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Design and Analysis of a Double-Stage Flyover Utilizing Various Girder Configurations with SAP2000

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Abstract

The primary objective of this project is to design and analyze a six-lane flyover using SAP2000. The flyover spans 400 meters in length and has a width of 15 meters. The diameter of the piers is approximately 2.5 meters, and the beams are designed with an I-section. The columns have a height of 4.2 meters. The flyover features a road width of 15 meters, including a 0.5-meter median. In the post-processing phase, after completing the design, the structure was examined and the bending moment and shear force values were analyzed. Additionally, the overall stability and performance under various load conditions were evaluated, ensuring compliance with relevant design codes and standards. The study also includes an assessment of material efficiency, construction feasibility, and cost-effectiveness. Furthermore, different girder configurations were explored to optimize the structural integrity and durability of the flyover. The project also involved a detailed seismic analysis to ensure the flyover's resilience to earthquakes, as well as a wind load analysis to evaluate the impact of aerodynamic forces. The drainage and water runoff management systems were designed to prevent water accumulation and enhance the longevity of the structure. Environmental impact assessments were conducted to minimize the ecological footprint during construction and operation. Advanced construction techniques were proposed to reduce the time and labor costs while maintaining high safety standards. The results from SAP2000 simulations were validated through comparative analysis with theoretical calculations and real-world case studies, demonstrating the reliability and robustness of the proposed design. This project provides a comprehensive framework for the development of modern flyover structures, contributing to improved traffic flow and urban infrastructure, while also addressing sustainability and resilience in civil engineering design.

Keywords: Flyover, design parameters, bending moment, shear force, girder, SAP2000

INTRODUCTION

The objective of this project is to evaluate the effectiveness of constructing a flyover in reducing traffic congestion, improving efficiency, and saving fuel. This analysis determined that approximately 35% of total traffic is diverted to the flyover, resulting in a 32% reduction in overall travel time and emissions. Utilizing the flyover emerged as the most efficient strategy for achieving these goals. The analysis considered the significant impact of fuel wastage during ignition and the costs incurred due to waiting at traffic signals [1–5].

Additionally, the flyover provides a crucial advantage during rainy conditions. While conventional roads often become flooded, the elevated structure of the flyover ensures unobstructed travel, highlighting the necessity for such infrastructure to mitigate weather-related disruptions [6–9].

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The construction of new roads and bridges is essential for the economic development of a country. Our study estimated the financial losses and fuel wastage associated with traffic delays, underscoring the importance of efficient infrastructure.

For the structural analysis of the flyover, various methods, including grillage and finite element analysis, were employed. Grillage analysis is widely used for bridge design, especially for medium to long spans, due to its reliability and effectiveness. Prestressed concrete emerged as the most suitable material for these spans, offering durability and lower maintenance costs compared to steel, which is prone to corrosion in extreme conditions. Since Freyssinet's introduction of prestressed concrete, it has become a preferred material for long-span bridges [10–15].

In concrete bridge construction, a common superstructure consists of precast girders combined with cast-in-place slabs, suitable for spans ranging from 20 to 40 meters. The T-girder and I-girder bridges are prevalent in this category due to their simple geometry, ease of erection, reduced dead loads, and cost-effectiveness.

This project emphasizes the necessity of innovative and feasible solutions in the design and construction of flyovers and bridges, contributing to improved traffic management, economic growth, and infrastructure resilience.

Types of Flyovers
1. Railway crossing
2. Road crossing

Parts of Flyover
1. Super structure
2. Sub structure Super structure

The superstructure consists of the components that span the obstacle the bridge is intended to cross and includes the following:
- Bridge deck
- Structural members
- Parapets (bridge railings), handrails, sidewalk, lighting and some drainage features.

LOADS ON FLYOVER

Types of Loads Considered
1. *Dead Load:* This includes the weight of the structural components themselves, such as the beams, columns, and deck.
2. *Live Load:* This refers to the transient loads that the flyover will support, including vehicles, pedestrians, and other moving loads.
3. *Dynamic Load:* These are loads that result from the motion of the structure and the forces applied by moving vehicles, including impacts and vibrations.
4. *Other Loads (IRC Class 70R Loading):* This loading is typically used for all roads with permanent bridges and culverts. Bridges designed for Class 70R Loading should also be evaluated under Class A Loading, as certain conditions might lead to heavier stresses under Class A.

Environmental and Structural Considerations
It is crucial to eliminate flyovers that become redundant over time and pose environmental threats. Initially productive, these structures can lose structural stability, leading to safety concerns. The design process must consider different topologies, such as loop and square configurations, to determine the most suitable one for the specific location [16–19].

Planning and Smart Systems

Proper planning is essential, and only after thorough testing should the structures be put into service. Issues often arise with oversized trucks, requiring smart systems that alert when such vehicles approach the flyover. These systems temporarily halt oversized vehicles to allow other traffic to clear the flyover, preventing collisions. While this approach is costly, it can be replaced by computer-aided mechanisms, though these systems can still cause delays [20–22].

Structural Integrity and Foundation

An ideal flyover must be robust enough to handle large volumes of heavy vehicles. Vibro pile construction, involving 318 piles, was analyzed and found suitable for low-volume overpasses. The Continuous Flight Auger (CFA) piling system is recommended for areas with high water tables, requiring extensive studies and experiments to ensure structural integrity through appropriate auger rotation. However, this method may not be economically viable for low-budget projects.

Testing and Reinforcement

Flyover pier testing, including core and pull-out/off tests, is conducted to assess basic functionalities such as thickness, elastic modulus, structural integrity, and surface absorption. Case studies, like that of a T-beam girder made of concrete, reveal that the strength of piers can be enhanced by adding reinforcement. Incorporating reinforced concrete helps prevent structural disintegration due to beam-column interaction.

In summary, comprehensive planning, advanced smart systems, and rigorous testing are essential for the successful construction and maintenance of flyovers. Utilizing appropriate construction techniques and materials ensures the long-term durability and functionality of these critical infrastructures.

Aim

The aim of this project is: “Design of a Double-Stage Flyover with Different Types of Girder Designs Using SAP2000.”

Problem Statement

The city bypass road faces significant traffic congestion due to insufficient road space at junctions during various times of the day. This congestion impedes the free flow of traffic and increases the likelihood of accidents.

Objectives

- Design and analyze a prestressed flyover using SAP2000 software.
- Apply time history analysis for the bridge.
- Design a double-deck flyover with different types of girders.
- Minimize traffic delays caused by heavy traffic and propose a flyover with aesthetically pleasing and architecturally sound design.
- Analysis and Design of Single-Pier Double-Deck Flyover Using SAP2000
- For two-lane rigid or flexible pavement roads of national highways, the structures are designed for four lanes as per IRC SP 84.
- Flyovers are designed on two separate piers for three lanes each.
- We will design a flyover on a single pier with a four-lane deck slab width of 20 meters.
- The location chosen is in a congested city area.
- The total length of the structure will be 450 meters with a span of 35 meters, consisting of 1 obligatory span, 9 piers with diameters ranging from 4 to 15 meters, and 2 abutments.
- The foundation types will include open and pile foundations.
- The superstructure will be of segmental type, consisting of precast wing and spine beams with a wearing coat.

- The flyover will also include curved sections.
- Project Comparison
- The design effects of single-pier and two-pier flyovers will be compared, considering cost estimation and project completion time.
- The cost comparison will consider the limitations of right-of-way (ROW) and land acquisition. Land acquisition is a major factor affecting the cost and timeline of highway projects.
- We will also evaluate the land saved due to constructing the structure on a single pier.
- The project design will be completed using SAP2000 and will adhere to various guidelines from MORT&H, IRC specifications, and government procedures for land acquisition.
- Input Parameters
- Flyover Design Specifications:
- Length: 400 meters
- Width: 1.5 meters
- Loading: Class 70R, IRC Class A Track, IRC Class A Wheel
- Pier Diameter: 2.5 meters
- Number of Piers: 19
- Longitudinal Beam Dimensions: 1.5 m x 1.5 m (X-axis), 1.2 m x 1.2 m (Z-axis)
- Deck Slab Thickness: 350 mm
- Loading Conditions: Dead load, bridge live load, live load, earthquake load (X and Y directions), wind load (as per Part-III -- 1987), and seismic code (IS 1893 Part 1-2002)
- Design and Modelling – Part I
- Design a 3D model of a double-decker flyover using I-girders with SAP2000. This model will incorporate various girder designs and evaluate their performance under specified loading conditions. The design process will ensure compliance with all relevant standards and guidelines to achieve optimal structural integrity and functionality (Figures 1--39).

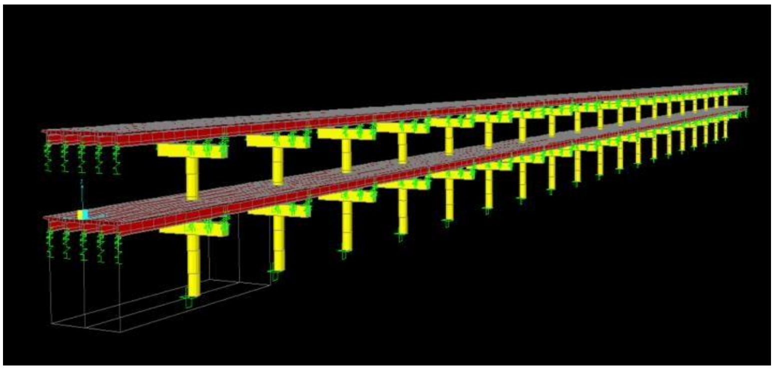

Figure 1. 3D view of model.

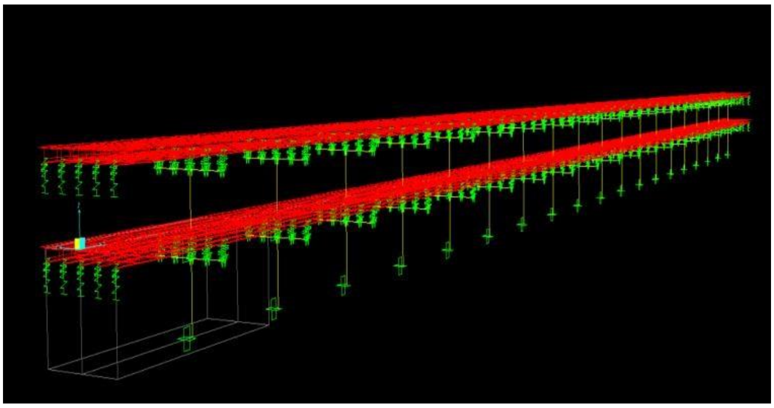

Figure 2. 3D view bridge model 2.

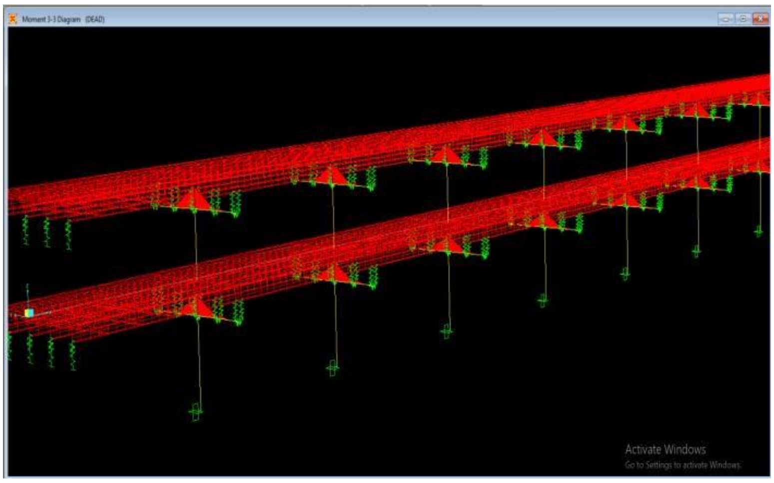

Figure 3. Bending moment diagram 3D view.

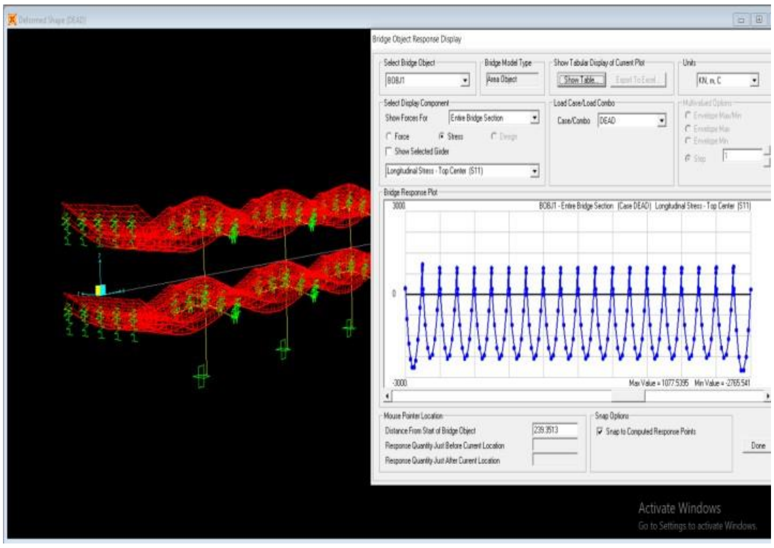

Figure 4. Bridge response due to loading (longitudinal stress diagram, max and min).

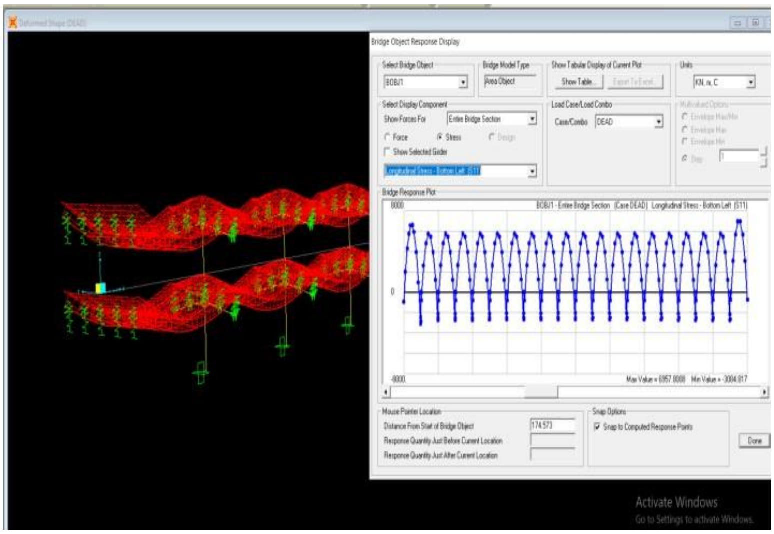

Figure 5. Bridge response due to loading (longitudinal stress at bottom left side, max and min).

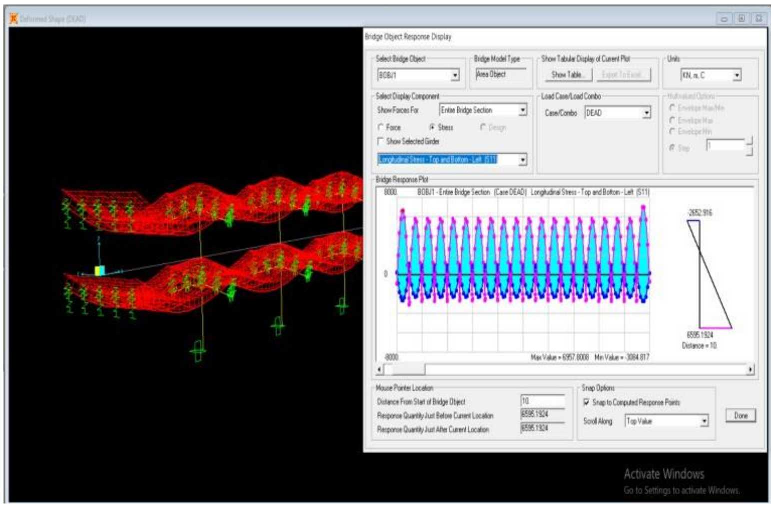

Figure 6. Bridge response due to loading (longitudinal stress at top and bottom left side, max and min).

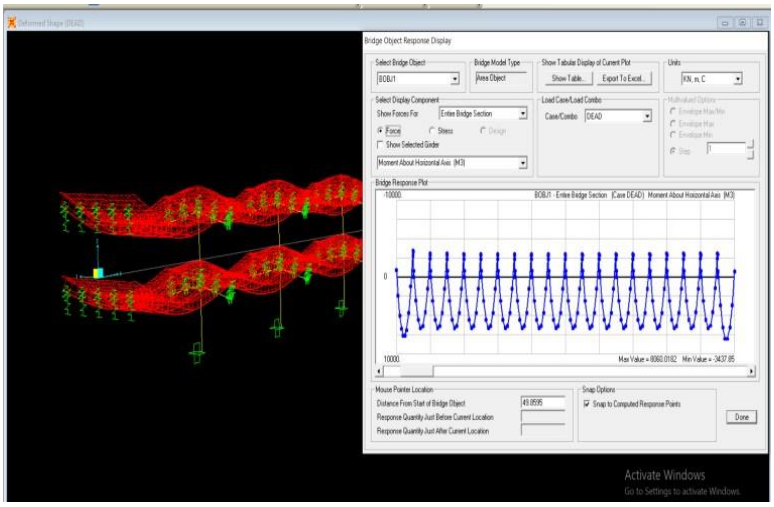

Figure 7. Bridge response due to loading (moment about horizontal axis diagram, max and min).

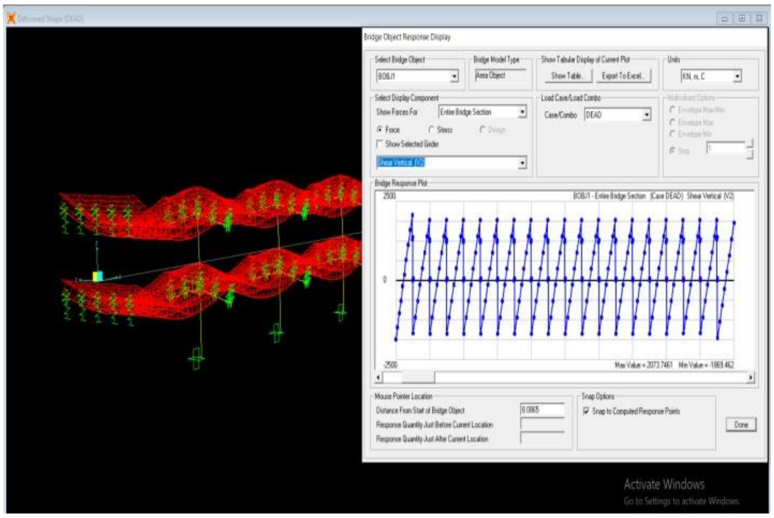

Figure 8. Bridge response due to loading (Shear vertical diagram, max and min).

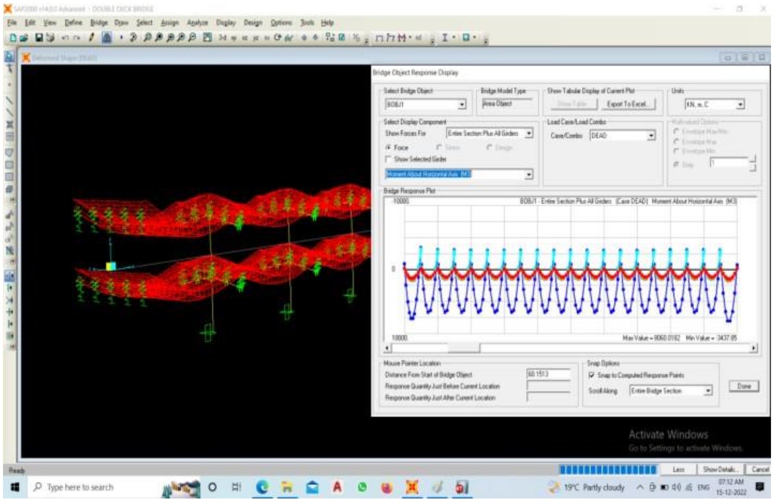

Figure 9. Bridge response due to loading entire section plus all girder (moment about horizontal axis, max and min).

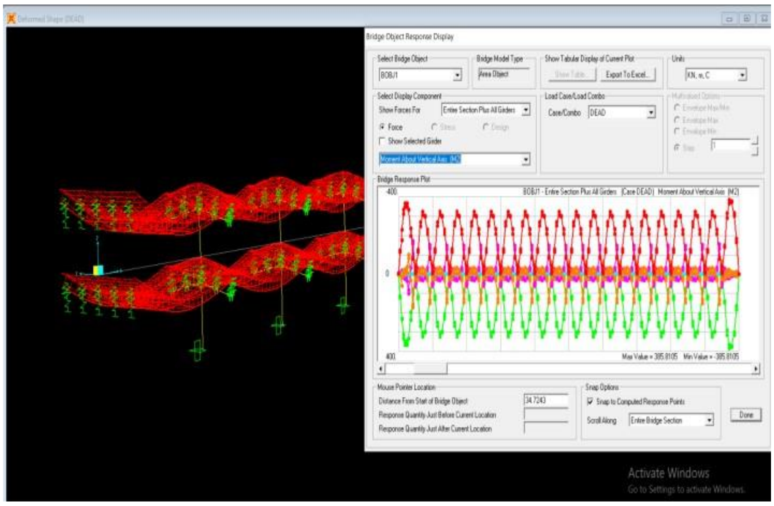

Figure 10. Bridge response due to loading entire section plus all girders (moment of shear vertical, max and min).

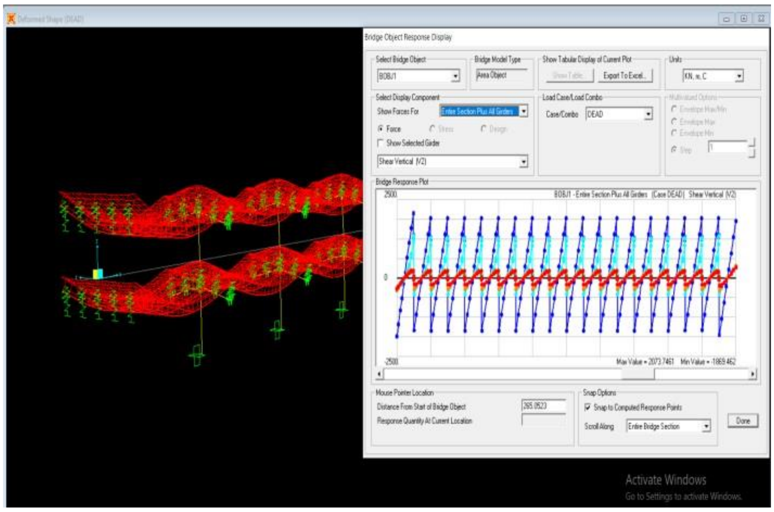

Figure 11. Bridge response due to loading entire section plus all girder (shear vertical, max and min).

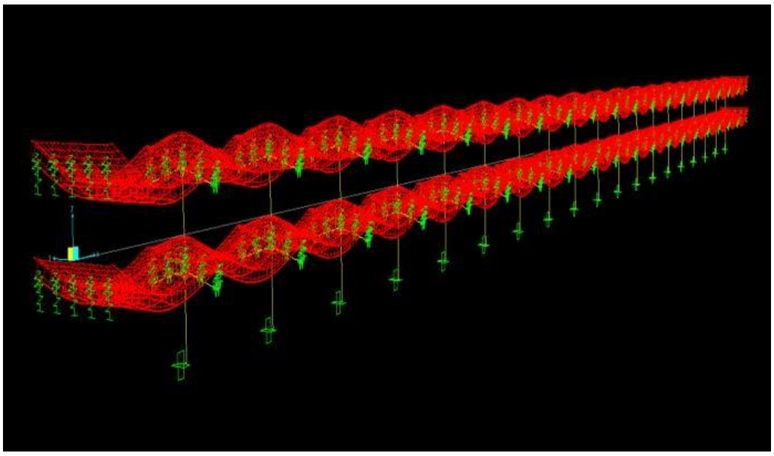

Figure 12. Displacement due to all loading.

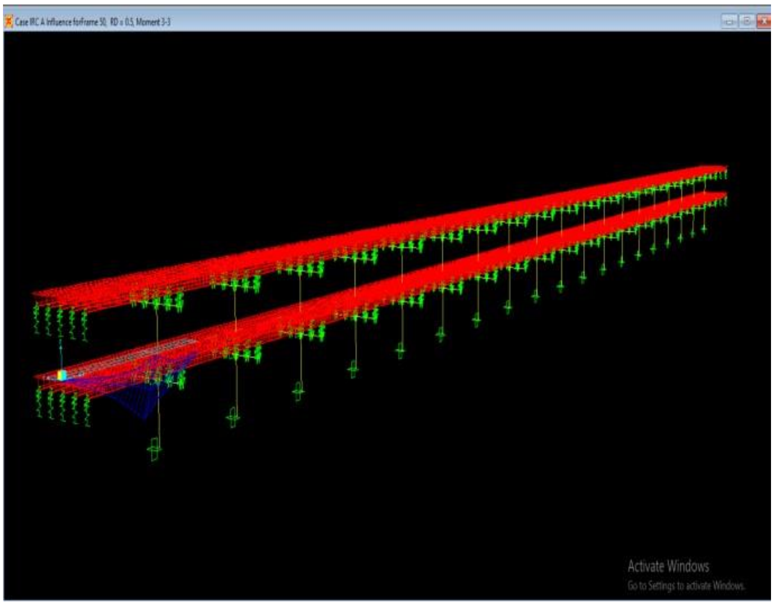

Figure 13. Influence line diagram on frame due to moment.

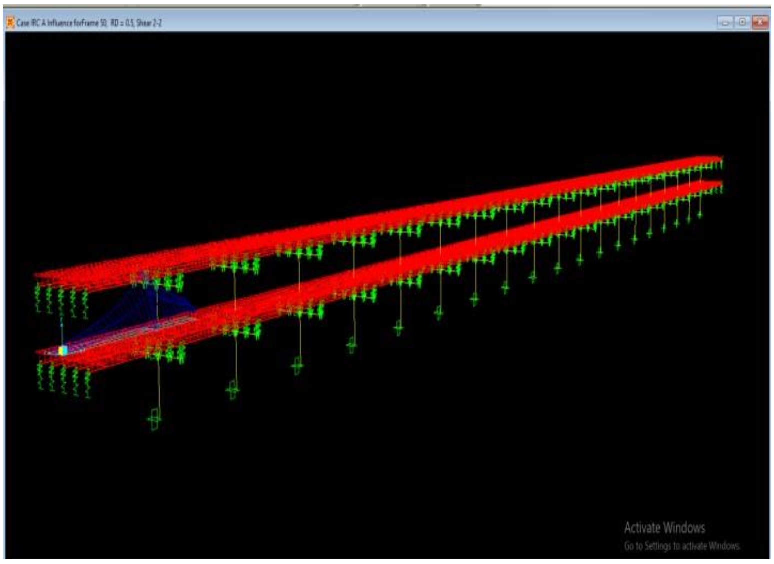

Figure 14. Influence line diagram on frame.

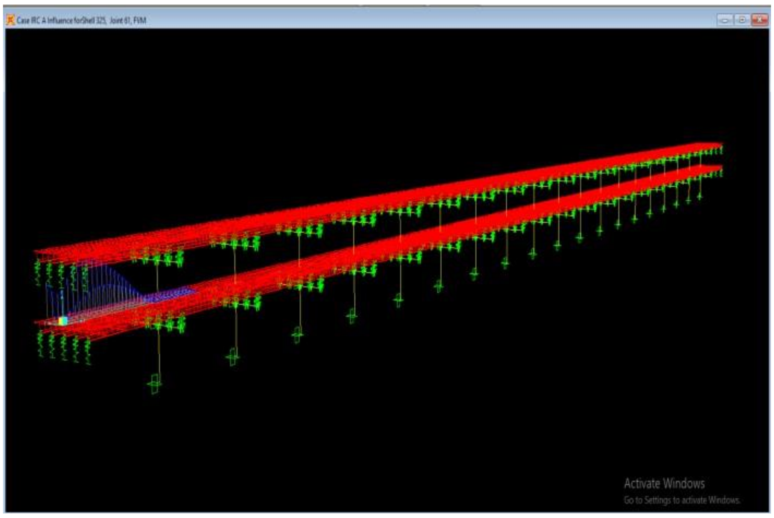

Figure 15. Influence line diagram on shell due to IRCA loading.

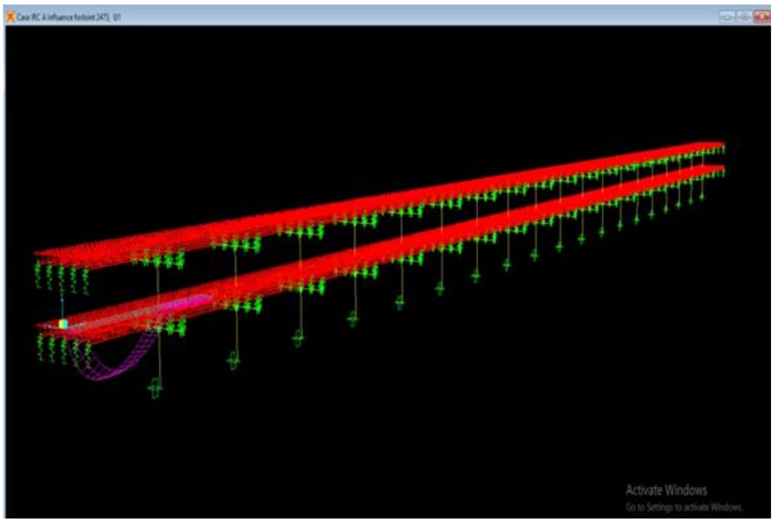

Figure 16. Influence line diagram.

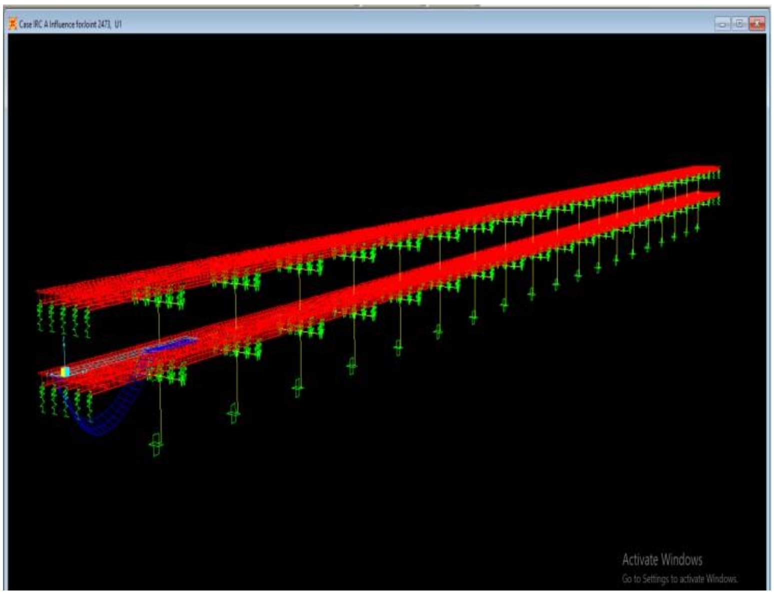

Figure 17. Influence line diagram2.

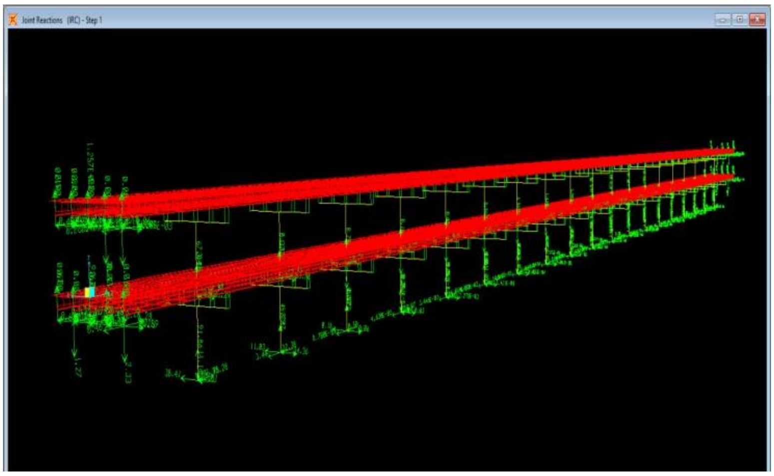

Figure 18. Joint reaction due to IRC loading.

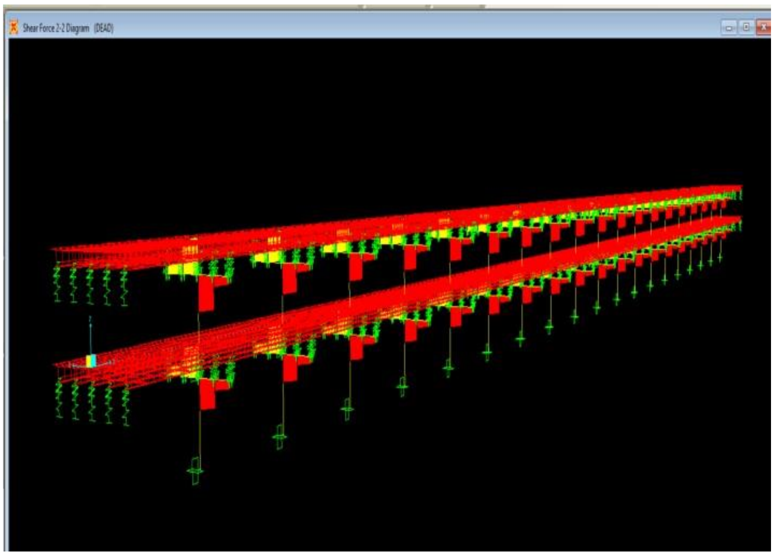

Figure 19. Shear force diagram 3D view.

Design and Modelling – Part-II

Design work on U-Girder design.

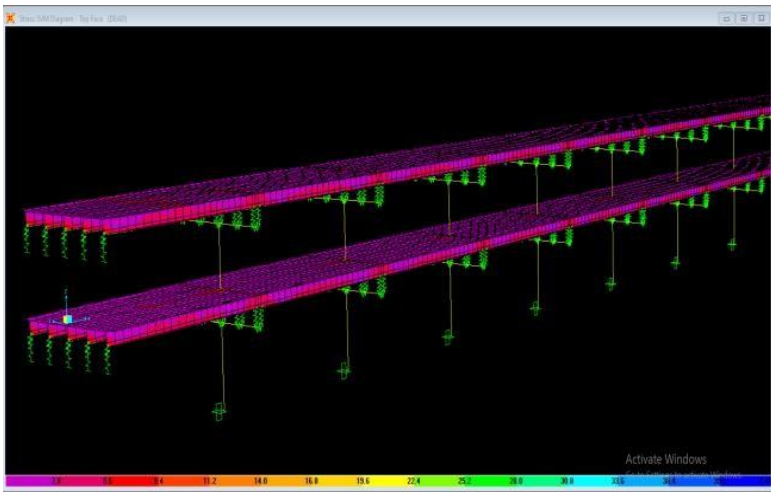

Figure 20. Shear stress on plane (max and min value shown) diagram 3D view.

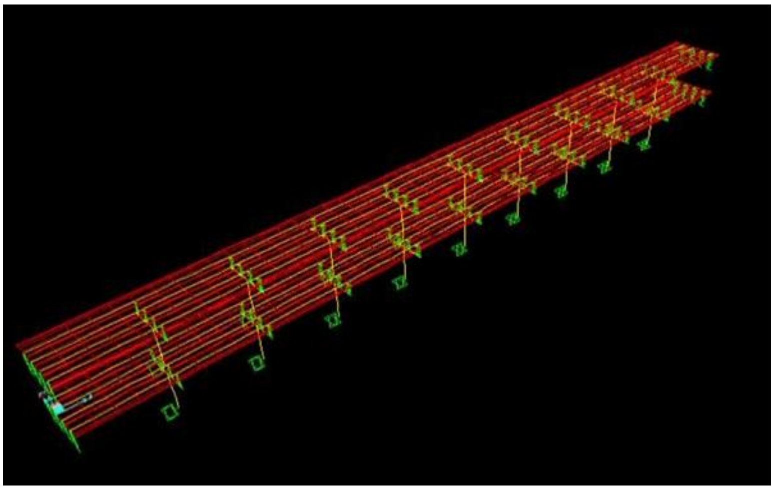

Figure 21. 3D model work of U-girder bridge work.

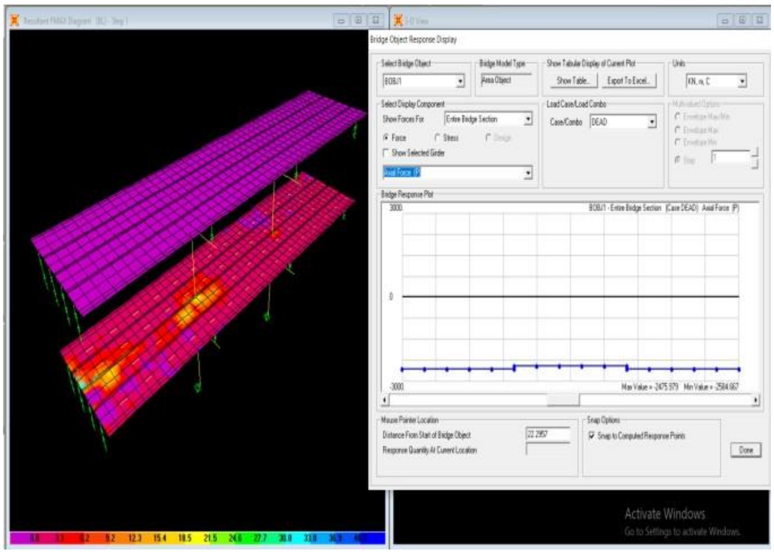

Figure 22. Axis force due to reaction.

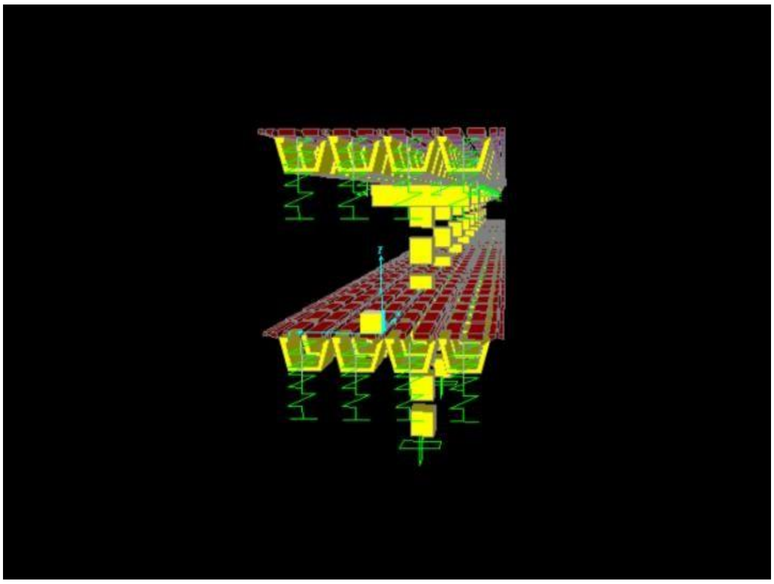

Figure 23. U-girder design.

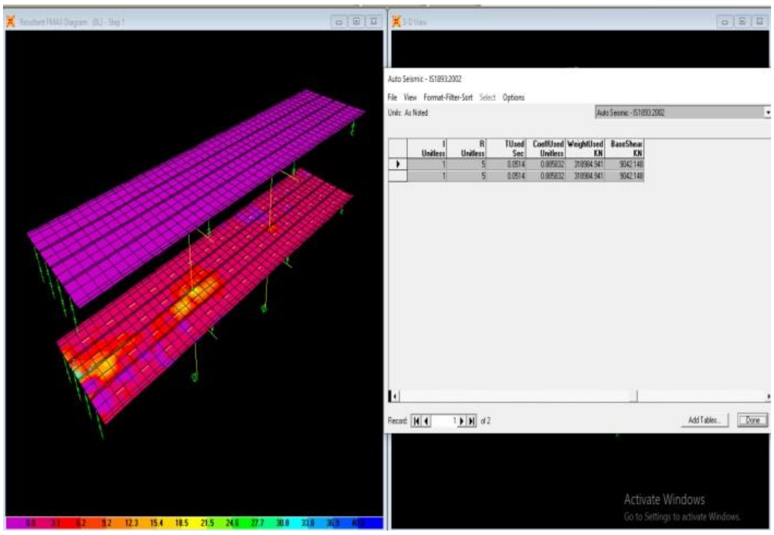

Figure 24. Base shear 9042 KN.

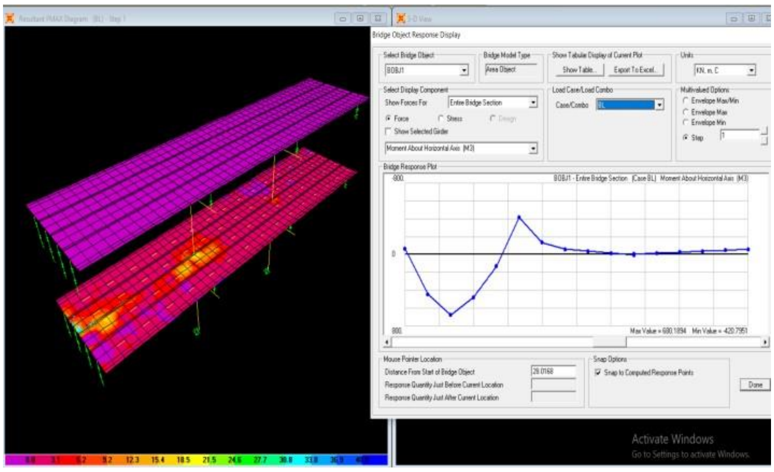

Figure 25. Bending moment direction.

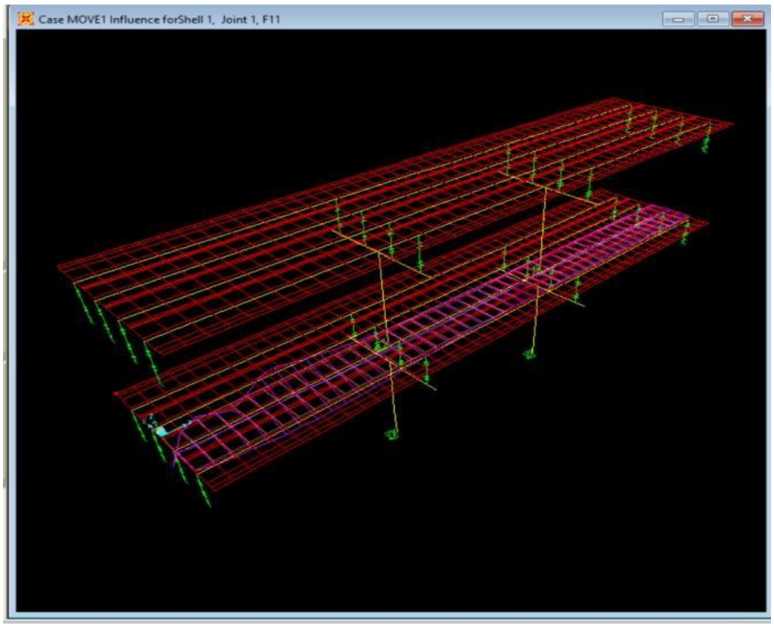

Figure 26. Influence line diagram 2.

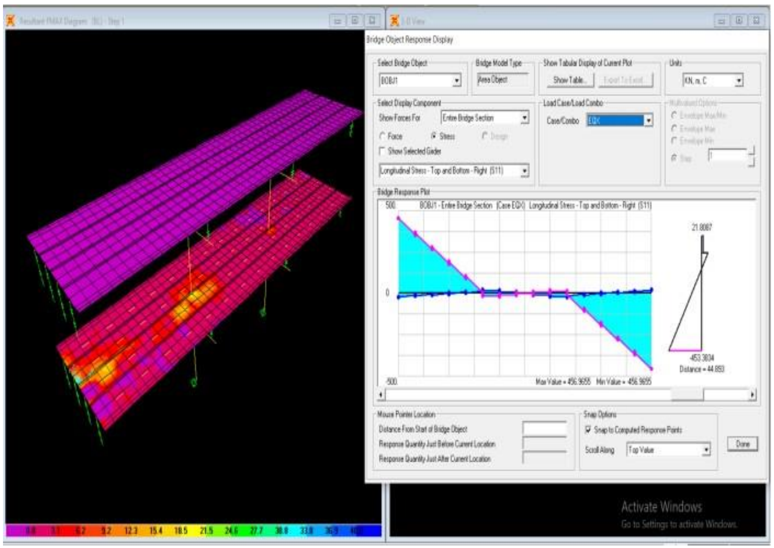

Figure 27. EQX and top and bottom.

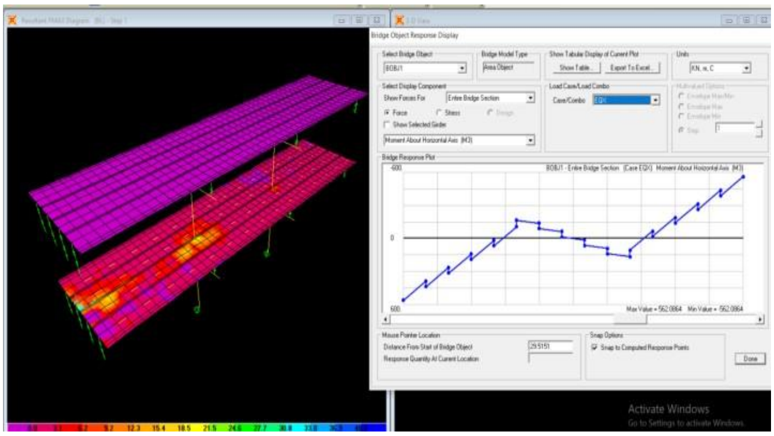

Figure 28. EQX reaction.

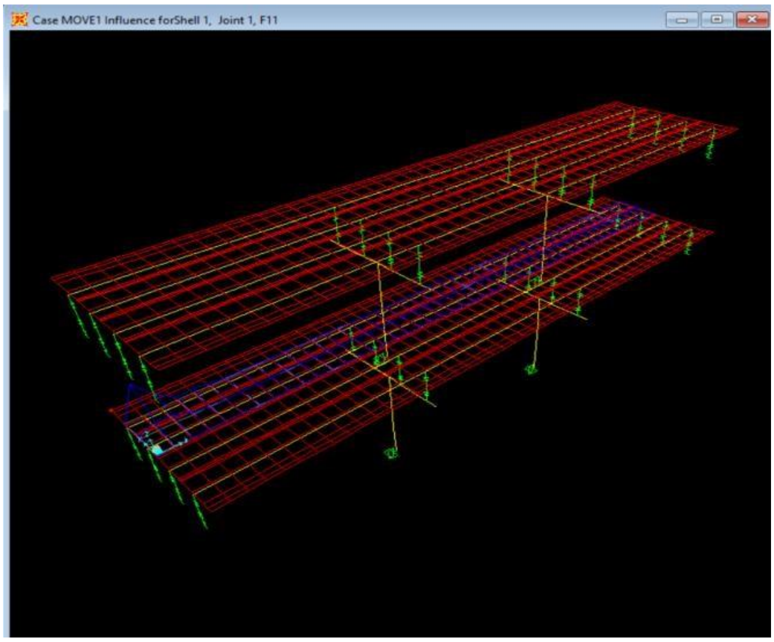

Figure 29. Influence line diagram.

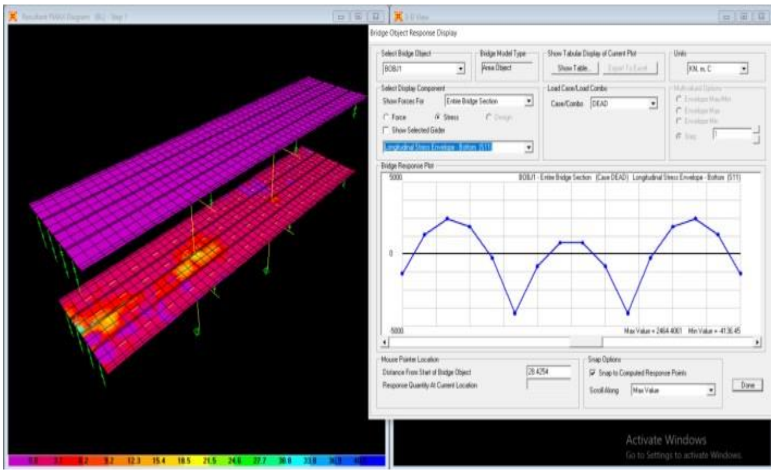

Figure 30. Longitudinal stress at bottom.

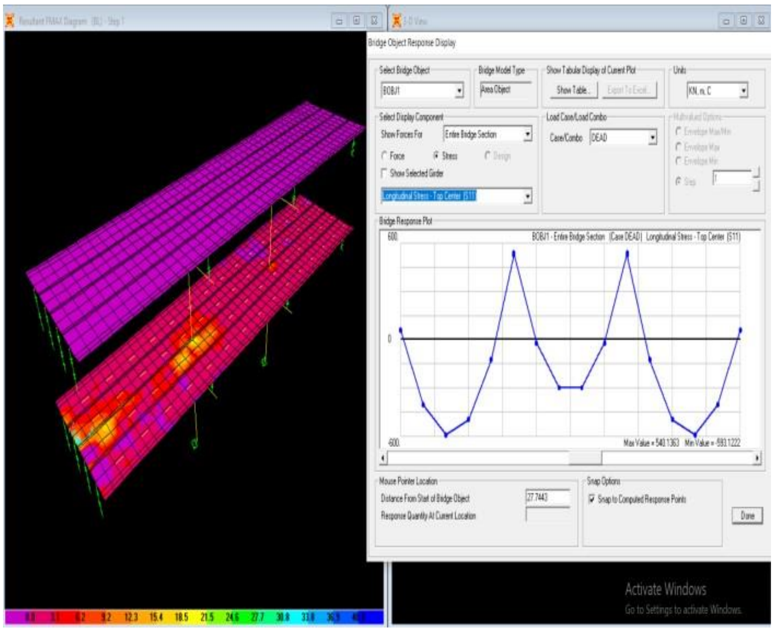

Figure 31. Longitudinal stress at plate.

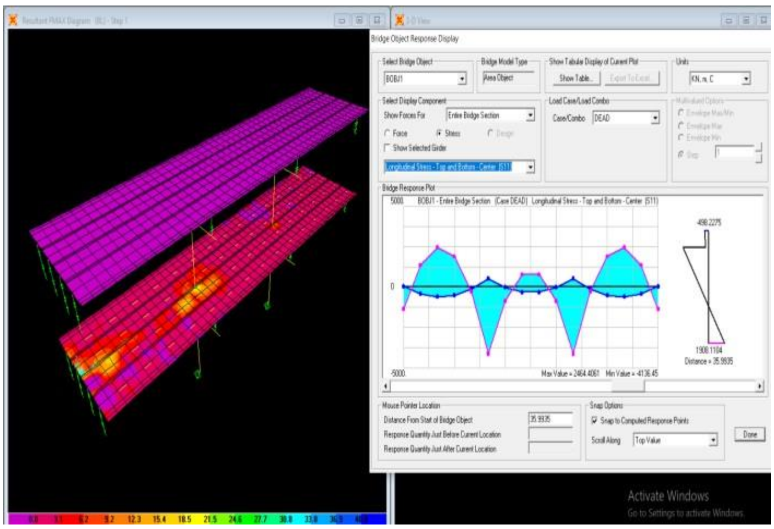

Figure 32. Longitudinal stress at top and bottom.

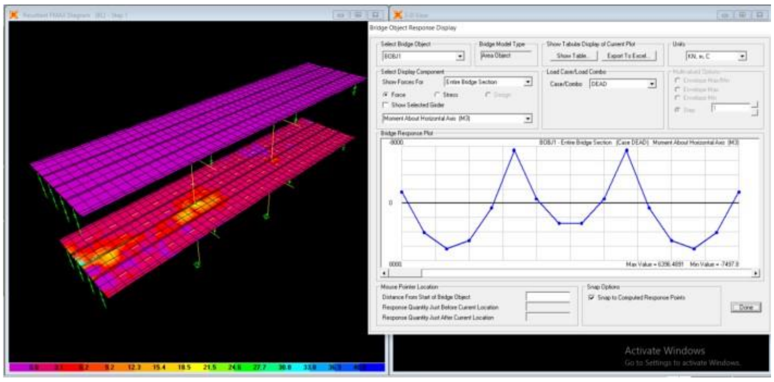

Figure 33. Moment about horizontal axis.

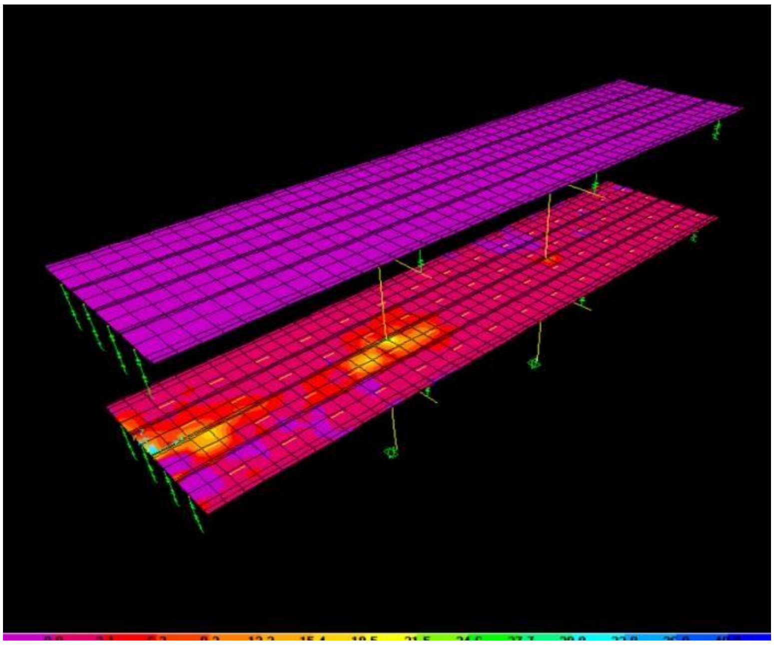

Figure 34. Plate force due to loading.

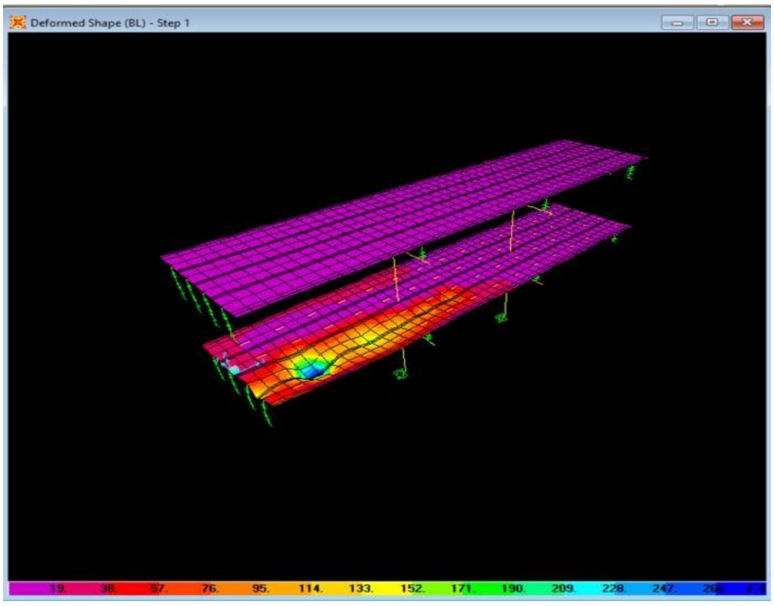

Figure 35. Plate stresses due to vehicle load.

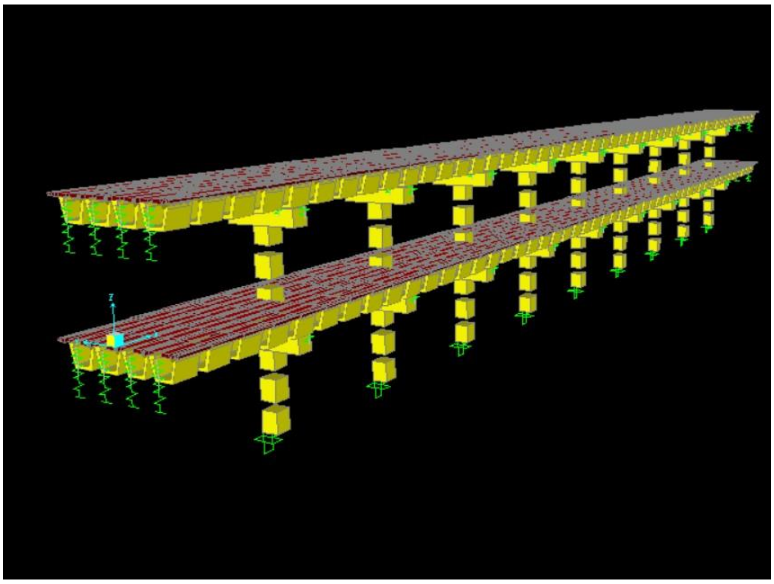

Figure 36. Render view.

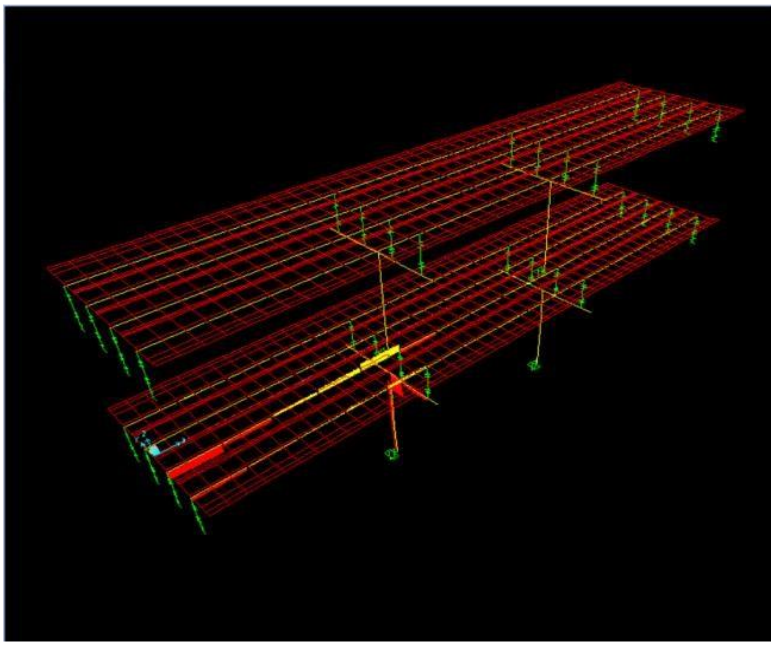

Figure 37. Shear force.

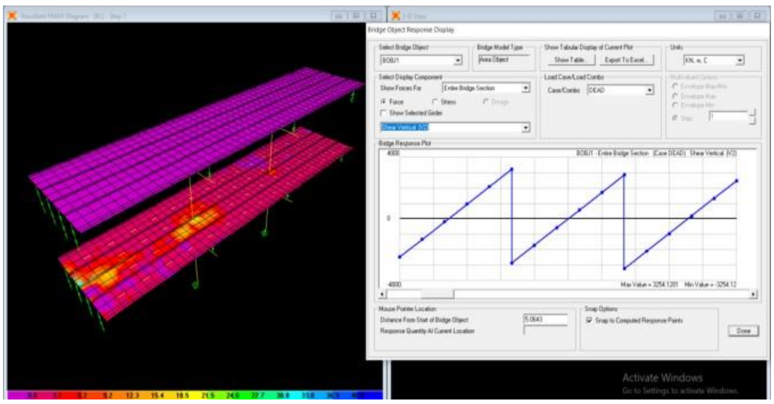

Figure 38. Shear vertical (v2).

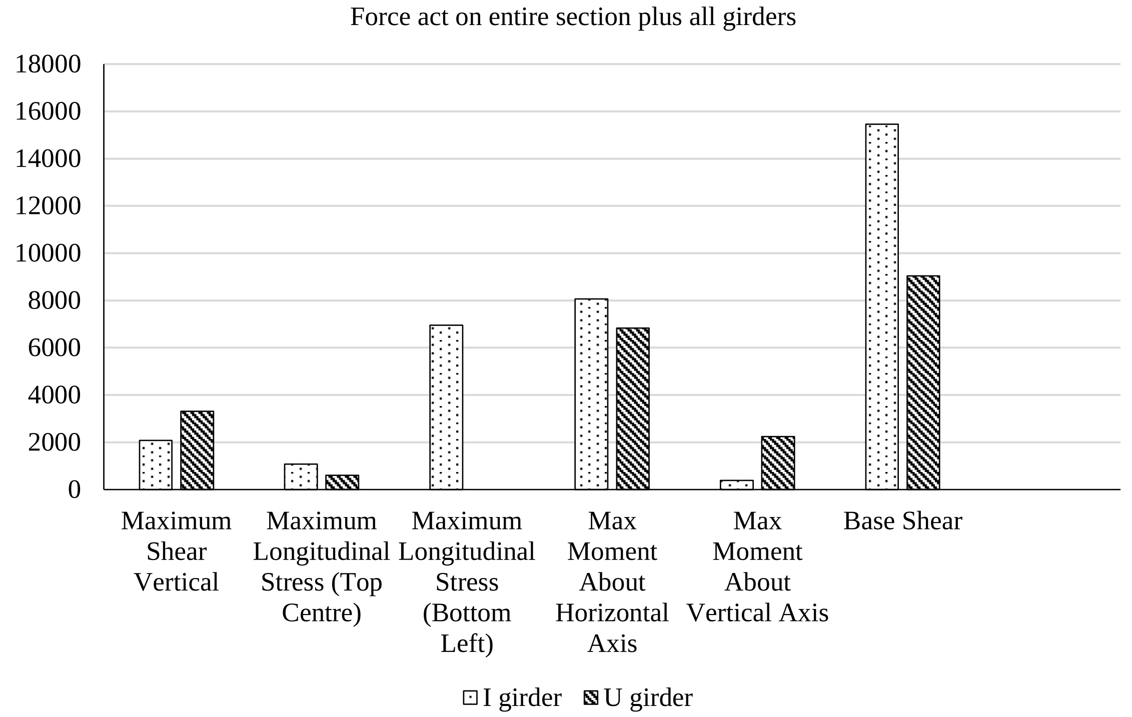

Figure 39. Forces between I-Girder and U-Girder.

RESULTS AND DISCUSSION

Comparative study of results of I & U-Girder Double-Deck Flyover (Tables 1–3).

Table 1. I-Girder of Double Decker Auto-Seismic IS-1893:2002.

Table: Auto Seismic -- IS1893:2002							
Load Pat	**Dir**	**Z-Code**	**Soil Type**	**I**	**R**	**T-Used**	**Base Shear**
Text	Text	Text	Text	Unit Less	Unit Less	Sec	KN
EX	X	0.36	II	1	5	0.5948	15455.706
EY	X	0.36	II	1	5	0.5948	15455.706

Table 2. U-Girder of Double Decker Auto-Seismic IS-1893:2002.

Table: Auto Seismic - IS1893:2002								
Load Pat	**Dir**	**Ct**	**Z-Code**	**Soil Type**	**I**	**R**	**T-Used**	**Base Shear**
Text	Text	Unit Less	Text	Text	Unit Less	Unit less	Sec	KN
EQX	X	0.075	0.16	II	1	5	0.0514	9042.148
EQY	X	0.075	0.16	II	1	5	0.0514	9042.148

Table 3. Forces between I-Girder and U-Girder.

Force Act on Entire Section Plus All Girders			
Bridge Object Response Display (Due to Loading)			
		IGirder	***U-Girder***
1	Maximum shear vertical	2074.74	3315.51
2	Maximum longitudinal stress (top center)	1077.54	607.54
3	Maximum longitudinal stress (bottom left)	6957.8	29.62.67
4	Max moment about horizontal axis	8060.01	6831.266
5	Max moment about vertical axis	385.81	2245
6	Base shear	15455.71	9042.148

CONCLUSION

Analysis of Prestressed Concrete Bridges. The analysis of prestressed concrete bridges was carried out using relevant IRC and IS codes.

Self-Weight of Girder Condition

For the U-girder bridge, the maximum vertical shear force was found to be 3315.51 kN, with the maximum bending moment being 6831.26 kN-m at the face of the girder.

For the I-girder bridge, the maximum vertical shear force was 2074.74 kN, with the maximum bending moment being 8060.01 kN-m at the face of the girder.

Longitudinal Stress

The maximum longitudinal stress at the top of the I-girder was 1077.54 MPa, and at the bottom, it was 6957.8 MPa.

For the U-girder, the maximum longitudinal stress at the top was 607.54 MPa, and at the bottom, it was 2962.67 MPa.

These results indicate that the I-girder experiences higher stress due to loading compared to the U-girder.

Design Basis and Loading

The structure was designed based on IRC Class A and IRC 70R loading. The IRC loading was applied to justify the bridge girder analysis.

The amount of steel provided in the U-girder bridge, compared to the I-girder bridge, indicates that the U-girder structure is more economical in terms of material use.

Comparative Analysis

The analysis clearly shows that the U-girder bridge is more stable in resisting loads.

However, it was also concluded that in terms of cost, the U-girder is more expensive compared to the I-girder.

This comparative analysis highlights the trade-offs between stability and cost in the selection of girder types for prestressed concrete bridge designs. The U-girder provides superior load resistance, while the I-girder offers a more cost-effective solution.

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