Available online: www.ijsrmes.com
International Journal for Scientific Research in Modern Engineering and Science
Published in: Vol. 1, Issue 1, pp. 7-13, March-April 2026

MODELING AND ANALYSIS OF BRIDGE DECK PERFORMANCE CONSIDERING DIFFERENT TYPES OF GIRDER AND SPAN LENGTH

Madhuri Ghosh[1]*, Mitali Shrivastava[2]

[1]*M. Tech. Student, Department of Civil Engineering, SSTC-SSGI, Bhilai, C.G., India.*
[2]*Assistant Professor, Department of Civil Engineering, SSTC-SSGI, Bhilai, C.G., India.*

Abstract

Bridge decks are constantly subjected to daily traffic, which can cause surface cracking from excessive stress or fatigue, necessitating repair or replacement. In India, bridge decks are the costliest part to build and maintain among specific bridges, driven not just by direct repair expenses but also by indirect costs stemming from traffic disruptions during repairs. To accurately forecast how a bridge deck will respond and the likelihood of damage, appropriate analytical tools are required to account for the dynamic interactions between the bridge and multiple vehicles. This numerical tool must be capable of offering a reasoned forecast for the bridge. Global and local responsesincluding deformation and stress on the bridge deck and other componentscan be utilized for assessing fatigue, vibration, or other types of damage. This work, design and analyze the various types of bridge structures with I-girder concrete bridge structure and I-girder composite with and without confining bridge structure. Present work the overall width is taken as 15m. The bridge consists of 5 spans. The variation of span is taken as 20m, 30m, 40m, 50m and 60m for each analysis to get the effect of span length on bridge. The bridge design for dynamic moving loading i.e., class AA loading whichever produces the worst effect. In this work, total deformation, von-mises stress, strains, shear stress, strain energy and frequency has been achieved with variation of span length and types of bridge deck or girder changes. All the five types of bridge for IRC Class-AA loading are analyzed using Ansys software. From the analysis it has been found that the model designed in this research work gives efficient results and also the results are satisfied.

Keywords: *Bridge deck, Girders, IRC-AA loading and Steel, Reinforcement.*

* *Corresponding author*

1. Introduction

A structure that allows passage over a gap while leaving the space beneath it open. The passage could be attributed to railways, roads, canals, and natural rivers, among other possibilities. At first, bridges were largely built using naturally occurring materials like stone and timber, but today, artificial materials such as cement concrete and steel are more commonly used in bridge construction. The typical design life of bridges is intended to ensure a satisfactory period of service. Over its lifetime, the bridge must satisfy key fundamental criteriaincluding structural strength, functionality, and longevitywhich are ensured through proper design, manufacturing, construction, and maintenance. Concerning the design, this is based on the consideration of ultimate and serviceability limit states that have to be verified for persistent, transient and accidental design situations. The objective of this paper is to provide a review on the work related to bridge super structure design, and to offer an insight of the real mechanism involved through a framework of a simple model. This is carried out to devise a sound basis for the possibility of a more economical design approach and justified recommendations for further research work.

1. Methodology

A nonlinear analysis of the bridge model was performed using a simulated wheel load from an IRC Class AA wheeled vehicle, in accordance with IRC Chapter 3. A specialized method is used to depict a moving load or vehicle. This approach employs transient solution analysis in Ansys, applying loads sequentially to one designated set of nodes at a time. The program splits the axle weights evenly and applies two-wheel loads at a distance equal to half the vehicle's width, positioned on either side of the vehicle's centerline. Figure 1 illustrates the IRC Class A train vehicle. Fatigue damage buildup from passing vehicles is essential for assessing the fatigue safety of current concrete bridges. Fatigue life can also be expressed in terms of years. Design traffic is evaluated based on the total number of standard axles. The cumulative number of standard axles is calculated in accordance with IRC 3. The following points are taken into account.

2.1 Modelling of Bridge Deck Structure in Ansys

Five types of bridge deck structure were modeled in Ansys, as illustrated in Figure 1. a)(b) and derive various outcomes by altering the bridge deck type and adjusting the span length of the bridge deck. Five distinct bridge deck systems have been developed, namely: i) Concrete I-shaped girders, ii) Composite steel plate girders: (a) without a confining concrete block, (b) upper flange bottom surface, (c) upper flange middle section, and (d) upper flange top surface.

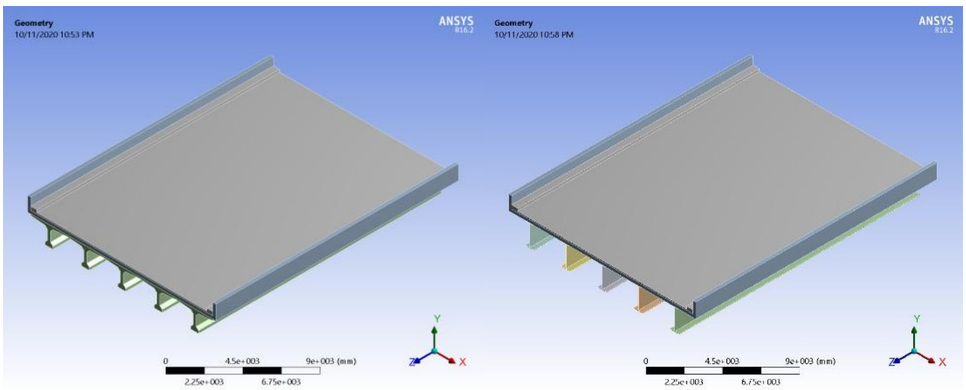

Figure 1. 3D Model of concrete bridge deck with 20m of span length (Type-A) and composite bridge deck with 20m of span length (Type-B)

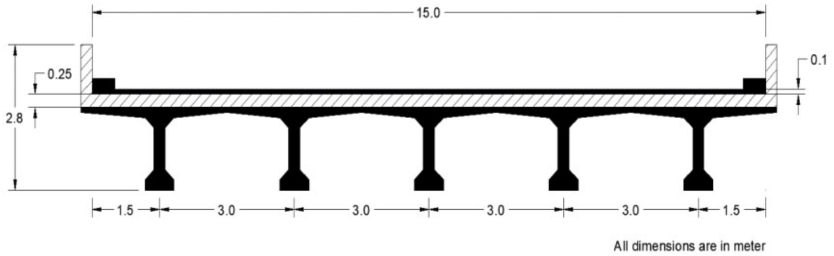

Figure 2. Dimensional view of I-concrete girder bridge deck

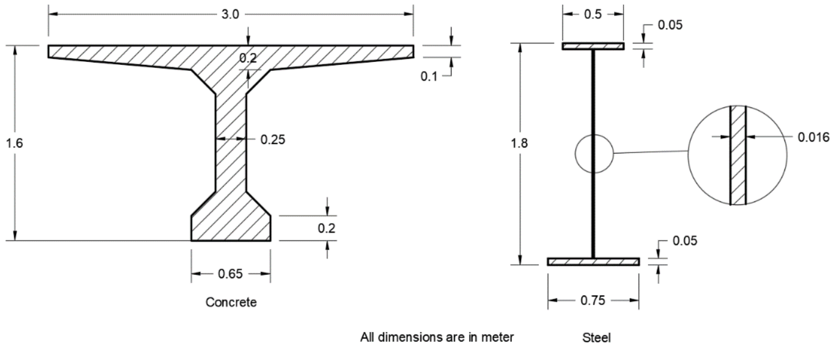

Figure 3. Cross-sectional and dimensional view of concrete and steel girder without confining concrete

Slab panels for the bridge deck, measuring 15m by 20 m and 0.25m thick, were modeled in Ansys. The deck slab's material properties include a Young's Modulus of 25000 MPa, a Poisson's ratio of 0.15, and a density of 2549 kg/m³. The slab is 15 meters wide, while its span and depth range from 15 meters to 60 meters respectively.

2. Results and Discussion

The highway bridge under study features four continuous spans along its length, with span lengths ranging from 20 to 60 meters. The bridge girders are spaced evenly across the transverse direction at 4-meter intervals. To identify the most effective design approachwhether concrete/ steel or plate sectionsthe position of the confining concrete section within the cross-section is adjusted, as detailed and illustrated in the preceding chapter. For type A, the effective height of the bridge cross section remains at 1.6 meters, while for the other three cases, it is maintained at 1.8 meters.

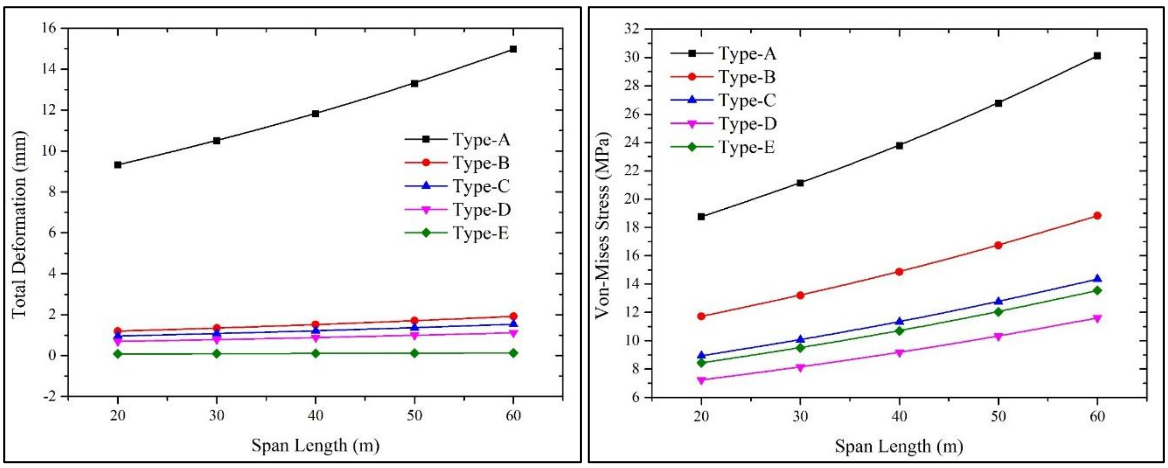

Figure 4. Effect of maximum total deformation and von-mises stresses due to IRC Class AA Loading condition in different types of bridge deck with variation of bridge span length

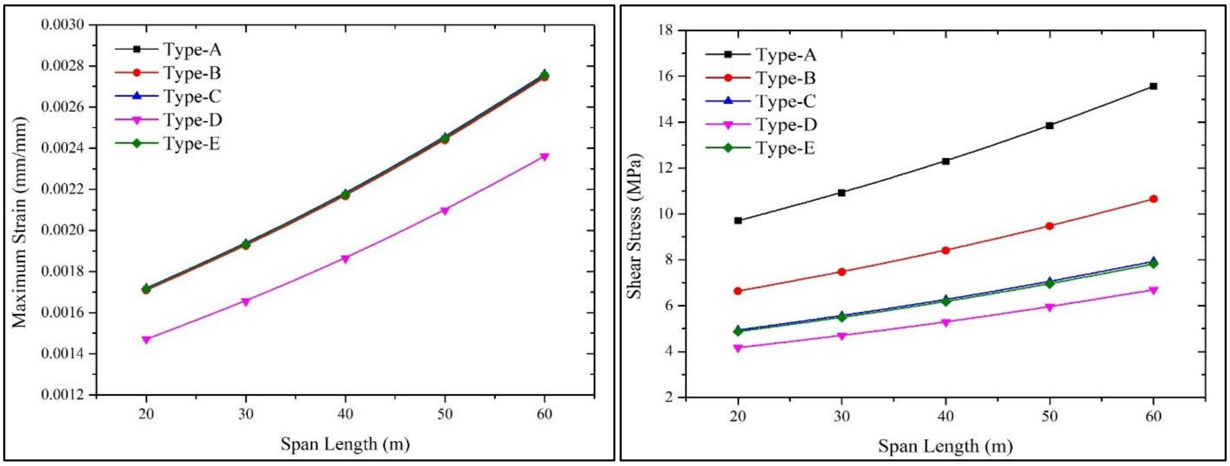

Figure 5. Effect of maximum equivalent strain and shear stress due to IRC Class AA Loading condition in different types of bridge deck with variation of bridge span length

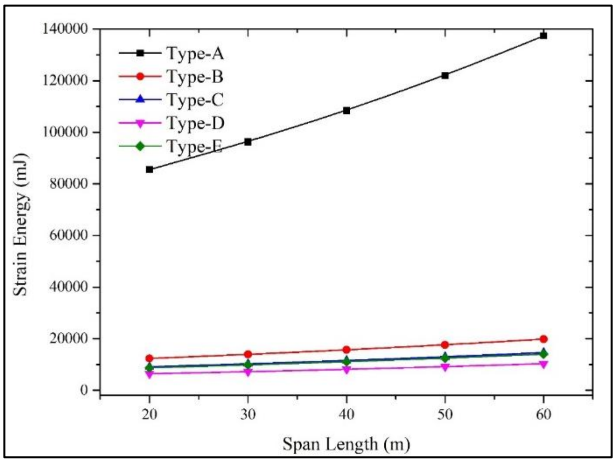

Figure 6. Effect of maximum strain energy due to IRC Class AA Loading condition in different types of bridge deck with variation of bridge span length

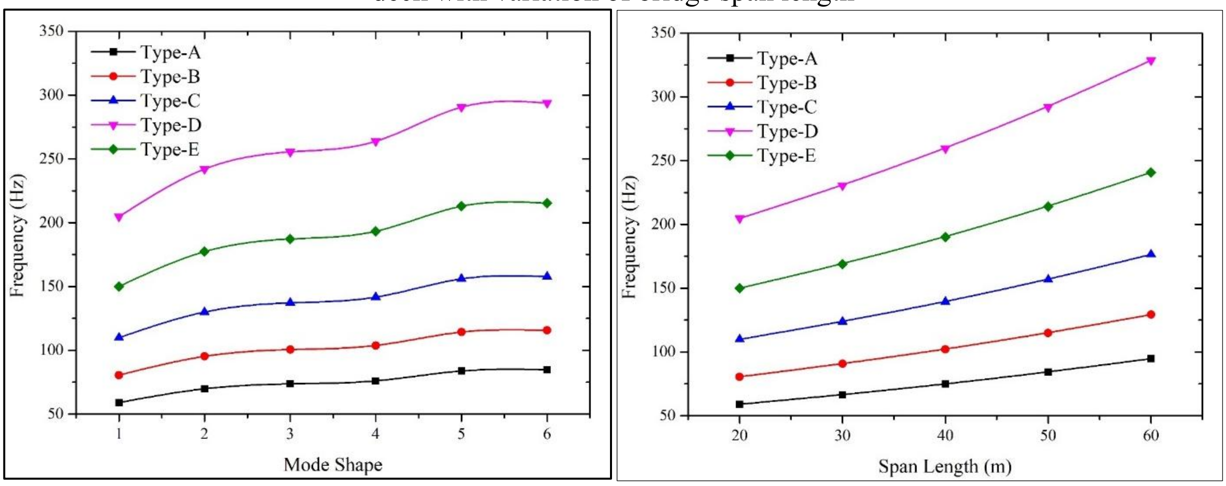

Figure 7. Effect of natural frequency with different mode shape in different types of bridge structure and with variation of bridge span length 20m – 60m

The Figure 4 – Figure 7 shows that the graphical representation of maximum deformation, von-mises stress, equivalent or maximum strain, shear stress, strain energy and vibration obtained from analysis. The Figures depicted that the maximum deformation, von-mises stress, strain energy developed in the all five types of bridge structure. The maximum total deformation is increases with increasing of the bridge span length and it has been observed that the Type A having more deformation as compared to the other types. And it is minimum for Type E bridge. In addition, the work is further extended to perform a modal analysis to obtained the natural frequency on different bridge deck, which is as shown in Figure 9. Figure depicted the natural frequency on different types of bridge deck is increasing with increasing a mode shape.

3. Conclusion

Following conclusions has been drawn on the basis of results obtained from this work of simplified models of the bridge:

- The maximum total deformation is increases with increasing of the bridge span length and it has been observed that the minimum deformation occurs in Type-E and Type D bridge as compare to other types.
- The maximum von-mises stress and strain are increases with increasing of the bridge span length and it has been observed that the in Type-D bridge gives the less von-mises stress and strain as compare to other types.
- Also, the maximum shear stress and strain energy are increases with increasing of the bridge span length and again it has been observed that the in Type-D bridge gives the less shear stress and strain energy as compare to other types.
- From above all conclusions, it has been observed that the in Type-D bridge is suitable for future application as compared to the traditional bridge structure.
- It has also been concluded that, the use of steel-based composite bridge decks is suitable for various aspects.
- The modal analysis result shows that, as the span length increases, the natural frequencies are also increases.
- The natural frequency on different types of bridge deck is increasing with increasing a mode shape. In this present work the maximum frequency is obtained at Types-D bridge deck.
- A further research for development of new technologies in composite construction such as CRF slab, slim-floor slabs with semi continuous connections to the columns, new steel sheets or systems to minimize the time of erection and assembly is desirable.

References

[1] B. Jeswani and D. Budhlani, "A Review Paper on Analysis and Design of Bridge Components using Staad Pro," Int. Res. J. Eng. Technol., vol. 7, no. 6, pp. 4707–4709, 2020.

[2] T. C. Nwofor and B. C. Nnoaham, "Analysis of Bridge Deck for Abnormal Load using the Acceleration-Displacement Ratio for a Balcony Function," SSRG Int. J. Civ. Eng., vol. 5, no. 3, pp. 35–41, 2018.

[3] A. K. Ajay, "Parametric Study On T-Beam Bridge", Int. Res. J. Eng. & Technol., vol. 8, issue 6, pp. 234–240, 2017.

[4] P. V. Rao, "Analysis of Girder Bridge with IRC And IRS Loadings – A Comparative Study", Int. Res. J. Eng. & Technol., vol. 6, issue 8, 2017.

[5] A. R. Powar and V. G. Khurd, "A Study on Dynamic Response of Bridge Deck Slab," Int. J. Res. Appl. Sci. Eng. Technol., vol. 5, no. XII, pp. 111–116, 2017.

[6] M. Balamurugan and N. Hemalatha, "Static and Dynamic Analysis of Tee Beam Bridge Deck," Int. J. Sci. Res. Dev., vol. 5, no. 04, pp. 1204–1207, 2017.

[7] G. H. Eom, S. J. Kim, T. H. Lee, and J. H. J. Kim, "Design optimization and structural performance evaluation of plate girder bridge constructed using a turn-over process," Materials (Basel)., vol. 10, no. 3, pp. 1–14, 2017.

[8] S. N. K. Kanth, V. A. Prasad, "Design and Analysis of Bridge Design Using STAAD.Pro", International Journal of Research Sciences and Advanced Engineering, Vol.2, Issue.12, pp.211-224, 2015.

[9] T. P. Kumar, G. P. Ram, "Analysis and Design of Super Structure of Road Cum Railway Bridge Across Krishna River", International Journal of Engineering & Science Research, Vol-5, pp.830-838, 2015.

[10] M. S. Kamatagi, "Comparative Study of Design of Longitudinal Girder Of T-Beam Bridge", Int. Res. J. Eng. & Technol., vol. 02, issue, 06, 2015.

[11] A. Ahmed, ''Comparative Analysis and Design Of T-Beam and Box Girders", Int. Res. J. Eng. & Technol., vol. 6, issue 8, 2015.

[12] P. Lu, F. Li, and C. Shao, "Analysis of a T-frame bridge" Math. Probl. Eng., vol. 2012, pp. 1–15, 2012.

[13] F. Abbasi and S. Pahwa, "Dynamic Analysis of Suspension Bridge using Matlab Simulation," Int. J. Sci. Res., vol. 6, no. 7, pp. 1175–1178, 2015.

[14] I. Dzolev, D. Ladjinovic, A. Raseta, A. Radujkovic, "Pushover analysis of RC bridge designed according to EN 1998-2", Construction of Unique Buildings and Structures, pp.116-125, 2014.

[15] S. Kulkarni and U.N. Karadi, "Nonlinear Analysis of Existing RC Bridge Using SAP 2000", Civil and Environmental Research, Vol.6, No.12, pp.30-37, 2014.

[16] P. Karthiga, S. Elavenil, K. M. P. Dinesh, "A Comparison of Road Over Bridge and Rail Over Bridge", Vol. 7, Issue 4, p35-47, 2014.

[17] C. Li, H. Hao, H. Li, "Life-Cycle Seismic Response Analysis of RC Bridges Considering Chloride Induced Corrosion", Australian Earthquake Engineering Society 2014 Conference, pp.1-9, 2014.

[18] S. Cao, W. Yuan, "Modified generalized pushover analysis for estimating longitudinal seismic demands of bridges with elevated pile foundation systems", Latin American Journal of Solids and Structures, pp.2696-2711, 2014.

[19] F. Paolacci, R. Giannini, S. Alessandri, L. D. Sarno, G. D. Corte, R. D. Risi, M. Erdik, C. Yenidogan, A. Marioni, F. Taucer, P. Pegon, R. Ceravolo, "Seismic analysis and retrofitting of an existing R.C highway bridge: investigation through pseudo-dynamic", World Conference on Earthquake Engineering, September 2012, Lisboa.

[20] Alireza Rahai, Babak Alipour Gorji and Farzad Hatami, "Seismic evaluation of pre-stressed concrete bridges by using DCM, CSM and spectrum analysis", World applied sciences journal, Vol. 8, No. 2, pp. 210-216, 2010.

[21] D. A. M. Jawad, "Analysis of The Dynamic Behavior of T-Beam Bridge Decks Due to Heavyweight Vehicles", Emirates Journal for Engineering Research, vol. 15, issue 2, pp. 29-39, 2010.

[22] S. Z. Al-sarraf, A. A. Ali, and A. A. Rana, "Analysis of Composite Bridge Superstructures Using Modified Grillage Method," Eng. Tech. J., vol. 27, no. 5, pp. 942–953, 2009.

[23] R. Monteiro, R. Ribeiro, M. Marques, R. Delgado, A. Costa, "Pushover Analysis of RC Bridges Using Fiber Models or Plastic Hinges", The 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China.

[24] M. E. Onyia, "Finite Element Model for the Analysis of Bridge Decks" Nigerian journal of technology vol 27 no.1 march 2008.

[25] M. N. Mahmood and A. T. S. Al-Ghabsha, "Dynamic Analysis of Bridges Subjected to Moving Vehicles," AL-Rafdain Eng. J., vol. 14, no. 4, pp. 34–50, 2006.