Economical Analysis of Integral Portal Frames Bridges by Changing Various Aspect Ratio

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***Abstract*—Integral portal frame bridges have become an effective alternative to conventional bridges because they eliminate expansion joints and bearings, thereby reducing maintenance costs and improving durability. This study investigates the influence of varying pier heights on the structural behaviour and economy of a four-bay semi-integral portal frame bridge. Numerical modelling was carried out using STAAD.Pro Connect Edition for deck spans of 10 m and 12 m with pier heights varying from 5 m to 9 m. The bridge was analysed under IRC load combinations including dead load, superimposed dead load, wearing coat, temperature effects, creep, shrinkage, seismic loads, water current force, braking force, and IRC 70R/Class AA live loads. The results indicate that the temperature-dominant load combination produces the highest bending moments. Increasing pier height significantly reduces bending moments in both the piers and deck slab, leading to improved structural efficiency and economy. The study demonstrates that selecting an optimum aspect ratio can reduce structural demand, enhance durability, and minimize construction and maintenance costs.**

I. INTRODUCTION

Conventional bridges require expansion joints and bearings to accommodate thermal movement and load transfer. These components are prone to deterioration due to water infiltration, corrosion, and environmental effects, resulting in high maintenance costs. Integral bridges eliminate these components by providing a monolithic connection between the superstructure and substructure, improving durability, structural continuity, and seismic performance. This study evaluates the structural and economical behaviour of semi-integral portal frame bridges by varying pier heights while maintaining constant deck spans.

1.1 Objective

- To determine the economical pier height for each span length of deck slab in order to ensure structural integrity and stability.
- To evaluate the structural performance of the integral bridge under different pier heights and span lengths by considering various loads.
- To analyze the feasibility and constructability of the integral bridge design with different pier heights.

1.2 Scope of Work

- Four bay Semi integral bridge were considered where expansion joint provided near abutment.
- Deck slab of 10m, 12m were considered with pier height varying from 5m to 9m.
- Load combinations were made from table of ultimate strength given in IRC 6.
- Load combination in which temperature load is leading dominates.
- Since expansion joint is provided near abutment it is not a part of our project. Only pier height is considered and hence foundation is also not a part. The integrity of the foundation and abutment is ensured and does not impact the results.

1.3 Methodology

1. Designed a four-bay portal frame semi-integral bridge with spans of 10 meters and 12 meters, and pier heights ranging from 5 meters to 9 meters, using consistent material throughout the study.
2. Modeled a 10-meter deck slab and applied load combinations: self-weight, superimposed load, wearing coat loads, temperature effects (rise and fall), creep, shrinkage, water current, seismic loads (longitudinal and transverse), afflux, and live load.
3. Investigated the impact of varying pier heights on structural behaviour by systematically altering pier

heights from 5 meters to 9 meters while keeping all other parameters constant.

4. Analysed resulting bending moments on the piers under the applied load combinations to identify the height that exhibits the minimum bending moment, which is crucial for reducing internal stresses, enhancing durability and safety, and achieving material savings and cost-efficiency.
5. Determined the optimal pier height for efficient bridge performance under various loading conditions, providing valuable insights into the design and construction of semi-integral bridges, contributing to the development of more resilient and economical infrastructure.

II. RESULTS

Table no 1. Load Combinations
(12m deck & 5m pier)

Basic Comb 1	Basic Comb 2	Basic Comb 3	Basic Comb 4
MX (local) kN-m/m	MX (local) kN-m/m	MX (local) kN-m/m	MX (local) kN-m/m
<= -417	<= -482	<= -501	<= -382
-371	-434	-448	-339
-325	-387	-396	-295
-278	-339	-343	-252
-232	-291	-290	-208
-185	-244	-238	-164
-139	-196	-185	-121
-92.4	-149	-132	-77.3
-46	-101	-79.8	-33.8
0.481	-53.7	-27.1	9.78
46.9	-6.1	25.5	53.3
93.3	41.5	78.2	96.9
140	89	131	140
186	137	184	184
233	184	236	228
279	232	289	271
>= 326	>= 279	>= 341	>= 315

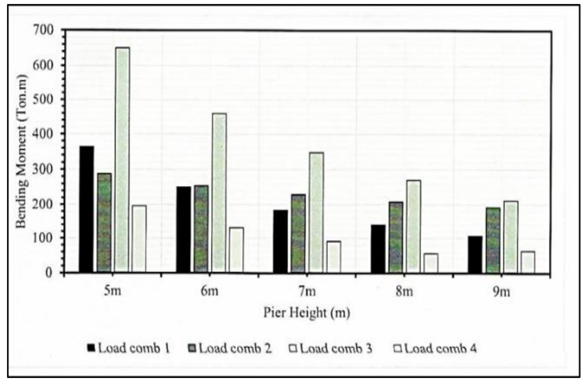


Figure no 1. Bending Moment for 12m deck vs Pier Height for pier section 1

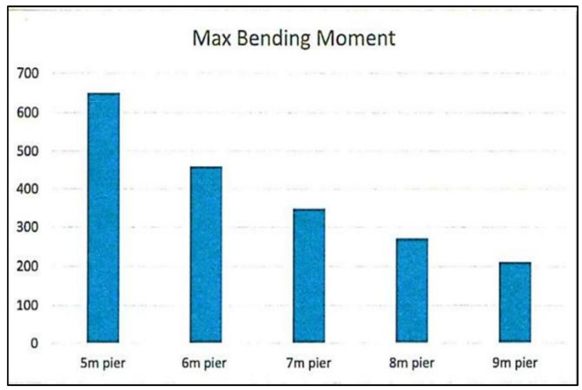
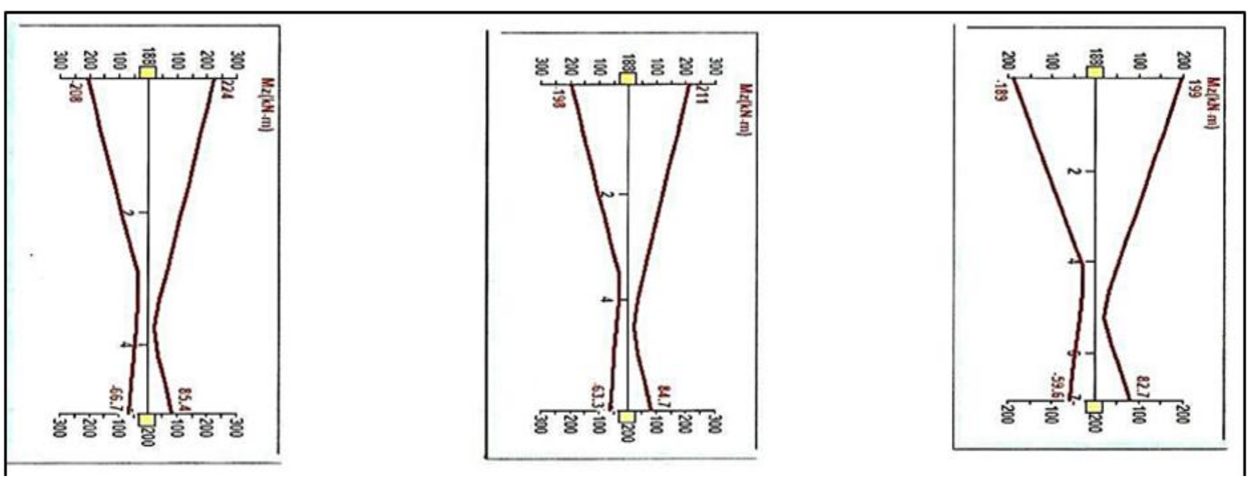


Figure no 2. Final Result-Bending Moment vs Pier Height for pier section 1



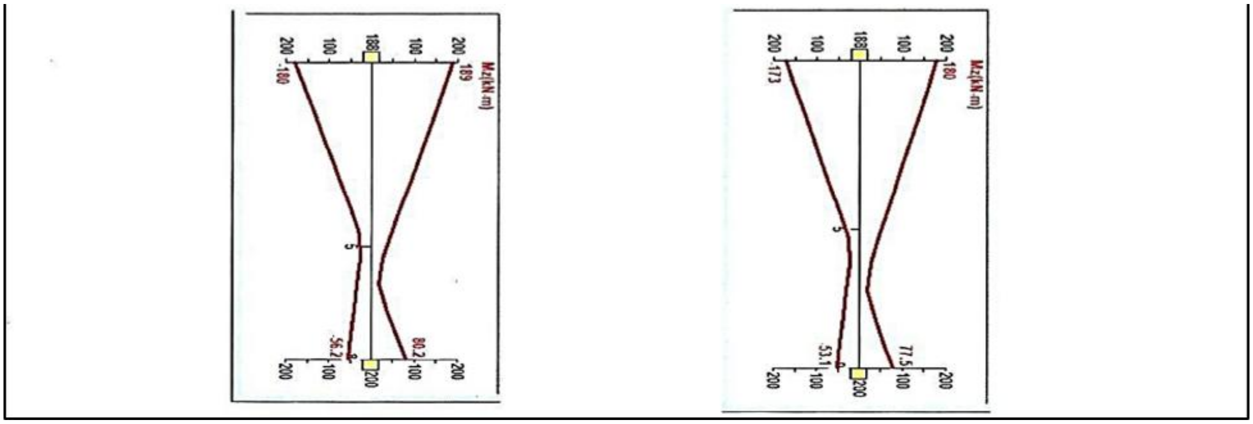


Figure no 3. Live load Stats with Single Pier for Pier Section 1

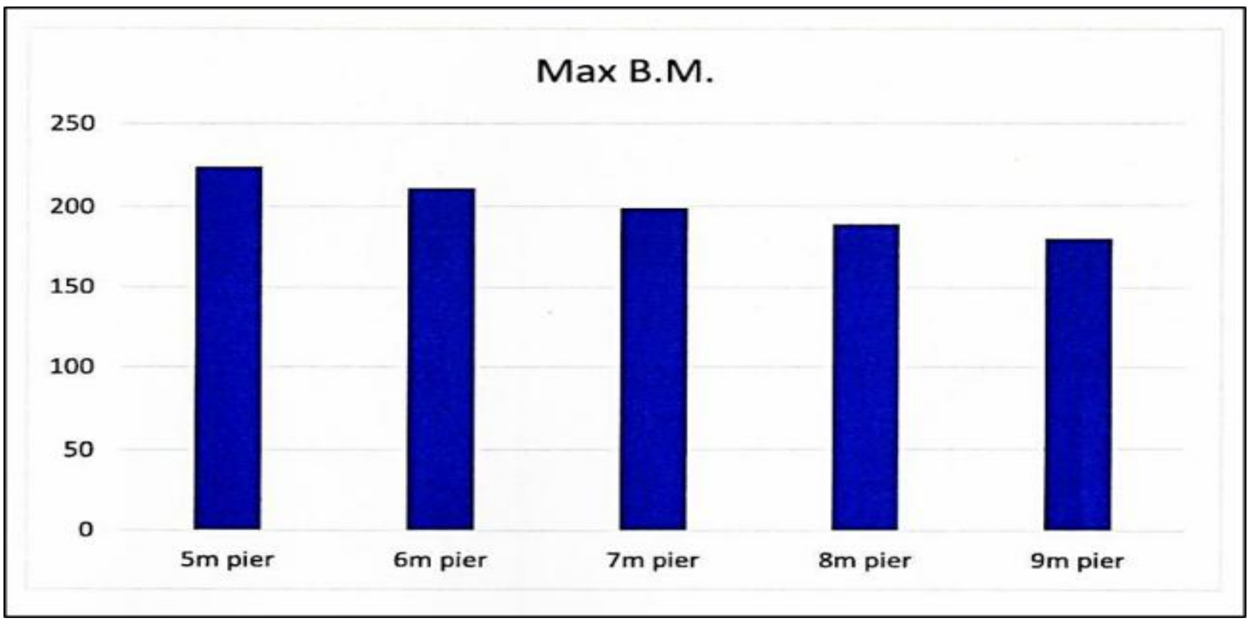
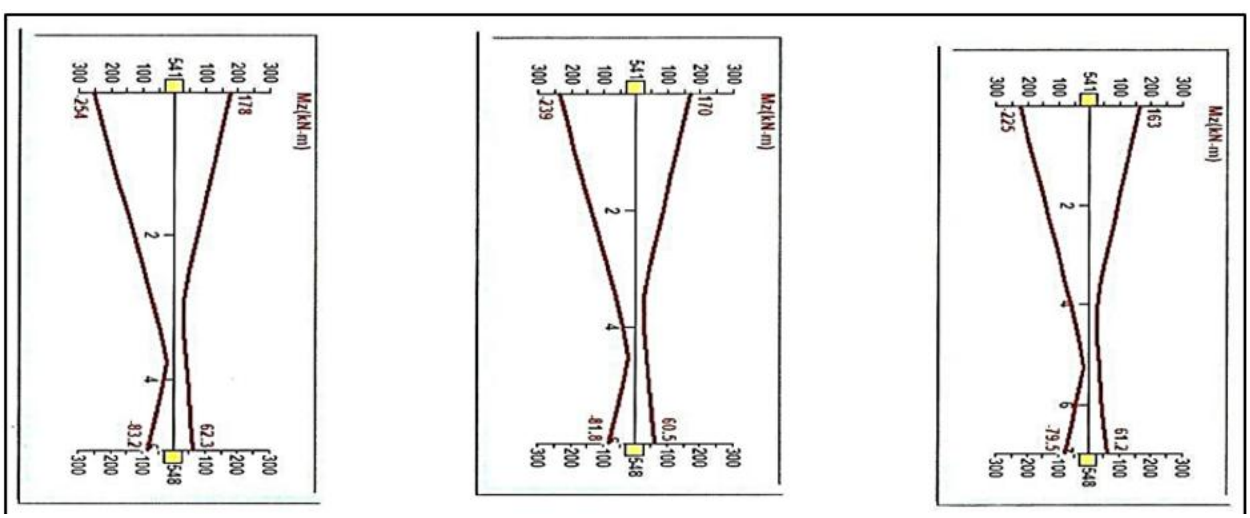


Figure no 4. Live Load for pier section 1- Induced Bending Moment vs. Pier Height for 12m deck



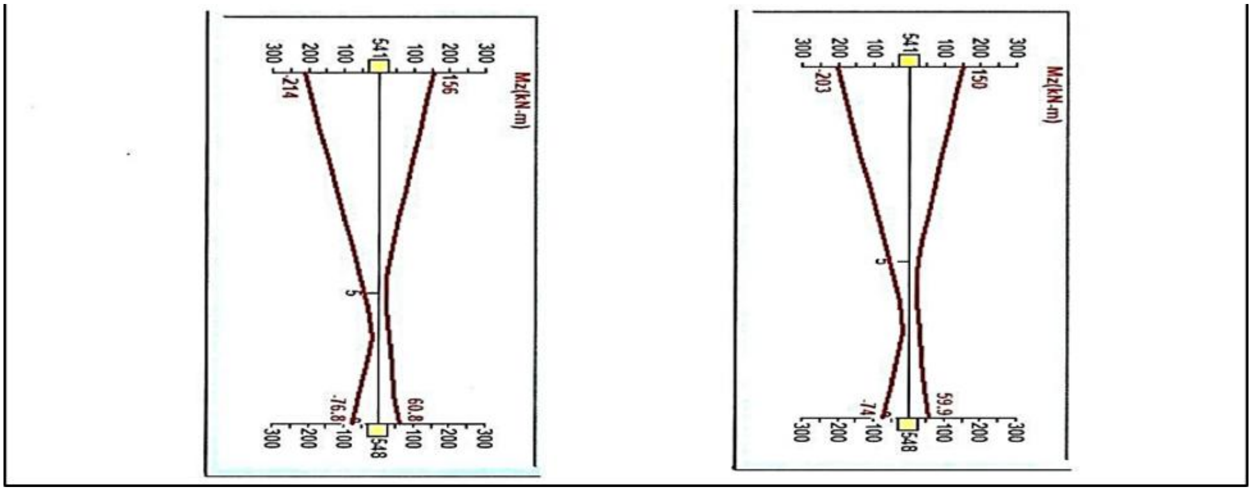


Figure no 5. Live load Bending Stats for 12m Deck- Section 2 Pier

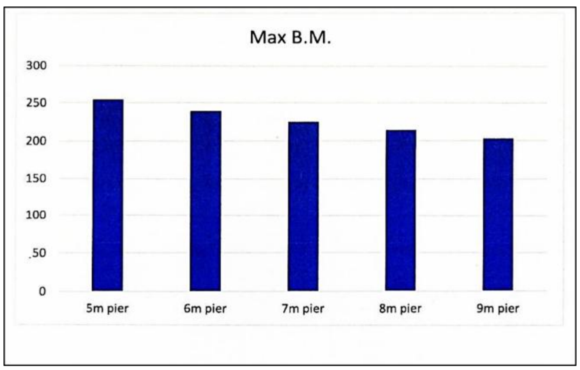


Figure no 6. Live Load for pier section 2- Induced Bending Moment vs. Pier Height for 12m deck

III. CONCLUSION

- Critical Load Combination Identification: The load combination where temperature load was the leading factor was found to be the most critical in terms of inducing maximum bending moments in the deck slab.
- Effect of Pier Height on Bending Moment: As the height of the pier increases, the bending moment resisted by the pier decreases. This was observed for pier heights ranging from 5 meters to 9 meters. Shorter piers (5 meters) experience higher bending moments compared to taller piers (9 meters), indicating that taller piers are more effective in counteracting bending moments.
- Live Load Analysis Consistency: The trend of decreasing bending moments with increasing pier height was consistent under live load conditions for both 70R and Class AA loading scenarios.
- Design Implications: The study provides valuable insights for civil engineers and bridge designers, emphasizing the need to carefully consider pier height during the design phase. Optimizing pier height can lead to better structural integrity and longevity of the bridge, ensuring it can effectively withstand various loading conditions.

REFERENCES

[1] Sakhare, Akshay, Piyush Punetha, Naveen Kumar Meena, Sanjay Nimbalkar, and G.-R. Dodagoudar. "Dynamic Behaviour of Integral Abutment Bridge Transition under Moving Train Loads," 2023.

[2] Zordan, Tobia, Bruno Briseghella, and Cheng Lan. "Parametric and Pushover Analyses on Integral Abutment Bridge," 2011.

[3] Nilson, Martin. "Towards a Better Understanding of the Behavior of Bridges with Integral Abutments," 2012.

[4] Arockiasamy, M., and M. Sivakumar. "Time-Dependent Behavior of Continuous Composite Integral Abutment Bridges," 2005.

[5] Kong, B., C. S. Cai, and X. Kong. "Thermal Property Analysis and Applications of GFRP Panels to Integral Abutment Bridges," 2014.

[6] Indian Road Congress. *Standard Specifications and Code of Practice for Road Bridges: IRC:6*. 2017.

[7] Bloodworth, A. G., M. Xu, J. R. Banks, and C. R. I. Clayton. "Predicting the Earth Pressure on Integral Bridge Abutments." *Journal of Bridge*

Engineering, vol. 17, no. 2, 2012, pp. 371–381.
[8] Banks, J., A. Bloodworth, T. Knight, and J. Young. "Integral Bridges—Development of a Constitutive Soil Model for Soil Structure Interaction." *Structures Congress: Crossing Borders*, 2008.
[9] Brena, S. F., C. H. Bonczar, S. A. Civjan, J. T. DeJong, and D. S. Crovo. "Evaluation of Seasonal and Yearly Behaviour of an Integral Abutment Bridge." *Journal of Bridge Engineering*, vol. 12, 2007, pp. 296–305.
[10] David, T. K., J. P. Forth, and J. Ye. "Superstructure Behaviour of a Stub-Type Integral Abutment Bridge." *Journal of Bridge Engineering*, vol. 19, no. 6, 2014.
[11] Dicleli, M. "Integral Abutment-Backfill Behaviour on Sand Soil—Pushover Analysis Approach." *Journal of Bridge Engineering*, vol. 10, no. 3, 2005, pp. 354–364.
[12] Dicleli, M. *Innovative Bridge Design Handbook*. Butterworth-Heinemann, Waltham, USA, 2016.
[13] Dunker, K. F., and D. Liu. "Foundations for Integral Abutments." *Practice Periodical on Structural Design and Construction*, vol. 12, 2007, pp. 22–30.
[14] Ghali, A., R. Favre, and M. Eldbadry. *Concrete Structures*. E&FN Spon, London, 2002.
[15] Gilbert, R. I., and G. Ranzi. *Time-Dependent Behavior of Concrete Structures*. Spon Press, London, 2011.
[16] Greimann, B. L. F., P. S. Yang, and A. M. W. Tinsae. "Nonlinear Analysis of Integral Abutment Bridges." *Journal of Bridge Engineering*, vol. 112, no. 10, 1986, pp. 2263–2280.
[17] Hambly, E. C. *Bridge Deck Behavior*. Taylor and Francis, London and New York, 1991.
[18] Huang, J., C. K. Shield, and C. E. W. French. "Parametric Study of Concrete Integral Abutment Bridges." *Journal of Bridge Engineering*, vol. 13, no. 5, 2008, pp. 511–526.
[19] Indian Road Congress. *Guidelines for Design of Integral Bridges: IRC:115*. 2018.
[20] Indian Road Congress. *Load and Load Combinations: IRC:6*. 2017.
[21] Indian Road Congress. *Seismic Design of Roads and Bridges: IRC:114*. 2018.
[22] Indian Road Congress. *Code for Concrete Road Bridges: IRC:112*. 2020.
[23] Public Works Department, Government of Maharashtra. *Guideline of Bridges*.