

# Dynamic analysis of three cell R.C. box girder with references to IRC loading

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**Abstract**—Guided by the nonlinear method and varying IRC loading scenarios, this dissertation focuses on the dynamic analysis of multi-cell box girder bridges utilizing CSI Bridge software to investigate the responses of three geometries: rectangular, circular, and trapezoidal, in accordance with Indian Road Congress (IRC) loading standards. By incrementally applying moving loads, truck loads, prestress, and axial forces in line with the Indian Road Congress guidelines, the study evaluated the behavior of three cell box girder bridges concerning support reaction shear forces, displacement using the nonlinear time history method while considering standard IRC Class AA and Class 70R wheeled loads. The results of this study indicate that the trapezoidal cell experiences less displacement compared to the rectangular cell, while the circular cell exhibits more displacement in comparison to the rectangular cell.

**Key Words:** Dynamic Analysis, IRC loading, multi cellure Box girder, non-linear method

## I. INTRODUCTION

Assessing the dynamic interaction between vehicles and bridges is a captivating subject within the field of bridge engineering. The dynamic impact factor relies on the dynamic characteristics of both the superstructure and the vehicle, including natural frequency, vehicle speed, and various other factors that are challenging to consider. (A. R. Khalim, 2014) The box-girder bridge has gained significant popularity recently because of its effective serviceability, stability, and structural efficiency. (Monu Kumar, 2021) (P. Agarwal P. P., 2022) The examination and planning of box-girder bridges is quite intricate due to their three-dimensional behavior, which includes torsion, distortion, and bending in both longitudinal and transverse directions (Monu Kumar, 2021) A bridge is a construction created to carry road

vehicles or various moving loads across an obstruction or other infrastructure. Box-girder bridges are gaining popularity these days and have firmly established their presence in medium and long-span bridge designs (P. Agarwal P. P., 2022) Box girders can be classified in several ways according to their method of construction, usage, and shape. They can be designed as single cell, double cell, or multicellular configurations. A closed box girder is constructed together with the deck in a monolithic manner, while an open box girder has the deck made separately afterward. Box girders may also adopt rectangular, trapezoidal, or circular forms.

A box girder is advantageous for curved bridge systems because of its excellent torsional strength. In bridges with mild curvature, the effects of curvature on bending, shear, and torsional shear stresses can be neglected if they fall within an acceptable range. One approach to simplify the analysis and design process is to treat horizontally curved bridges as straight, under certain limitations. (P. Agarwal P. P., 2022)

The dissertation work employs dynamic analysis of multi cellure box Girder Bridge based on CSI bridge software to examine the responses of three cell rectangular, circular and trapezoidal geometries with references to Indian Road Congress (IRC) loading. This study examines the dynamic characteristics and behavior of multi cellure box girder bridges with respect to support reaction shear force, displacement using nonlinear tie history method considering standard IRC Class AA wheeled and Class 70R wheeled loading was scrutinized.

*A. Non-Linear Time History Method*

The time history analysis method, when applied, should rely on a suitable ground motion and adhere to recognized principles of dynamics. This method examines the structure's dynamic response at each time increment while its base experiences a defined ground motion time history. Time history analysis is a computational simulation technique utilized to forecast the dynamic behavior of structures by considering actual loads that change over time. In contrast to simplified static analysis, which posits a constant and instantaneous application of loads, time history analysis recognizes the fluctuating nature of forces throughout time.

## II. LITERATURE REVIEW

Brinissat Marame, Rajmund Kuti, Richard P Ray, (2024) “Truck Load Positions Effect on Dynamic Behavior of Fractured Steel Box Girder Bridge”

This study examines the dynamic characteristics of the Szapáry Bridge, a steel box girder structure, which has a damaged girder that experiences moving truck loads. First, a finite element model is employed to simulate the performance of the seven-span continuous bridge during static loading tests. The findings from the parametric analysis underscore that multiple factors, such as the velocity and placement of trucks, the length of bridge spans, and the lateral spacing of trucks, considerably impact the dynamic vibrations of the damaged bridge. These results provide valuable insights into the utility of dynamic response analysis for maintenance based on condition and damage assessment. (Brinissat Marame, 2024)

Raisa Tabassum Ira, (2022) “Analysis and Design of Prestressed Concrete Box Girder Bridge”

In this study, the analysis and design of prestressed concrete box girder bridges are conducted using MIDAS Civil design software, with a prestressed balanced cantilever span chosen for the design. The primary objective of this study is to assess the structural behavior, including bending moments, deflections, forces, compressive strengths, flexural strengths, crack widths at service, principal stresses, and shear stresses of a three-span box girder bridge under various loading conditions, as well as the geometrical and material requirements for the bridge components and their performance throughout different stages of construction. (Raisa Tabassum Ira, 2022)

Preeti Agarwal, Priyaranjan Pal, Pradeep Kumar Mehta, (2022) “Box-Girder Bridges- Modeling and Analysis”

This study introduces a streamlined modeling process for the analysis of simply supported reinforced concrete (RC) box-girder bridges, encompassing configurations such as straight, skew, curved, and skew-curved geometries, within the context of Indian loading standards. The modeling methodology is anchored in the Code provisions outlined in Indian Road Congress (IRC) 6:2017 and IRC 21:2000. A variety of parameters, including span lengths, span-depth ratios, and cell quantities, are systematically evaluated to meet specific project requirements. The methodology is specifically applicable to the analysis of RC box-girder bridges with spans up to 50 meters, excluding the construction processes. (P. Agarwal P. P., 2022)

Abdul Khader A.S, A.R. Pradeep, (2019) “Parametric Behavior of Box Girder Bridges under Different Radius of Curvature & Varying Spans”

This study explores the analysis of an elevated box girder structural system. A parametric evaluation of box girder bridges using Finite Element Method (FEM) techniques showed that as curvature decreases, the responses—including longitudinal stresses at the top and bottom sections, shear stress, torsional moments, bending moments, and deflections—also decrease across the three types of box girder bridges. It has been noted that as the span length increases, the longitudinal stresses at the top and bottom, shear stresses, torsional stresses, bending moments, and deflections rise for these three varieties of box girder bridges. Additionally, it is important to highlight that as the ratio of span length to radius of curvature increases, response parameters such as longitudinal stresses at the top and bottom, shear stresses, torsional stresses, bending moments, and deflections also increase for all three types of box girder bridges. (Abdul Khader A.S, 2019)

Punil Kumar M P, Shilpa B S, (2016) “Dynamic analysis of box girder bridges”

This analysis includes studying the bridge's performance with and without the imposition of dynamic loads. By introducing moving loads, such as vehicles or truck loads, along with pre-stress and axial forces, the effects on the bridge model are meticulously analyzed. Box girder bridges can significantly affect the overall behavior of the

structure, particularly over short to medium spans like 30m, 40m, and 50m. In this project, we investigate the behavior of box girder bridges concerning support reactions, shear forces, bending moments, torsion, and axial forces under the stipulations of standard IRC Class AA loading, employing the finite element method for analysis. (Punil Kumar M P, 2016)

III. OBJECTIVES

A. Research objectives

The objectives of research are as follows:

1. To study the behaviour of Rectangular, Trapezoidal and circular multicellular box girder bridge considering different IRC loading.
2. To carry out Dynamic analysis using non-linear method for multicellular RC box Girder using CSI Bridge software.

IV. ANALYSIS

A. Geometrical details of multi cellure R.C box girder

The geometrical details considered for the analysis of multi cellure R.C box girder. (See Table. 1)

Table 1: Geometrical details of multi cellure R.C box girder

Parameters	Particulars
Span of bridge	30 m
Total width of bridge	12.6 m
Height of bridge	2 m
Thickness of pavement	0.08 m
Thickness of slab	0.3 m
Width of carriageway	7.5 m
Barrier	0.38 m
Multicellular cells	Three Cell (Rectangular, Circular, Trapezoidal)
Load Case	IRC Loading (Class AA Wheeled, Class 70 R Wheeled)
Grade of steel	Fe 500
Grade of concrete	35 Mpa

B. Modeling of multi cellure box Girder Bridge

This dissertation work is about the dynamic analysis of the multi cellure box girder bridge model with different geometry using non- linear method using CSI bridge software. Modeling and Dynamic analysis adopting nonlinear time history method by using CSI bridge software for the various multi cellure models like rectangular, circular and trapezoidal geometry are calculated for optimum geometry considering Class AA wheeled and Class 70R IRC loading according to IRC: 6. Analysis Results obtained from this models was enhanced according to their behaviour for bending

moment, shear force and displacement are extracted considering different moving load case along with stress variations along different section. Total 6 models of multi cellure box girder bridge were developed considering Class AA wheeled and Class 70R wheeled IRC loading for rectangular box girder (fig. 1, a), circular box girder (fig. 1, b), and trapezoidal box girder (fig. 1, c).

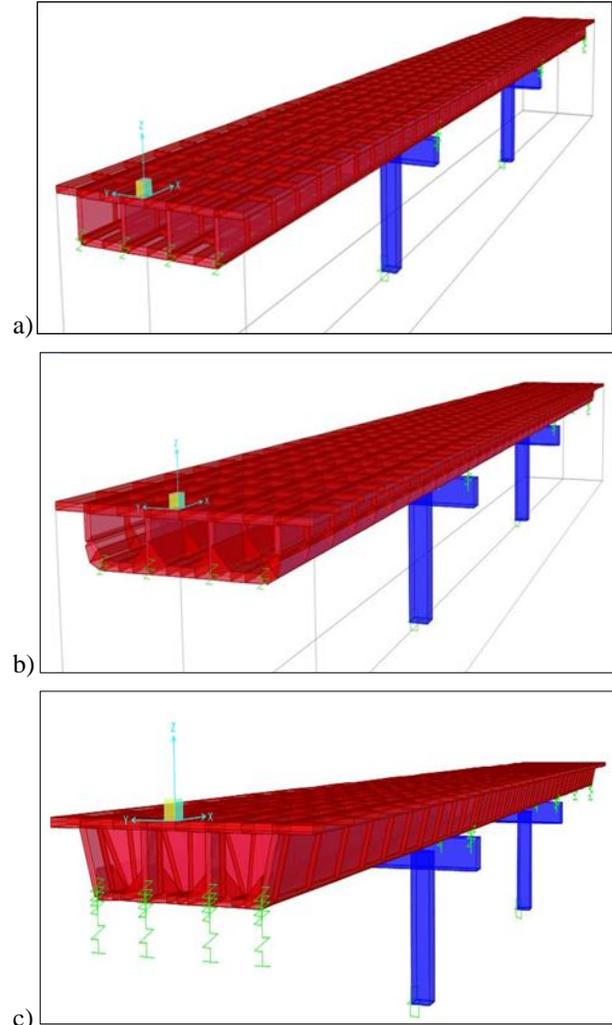


Fig. 1. Types of multi cellure models  
 a) Rectangular box girder, b) Circular box girder,  
 c) Trapezoidal box girder.

V. RESULTS AND DISCUSSION

The preliminary results regarding the displacement are within the acceptable limits for the evaluated models of multi-cell box girder bridges. This study seeks to perform a dynamic analysis of the box girder bridge through a nonlinear time history method incorporating moving load scenarios for IRC class AA wheeled

vehicles and IRC class 70 R wheeled vehicles. The variations in displacement values among the different models generated under IRC class AA loading are depicted visually in the accompanying graphs.

The analysis results show that rectangular box girder has 32.25% more vertical displacement than trapezoidal box girder. While, circular box girder has 53.06% more vertical displacement than rectangular box girder. Hence, circular box girder has 67.13 % more vertical displacement than other section and trapezoidal box girder have 43.27% less vertical displacement than other section for class AA (See fig. 2, a) and Class 70R IRC (See fig. 2, b) loading.

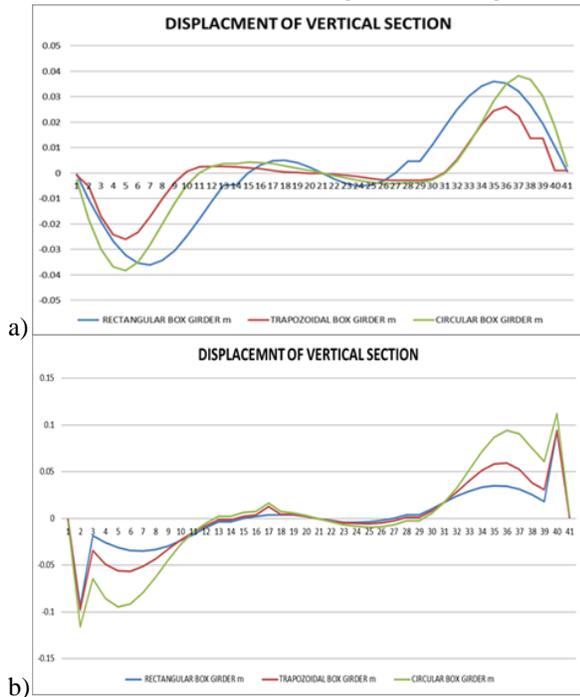


Fig.2. Vertical Displacement of rectangular, trapezoidal and circular section for a) IRC Class AA wheeled and b) IRC Class 70 R wheeled

The analysis results shows that Rectangular Box Girder has 63.73% more Traversed Displacement than Trapezoidal Box Girder. While, Circular Box Girder has 56.23% less Vertical Displacement than Trapezoidal Box Girder. Hence, Circular Box Girder have 81.2 % less Traversed Displacement than other section for class AA (See fig. 3, a) and Class 70R IRC (See fig. 3, b) loading.

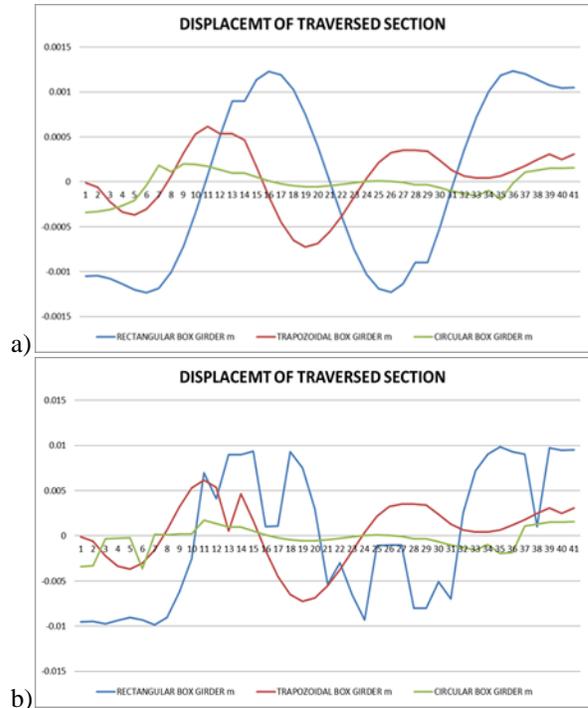
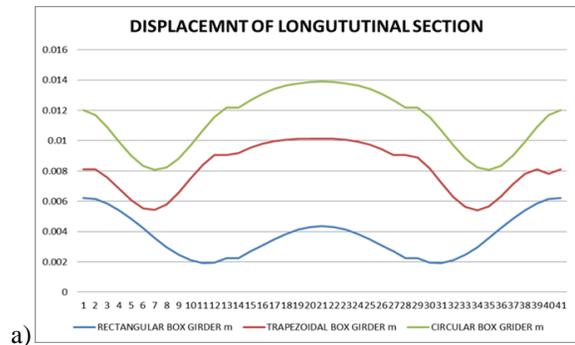
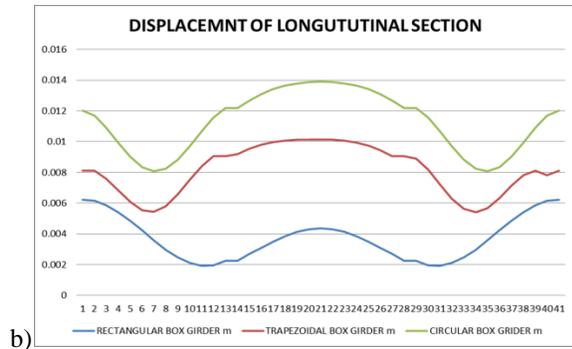


Fig.3. Traversed Displacement of rectangular, trapezoidal and circular section for a) IRC Class AA wheeled and b) IRC Class 70 R wheeled

The analysis results shows that Rectangular Box Girder has 45.1% less Longitudinal Displacement than Trapezoidal Box Girder. While, Circular Box Girder has 76.96 % more Vertical Displacement than Rectangular Box Girder. Hence, Circular Box Girder have 66.23 % more vertical Displacement than other section and Rectangular Box Girder have 58.2 % less vertical Displacement than other section for class AA (See fig. 4, a) and Class 70R IRC (See fig. 4, b) loading.





b) Fig.4. Longitudinal Displacement of rectangular, trapezoidal and circular section for a) IRC Class AA wheeled and b) IRC Class 70 R wheeled.

This dissertation intends to provide comprehensive recommendations for designers to consider the impact of moving loads dynamically. The dynamic analysis utilizes a nonlinear approach with CSI Bridge software, addressing the key elements that affect the dynamic behavior of bridges while eliminating non-essential predictors in relation to IRC load scenarios. The following predictions emerged after completing the dissertation work:

- The Circular Box Girder experiences a vertical displacement that is 67.13% greater than that of other sections, while the Trapezoidal Box Girder demonstrates a 43.27% reduction in vertical displacement compared to other sections for IRC class AA wheeled loads. (See Table 2)
- For IRC class 70 R wheeled loads, the Circular Box Girder shows 66.23% more vertical displacement than other sections, whereas the Rectangular Box Girder exhibits a 58.2% decrease in vertical displacement compared to other sections. (Table 2)
- As a result, the Circular section accounts for 37.28% more displacement than other sections, while the Trapezoidal section shows 50.23% less displacement than other sections.
- Furthermore, the IRC class AA wheeled loading results in lower displacement than the IRC class 70 R wheeled loading.

Table 2: Displacement obtained from analysis of multi cellure box Girder Bridge for different IRC loading.

VI. CONCLUSION

The following conclusions have been drawn based on the results obtained from the analysis of three cells Box Girder Bridge for different IRC loading:-

- 1)The reduction in displacement is greater for trapezoidal cells compared to rectangular ones, indicating that trapezoidal cells result in less displacement than rectangular cells.
- 2)The increase in displacement is higher for circular sections than for rectangular ones, demonstrating that circular cell produce more displacement than rectangular cells.
- 3)The highest vertical deflection is observed near the midpoint of the central lane for all six geometries of multi-cell box girders.
- 4)The displacement resulting from various loading conditions and at service levels remains well within the acceptable limits as per IRC guidelines.

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Span	Cell	Class AA Wheeled	Class 70 R Wheeled
30 m	Rectangular	0.0351	0.0360
30 m	Circular	0.058	0.0619
30 m	Trapezoidal	0.0253	0.0260

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