Structural Analysis of a Three-Deck Flyover for Traffic Decongestion in Urban Corridors with Different Piers

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Abstract— **Rapid urbanization and the continuous increase in vehicular traffic have created major congestion problems in urban corridors across metropolitan cities. To address these challenges, multi-level flyovers have become an important solution for improving traffic movement and reducing travel delays in densely populated areas. Among various structural components of flyovers, the pier system plays a significant role in determining the stability, strength, and overall performance of the structure. This review paper presents a detailed study on the structural behavior of three-deck flyovers with different pier configurations such as circular, rectangular, and portal piers. The paper reviews previous research related to multi-level flyovers, pier geometry, and structural analysis carried out using software such as STAAD. Ro under different loading conditions including dead load, live load, wind load, and seismic load. The comparative findings from earlier studies indicate that pier shape directly affects important structural parameters such as bending moment, shear force, axial load, displacement, stiffness, and base reaction. Different pier configurations show varying behavior under lateral and vertical loads, influencing both safety and economy of the flyover structure.**

Index Terms— **Three-deck flyover, Pier shape, STAAD. Ro analysis, Structural performance, Urban traffic decongestion.**

I. INTRODUCTION

A three-deck flyover is an advanced structural configuration designed to accommodate multiple traffic levels, thereby enhancing vehicular flow efficiency without requiring additional horizontal land area. Such structures are especially beneficial in metropolitan regions where available space is limited and land acquisition is costly. By segregating traffic based on direction or type such as local, express, and transit lanes a three-deck flyover can significantly reduce intersection delays and improve traffic movement.

Urban areas are witnessing exponential growth in traffic density due to rapid urbanization and population increase. Conventional two-deck flyovers often fail to accommodate the complex traffic patterns at major intersections and junctions. To address this, three-deck flyovers have emerged as an innovative structural solution that enables grade separation across three levels, ensuring smoother traffic flow and reduced travel time.

A. Types of Piers Used in Flyovers

Circular Pier

Circular piers are cylindrical reinforced concrete members widely used in flyover construction. These piers provide uniform stress distribution and perform effectively under axial and lateral loads. Because of their symmetrical geometry, circular piers reduce stress concentration and torsional effects. They are aesthetically attractive and occupy less ground space, making them suitable for congested urban areas. Circular piers also offer better aerodynamic performance under wind loading conditions.

Rectangular Pier

Rectangular piers are commonly used in bridge and flyover structures because of their high stiffness and load carrying capacity. Their larger cross-sectional area provides better resistance against bending and shear forces. Rectangular piers are suitable for supporting wider decks and multi-lane flyovers. They also allow easy connection with pier caps and girders. However, their larger size may require more space and material compared to circular piers.

Portal Pier

Portal piers consist of two vertical columns connected by a horizontal beam, forming a rigid frame system.

This configuration provides excellent lateral stiffness and improved seismic resistance. Portal piers effectively distribute loads between columns and reduce bending moments at the base. They are particularly useful in urban areas where open space below the flyover is required for vehicle movement, pedestrian access, or utility services. Because of their superior lateral stability, portal piers are often preferred for multi-level flyover structures subjected to wind and earthquake forces.

II. PROBLEM STATEMENT

With increasing traffic congestion in urban areas, the need for multi-deck flyovers is becoming more pronounced. However, the selection of an appropriate pier configuration remains a design challenge due to variations in load transfer mechanisms, seismic response, and construction feasibility. Inadequate selection of pier geometry can result in excessive deflection, higher bending moments, or inefficient use of materials, leading to increased construction costs and reduced service life. Therefore, it is essential to evaluate and compare the structural behavior of different pier shapes supporting a three-deck flyover to identify the configuration that ensures optimal performance under multiple loading conditions.
This research focuses on the structural analysis of a three-deck flyover designed to alleviate urban traffic congestion. The study involves modeling the structure using STAAD. Ro software and analyzing its response under different loads dead load, live load, wind load, and seismic load according to relevant Indian standards.

Four different pier shapes will be considered:
- Circular Pier
- Rectangular Pier
- Portal Pier

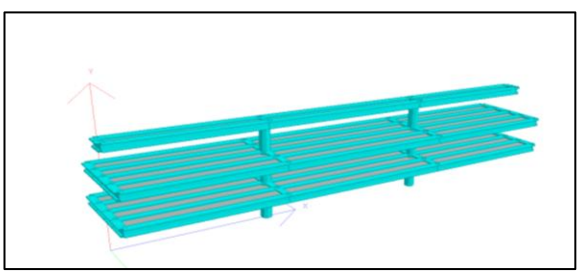


Fig 1 Model 1: Single Circular Pier

Figure 1 illustrates the STAAD-PRO analytical model of the three-deck flyover supported on a single circular pier.

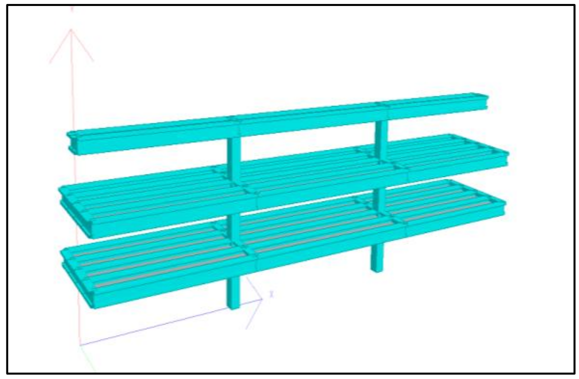


Fig 2 Model 2: Single Rectangular Pier
Figure 2 illustrates the STAAD-PRO analytical model of the three-deck flyover supported on a single rectangular pier.

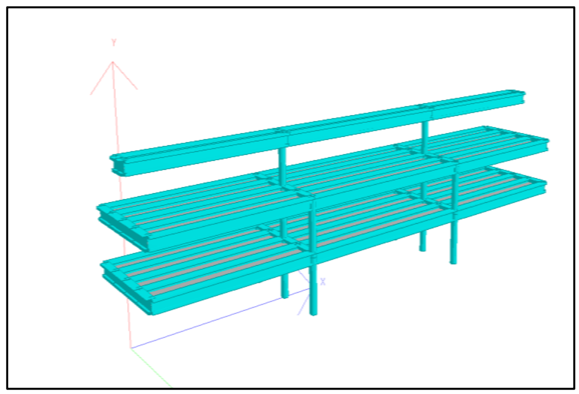


Fig 3 Model 3: Circular Portal Pier
Figure 3 illustrates the STAAD-PRO analytical model of the three-deck flyover supported on a circular portal pier configuration.

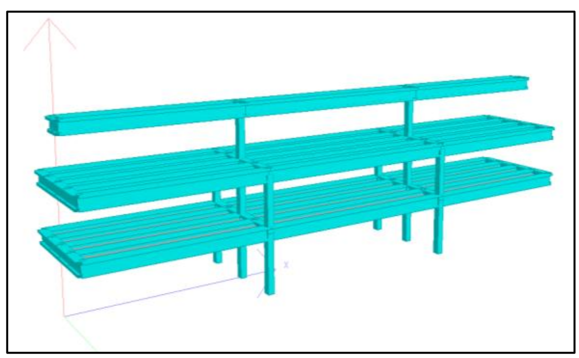


Fig 4 Model 4: Rectangular Portal Pier
Figure 4 illustrates the STAAD-PRO analytical model of the three-deck flyover supported on a rectangular portal pier configuration. T

III. LOADING IN STAAD-PRO

1. Deck Details (All Three Decks)
- Carriageway width (each deck): 7.5 m (2-lane)
- Deck slab thickness: 250 mm

2. Span Arrangement
- Typical span layout:

25 m + 30 m + 25 m
- Girder spacing: 3.75 m

3. Girder Size
- Overall depth: 1600 mm
- Top flange: 1200 mm × 250 mm
- Web thickness: 200 mm
- Bottom flange: 800 mm × 300 mm

4. Circular Pier Details- (Area = 2.55m^2)
- Pier diameter: 1.8 m
- For Portal - 1.05 m
- Concrete grade: M40

5. Rectangular Pier Section - (Area = 2.55m^2)
- Width (B) = 1.5 m
- Depth (D) = 1.7 m
- For Portal - Size = 0.85 m × 1.0 m

A. Dead Load (Dl)
- Self-weight

(a) Vehicular Decks – 1st & 2nd Levels
- Wearing course: 2.2 kN/m^2 (IRC:6–2017, Clause 202.2)
- Crash barrier: 10 kN/m

(b) Metro Desk – Top Level
- Track plinth + rail: - 15 kN/m (IRC: SP:114–2018 (for metro viaducts – loading guidance)

B. Live Load (LL)

(a) Vehicular Decks
- Uniformly Distributed Load (UDL): - 20 kN/m (IRC Class A loading)
- Braking / Traction Force: - Braking Force = 20% of Live Load = 4.0 kN/m

(b) Metro Deck

Train Load IRC: SP:114–2018
- Axle load: 170–180 kN
- Equivalent UDL: 60–80 kN/m per track

IV. RESULT AND DISCUSSION

A. Result for Max Bending Moment Kn

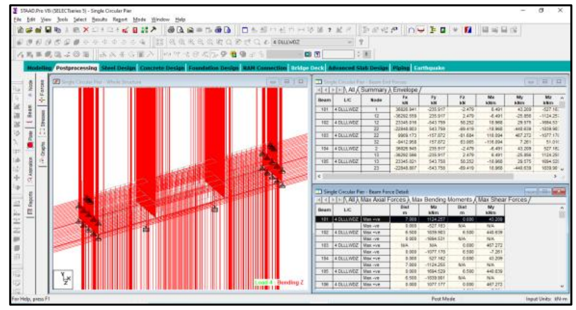


Fig 5 Max Bending Moment for Model 1: Single Circular Pier

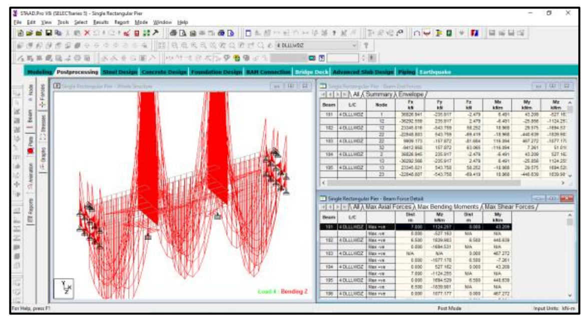


Fig 6 Max Bending Moment for Model 2: Single Rectangular Pier

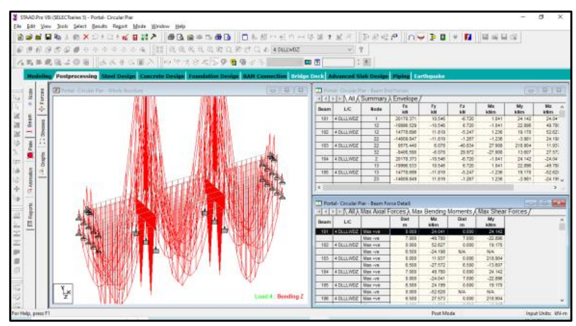


Fig 7 Max Bending Moment for Model 3: Circular Portal Pier

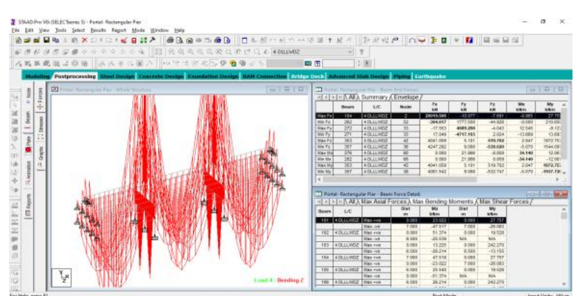
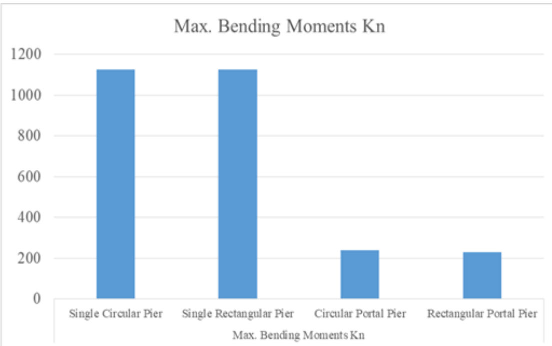


Fig 8 Max Bending Moment for Model 4: Rectangular Portal Pier

Table 1 Max. Bending Moments Kn

Max. Bending Moments Kn			
Single Circular Pier	Single Rectangular Pier	Circular Portal Pier	Rectangular Portal Pier
1124	1124	240.41	230.22



Graph 1 Max. Bending Moments Kn

Table 1 indicates that single circular and single rectangular piers develop identical maximum bending moments, showing negligible influence of pier shape for equal cross-sectional area. Compared to single pier models, the circular portal pier reduces maximum bending moment by about 78.6%, while the rectangular portal pier shows the highest reduction of approximately 79.5%. The rectangular portal pier further records around 4.2% lower bending moment than the circular portal pier, indicating more efficient moment distribution and higher stiffness.

B. Bending Moment kN-m/m

Bending Moment (kN-m/m) represents the internal moment developed per unit width of the deck slab due to applied loads. It is an important response parameter for assessing the flexural behaviour and load distribution in bridge decks.

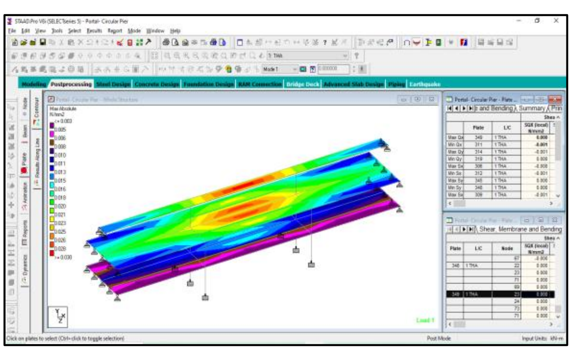


Fig 9 Time vs Displacement for Model 3: Circular Portal Pier

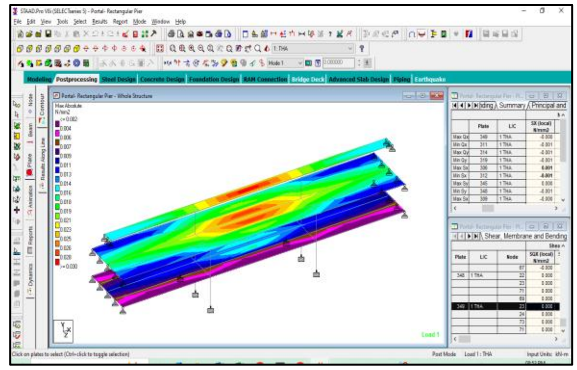
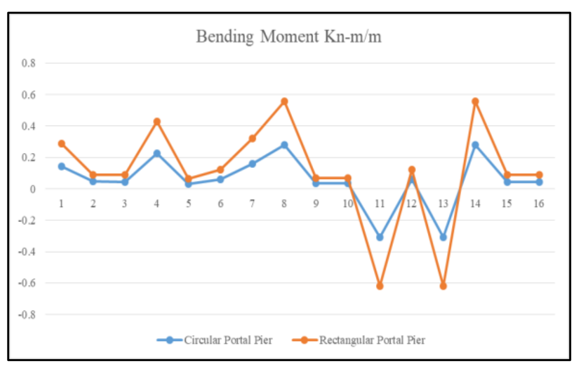


Fig 10 Time vs Displacement for Model 4: Rectangular Portal Pier

Table 2 Bending Moment kN-m/m

Bending Moment kN-m/m		
Plate No	Circular Portal Pier	Rectangular Portal Pier
349	0.144	0.144
311	0.047	0.043
314	0.045	0.044
319	0.225	0.204
306	0.032	0.033
312	0.061	0.062
345	0.16	0.161
348	0.278	0.28
309	0.035	0.032
313	0.035	0.032
322	-0.309	-0.311
312	0.061	0.062
322	-0.309	-0.311
348	0.278	0.28
314	0.045	0.044
310	0.045	0.044



Graph 2 Bending Moment kN-m/m

Graph 5.6 presents the bending moment distribution obtained from time history analysis for deck plates supported on portal pier configurations. It is observed that bending moment values for both circular and rectangular portal piers are very close, indicating similar load transfer behaviour. The maximum positive bending moment differs by less than 1%, while the maximum negative bending moment shows a variation of about 0.6%, which is negligible. Overall, the rectangular portal pier exhibits slightly lower bending moments at critical plates, indicating marginally better moment control under dynamic loading, though both portal configurations demonstrate comparable performance.

IV. CONCLUSION

- The analysis showed that both single circular pier and single rectangular pier developed the same maximum bending moment of 1124 kN, indicating similar structural behaviour under the applied loading conditions.
- The shape of the single pier had negligible influence on bending moment when the cross-sectional area and loading conditions were kept constant.
- Portal pier configurations significantly improved structural performance compared to single pier systems due to better load sharing and higher stiffness.
- The circular portal pier reduced the maximum bending moment by approximately 78.6% compared to the single pier models.
- The rectangular portal pier showed the highest reduction in bending moment, approximately 79.5%, indicating superior flexural performance.
- The rectangular portal pier recorded about 4.2% lower bending moment than the circular portal pier, demonstrating slightly better moment distribution and lateral stability.
- Time history analysis results indicated that both circular and rectangular portal piers exhibited nearly similar bending moment behaviour under dynamic loading conditions.
- The variation between maximum positive and negative bending moments of the two portal pier models was found to be negligible, showing comparable structural response.
- The rectangular portal pier consistently showed slightly lower bending moment values at critical deck plates, indicating improved stiffness and better control of structural deformation.
- Based on the comparative analysis, the rectangular portal pier was identified as the most efficient and suitable configuration for three-deck urban flyovers due to its lower bending moments, enhanced stability, and effective load transfer characteristics.

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IS CODES

- IS 456: 2000 Plain and Reinforced Concrete – Code of Practice Used for the design and detailing of reinforced concrete components such as decks, piers, pier caps, and foundations.
- IS 1343: 2012 Code of Practice for Prestressed Concrete Referred where prestressing is adopted in girders or deck slabs.
- IRC 6: 2017 – Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Load Combinations
- IRC 21: 2000 – Standard Specifications and Code of Practice for Road Bridges – RCC Bridges
- IRC 112: 2020 – Code of Practice for Concrete Road Bridges