying Capacity for RCC and SRC Bridge.



Comparative Evaluation of Moment Carrying Capacity for RCC and SRC Systems: The above graph shows the comparison of the Moment carrying capacity comparison of the Reinforced Cement Concrete and Steel Reinforced Concrete across all the spans.

- The RCC system carries moments ranging from 415 kN-m at the abutments to 1253 kN-m at the mid-span, indicating uniform loading due to the symmetrical configuration of the sections.
- The maximum moment occurs at Spans 3 and 4, reflecting higher flexural demand at the mid-span region.
- The bending moment-carrying capacity is significantly higher in the SRC system because of the composite action between steel and concrete, which enhances overall strength and ensures a more uniform load distribution due to the structural symmetry.
- The RCC system carries moments ranging from 415 kN-m at the abutments to 1253 kN-m at the mid-span, indicating uniform loading due to the symmetrical configuration of the sections.
- The maximum moment occurs at Spans 3 and 4, signifying higher flexural demand in the mid-span region.
- The bending moment-carrying capacity is considerably higher in the SRC system as a result of the composite action between steel and concrete, which enhances the overall flexural strength and ensures a uniform load distribution due to the symmetry of the structure.

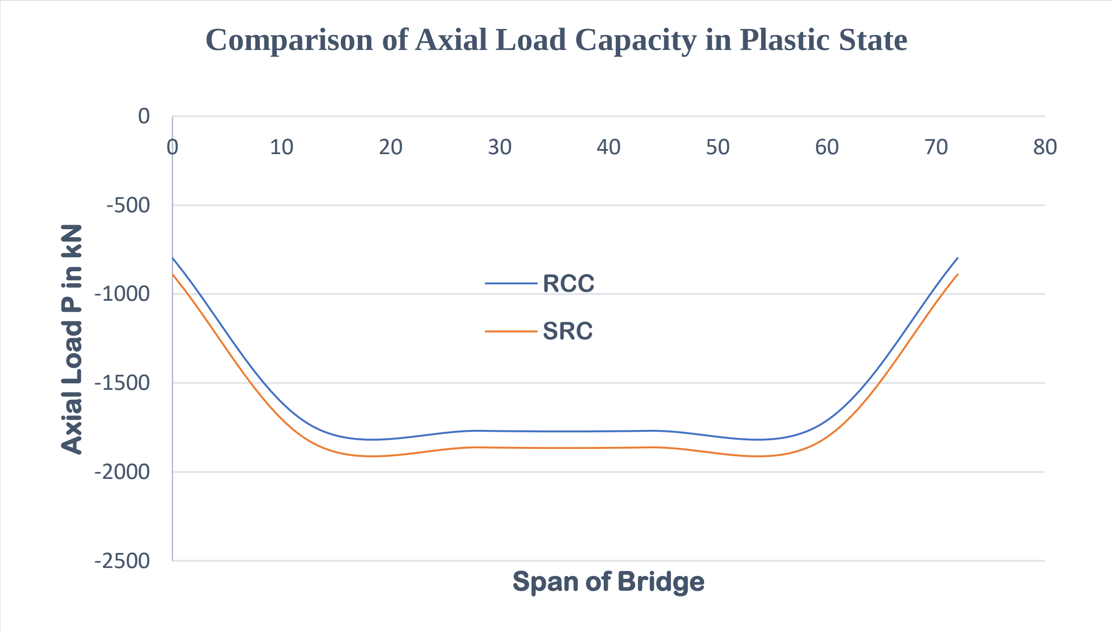
4.5 Comparison of Results of Analysis with respect to Hinge Formation & Plasticity: A comparison of the Plastic Axial Load carrying capacity of the RCC and SRC bridge are tabulated and results are compared.

Table 7: Comparison of Axial Load capacity in Plastic State

Span Name	Station	Axial Load Capacity in kN	
	m	RCC	SRC
Start Abutment	0	-797.9	-889.67
Span 2	12.75	-1740.33	-1832.81

Span 3	28.25	-1769.14	-1861.49
Span 4	43.75	-1769.14	-1861.49
Span 5	59.25	-1740.32	-1832.81
Span 1	72	-797.53	-889.32

Figure 5: Comparison of Axial Load Capacity in Plastic State for RCC & SRC Bridge.



Comparative Evaluation of Axial Load Carrying capacity in Plastic state for RCC and SRC Systems: The above table and data show the comparison of the Axial load carrying capacity comparison of the Reinforced Cement Concrete and Steel Reinforced Concrete in Plastic state across all the spans.

- The SRC bridge exhibits a higher load-carrying capacity than the RCC sections across all spans. In both bridge types, the start and end abutments experience lower axial loads compared to the mid-span regions.
- The mid-spans, particularly Spans 3 and 4, show higher axial loads for both RCC and SRC pier sections, indicating greater load concentration and structural demand in the central portions of the bridge.

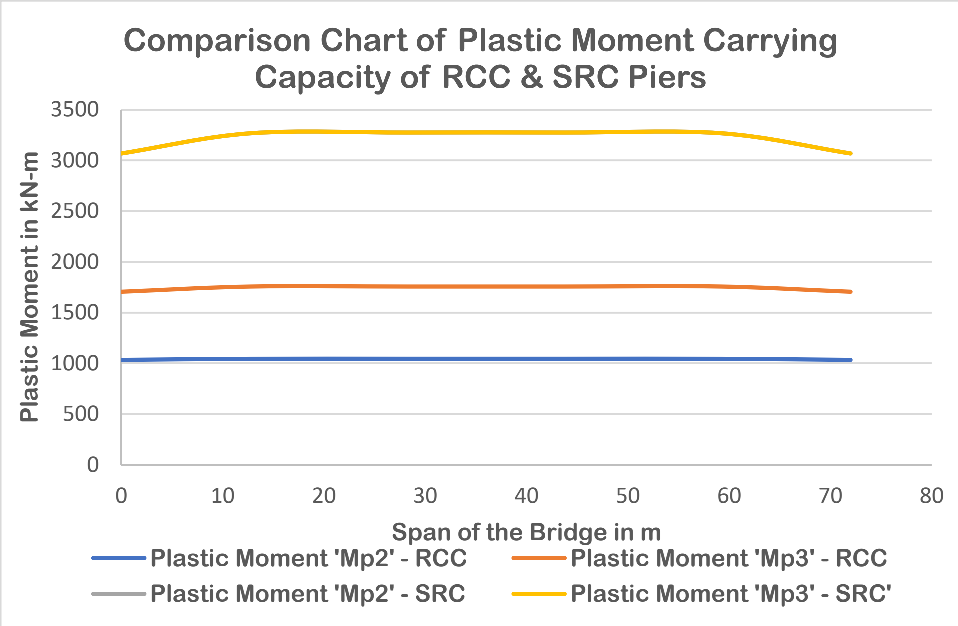
4.6: Comparison in terms of Moment Carrying Capacity in Plastic State: A comparison of the Moment carrying capacity (M2 & M3) of the RCC and SRC bridge are tabulated and results are compared.

Table 8: Comparison of Plastic Moment Carrying Capacity for both RCC and SRC Bridge.

Span Name	**Station**	**Moment (M2) kN-m**		**Moment (M3) in kN-m**	
	m	**RCC**	**SRC**	**RCC**	**SRC**
Start Abutment	0	1035.71	3097.50	1709.63	3097.50
Span 2	12.75	1046.61	3297.31	1756.57	3297.31
Span 3	28.25	1047.15	3304.62	1756.52	3304.62
Span 4	43.75	1047.15	3304.62	1756.52	3304.62

Span 5	59.25	1046.61	3297.31	1756.57	3297.31
Span 1	72	1035.7	3097.41	1709.6	3097.41

Figure 5: Comparison of Moment Carrying Capacity in Plastic State for RCC & SRC Bridge.



Comparative Evaluation of Moment Carrying Capacity in Plastic state for RCC and SRC Systems: The above table and data show the comparison of the Moment carrying capacity comparison of the Reinforced Cement Concrete and Steel Reinforced Concrete in Plastic state across all the spans.

- The SRC bridge demonstrates significantly higher moment-carrying capacity compared to the RCC bridge due to its composite action, which enhances overall stiffness and structural performance.
- The mid-spans (Spans 3 and 4) experience higher moments compared to the start and end spans, with the SRC exhibiting superior load-carrying capacity and improved flexural strength throughout the structure.
- The SRC bridge shows a significantly higher moment-carrying capacity compared to the RCC bridge due to its composite action, which enhances stiffness and overall strength.
- The mid-spans (Spans 3 and 4) experience higher moments than the start and end spans, with the SRC bridge exhibiting superior load-carrying capacity and better structural efficiency.

Conclusions:

The comparative evaluation of the parameters shows that the SRC piers are better suited for the flexural demands. These are preferred for the high axial load and moment is required. The RCC piers maybe adequate for the less critical spans. Although the SRC pier exhibit higher strength, load carrying capacity and other parameters due to composite action. The RCC design has the prescribed code for the design, however the SRC design doesn't have any prescribed code and standard approach. The design of SRC need to be executed with trial-and-error method. Hence, these composite structures are not considered or preferred by the engineers.

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