STRUCTURAL BEHAVIOUR OF CURVED BOX GIRDER BRIDGE

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Abstract: *Curved box girder bridge is extensively used in metro rail bridges. It is vital to build bridge constructions with curved plans as horizontally curved alignments for railway bridges and urban interchanges are becoming more common. Torsional moments are mostly present because of the influence of the box girders' horizontal curvature. This study's primary goal is to evaluate the analytical results of horizontally curved box girder bridges having different parameters. In this paper, the numerous models for curved box girders are analyzed using MIDAS software for different parameters such as span lengths, radius of curvature, and loadings. The results obtained are in terms of shear force, bending moment, torsional moment, and midspan deflection. It is observed from the results that there is no significant change in bending moment and shear forces for each radius of curvature but with increasing Radius of curvature there is an appreciable decrease in the value of torsional moment.*

Keywords:- Curved box girders; prestressed concrete; Torsional behaviour; mid-span deflections; finite element method, MIDAS Software.

1. INTRODUCTION

Curved box girder bridge is used in metro rail bridges and highway bridges. It is made up of structural steel, reinforced concrete, or pre-stressed concrete and the box is a single-cell, double-cell, multi-cell, and multi-spine with rectangular, circular, or trapezoidal in cross-section. In box girder bridges the girders is in the form of hollow box section. It can also be used for various purposes such as electric supply lines, telephone cables, water supply lines, sewers, etc. and the box girder section has the additional advantage that it is lighter in weight. In the current specifications of the Indian railway code, no separate guideline is available for the curved box girder bridge except for consideration of torsional moment. There are various methods available for the analysis of box girders such as the orthotropic plate theory method, folded plate method, grillage analogy method, finite strip method, finite element method, computer programming & experimental studies. H. Zuwei et al.[1] used grillage analogy method for multi-cell box girder with transverse slope. B. Al-Masoud et. al.[2] used folded plate method for the analysis of roofs and cellular bridges and compare the result with various methods. W. Feng et. al.[3] developed finite strip method to analyze the Single Cell Curved Box Girder Bases. C. P. Heins et al.[4] developed a program for the analysis of simple or multi-span composite or non-composite steel box girder bridges R.Shreedhar et. al.[5] performed a Comparative study of the Grillage method and FEM method of the RCC Bridge Deck. K. Shushkewich [6] has developed an approximate analysis of a concrete box girder bridge by using a folded plate, finite strip, and finite element method by using some simple membrane equations. N. Gupta et. al.[7] Analyzed RCC curved box girder bridges by using a finite element approach. S. Gajera et. al.[8] performed a Parametric Study of Horizontally Curved Pre-Stressed Concrete Continuous Box Girder Bridges. A. Sarode et. al.[9] analyzed the Torsional Behavior and Constancy for Horizontally Curved Box Girders. D. B. Kulkarni et. al.[10] performed Dynamic analysis of RCC curved beam using the software. R. Jain et. al.[11] performed Stability analysis and Torsional Behavior of Horizontally Curved Box Girders. K. M. Sennah et. al.[12] investigated approximate and conservative methods for the analysis and design of straight and curved box girder bridges. A. S. Khairmode[13] Analyzed the Prestressed Concrete Multi-Cell Box Girder Curved Bridge. M. Pathak [14] used SAP software for presenting several behaviours for horizontally curved RCC box bridges. R. Jaiswal et. al.[15]Analyzed the elevated Metro Bridge as per IRC 70R loading and it can be done by using STAAD.Pro software.

In this paper, numerous models are analyzed for different parameters such as radius of curvature, span length, and various loadings. Torsional moments predominate because of the horizontal curvature of the box girders. Also due to loading, more deflections are occurred at mid-span. Hence the flexural behaviour, torsional behaviour, stability, and mid-span deflections of the curved box girders of different parameters are discussed in this paper.

2. SCOPE OF THE STUDY

a) To analyze the three-dimensional finite element models of the Box girder for different parameters such as span length, the radius of curvature, depth of the box girder under Metro railway loadings

b) To compare the variation of bending moments, torsion, and shear force due to changes in the Radius of curvature.

c) To find variation in deflections at the mid-span of the box girder and twist of the cross-section.

3. METHODOLOGY

A parametric study of curved Prestress box girder is undertaken. For study purposes, a 20m - 45m span of bridge curved in plan is considered. single cell Rectangular Curved box girder with Prestressed configuration is considered. Parameters such as span, and curvature are varied, and span to depth ratio is constant for analysis, effects of these changes on the shear force, torsional moment, bending moment, and deflection are carried out.

3.1 Design Consideration -

Span Length = 20 m

Deck width = 9.6m.

The radius of Curvature = $\frac{a^2+h^2}{2h} = \frac{10^2+0.67^2}{2*0.67}$ = 75 m

Span to Depth Ratio = 16

Modulus of Elasticity E= 35.355×10^9 N/m^2

Density ρ= 2400 kg/m^3

Nine prestressed tendons are located at the girder soffit.

The modulus of elasticity for the tendons is 200×10^9 N/m^2

3.2 Design Load

The Loading considered in the analysis are –

A. **Self-weight (DL) of box girder: -** A dead load of different components of the superstructure is considered by using a standard unit weight based on the IRS code provisions. This includes the self-weight of the deck slab and girders.

B. **Superimposed dead load (SIDL) form crash barriers and wearing coat: -** the elements which are taken into consideration for calculating super-imposeddead load such as Cables, Handrail, Parapet, Cable Trays, Track Plinth, Miscellaneous (E&M) Rail and Pad, etc.

C. **Live Load (LL): -** Live Load (LL) is taken as per the IRS CBC Loading. DFC Combination-1 for Broad Gauge is considered. The appropriate impact factors as per Indian Railway Standards are applied to live load for different span lengths.

4. FINITE ELEMENT MODELING AND ELEMENT DESCRIPTION

For finite element modeling MIDAS Software is used. For all kinds of linear and nonlinear stress, dynamic, and thermal/field issues, the MIDAS system utilizes finite element analysis techniques to deliver exact solutions. The study of the specified problem is performed by the effective finite element analysis using MIDAS Civil software. The thick shell surface geometry is used to simulate the box girder's components, which are then discretized by creating a mesh of elements with four nodes, thicknesses, and material properties specified per IRS CBC 1997.[16].

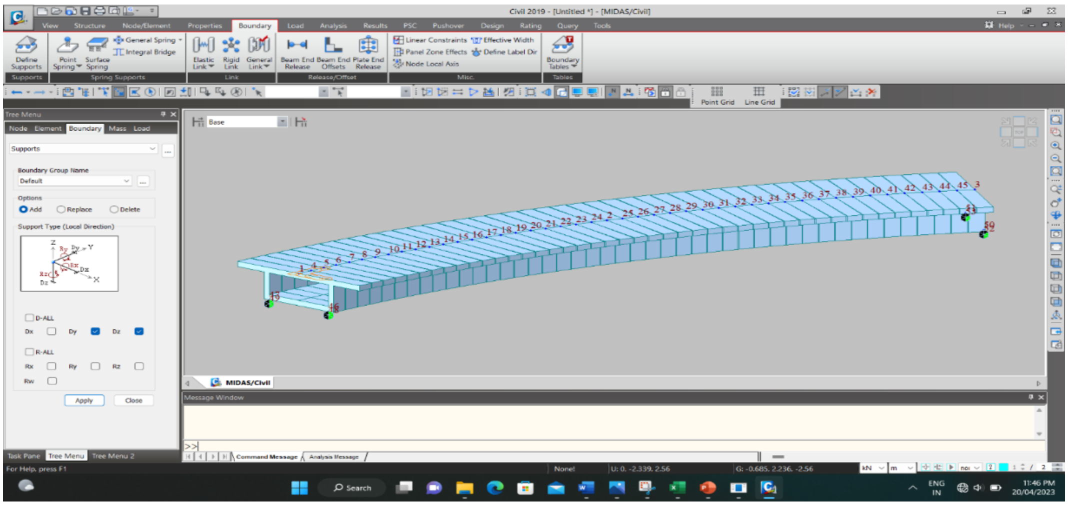

Fig. Curved Box girder model developed with MIDAS.

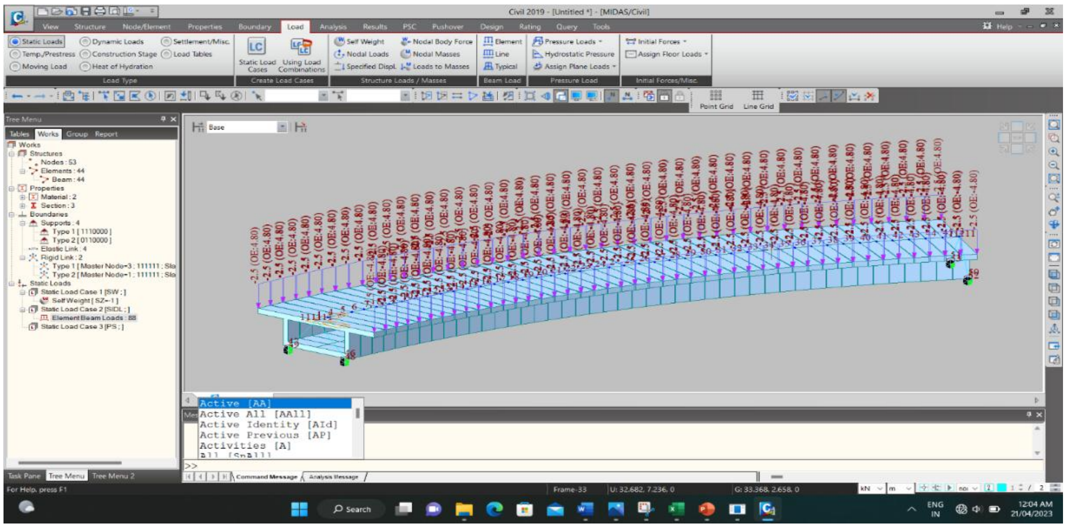

Fig. Model with load application

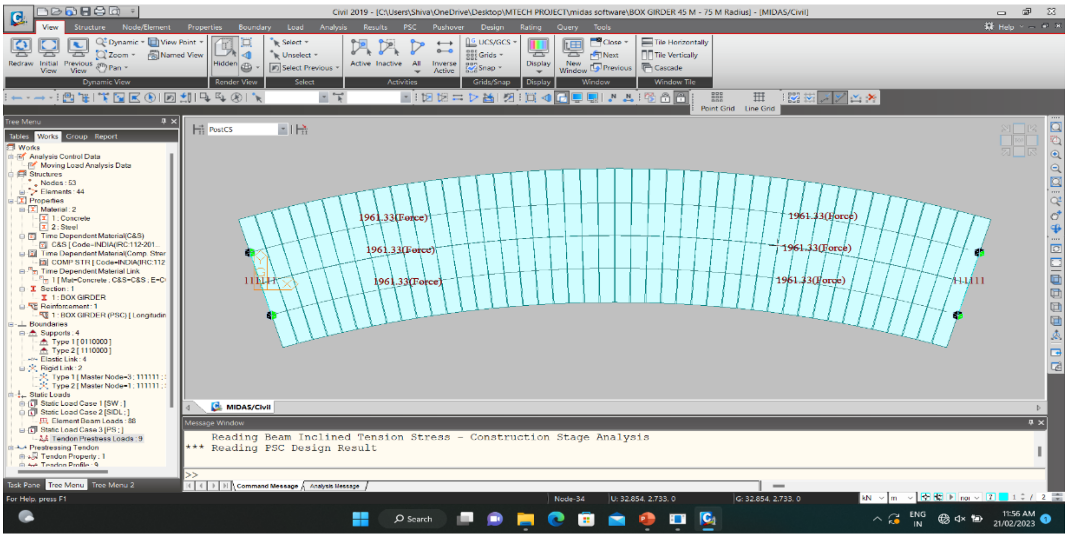

Fig. Model with Tendon Prestress load

5. RESULTS AND DISCUSSION

The horizontally curved box girders of span lengths 20m to 45m with a radius of curvature 75m, 100m, 200m, and 300m. A total of 24 models are analyzed using the finite element analysis method. MIDAS civil software is used to carry out the analysis and the results for torsional moments, mid-span deflections bending moments and shear forces the reactions for Dead Load, Super-imposed Dead Load, and Live Load are presented.

a) Variation in torsion, bending moments and shear against span radius.

The maximum torsion, bending moments, and shear forces for various span lengths and radii are compared.

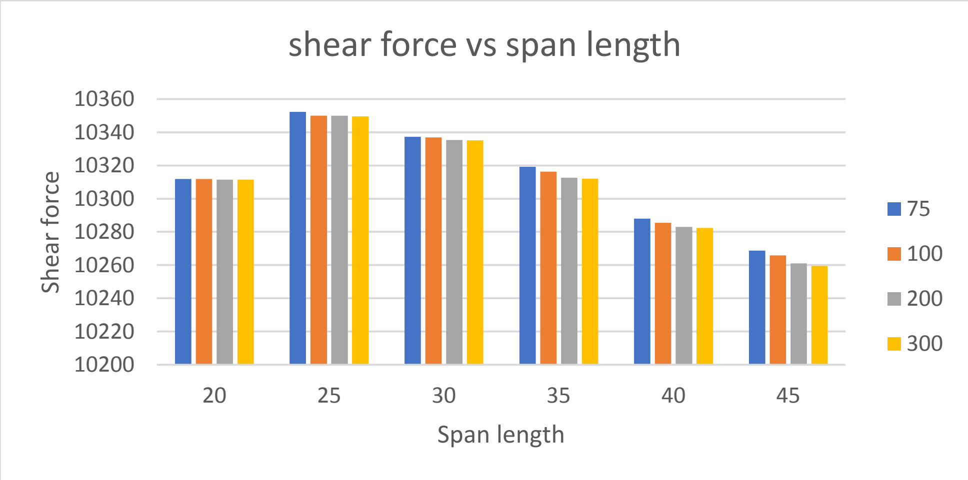

Fig. Variation in shear force for various span lengths and radii

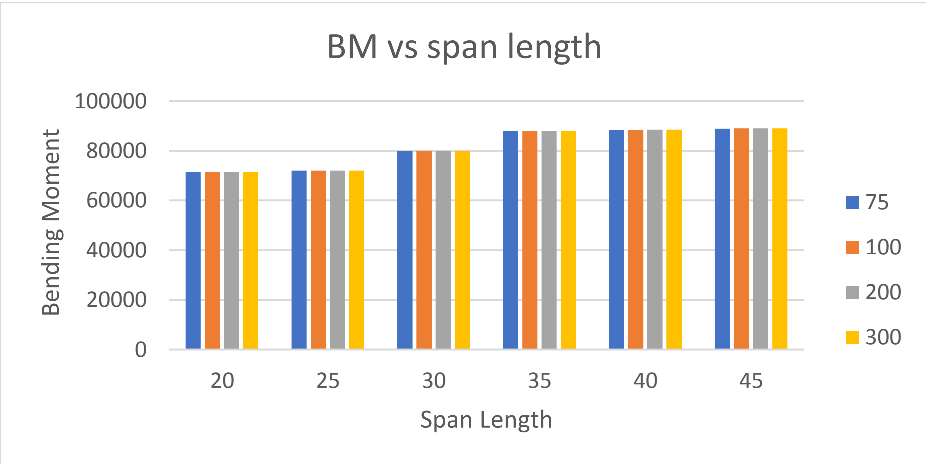

Fig. Variation in Bending Moment for various span lengths and radii

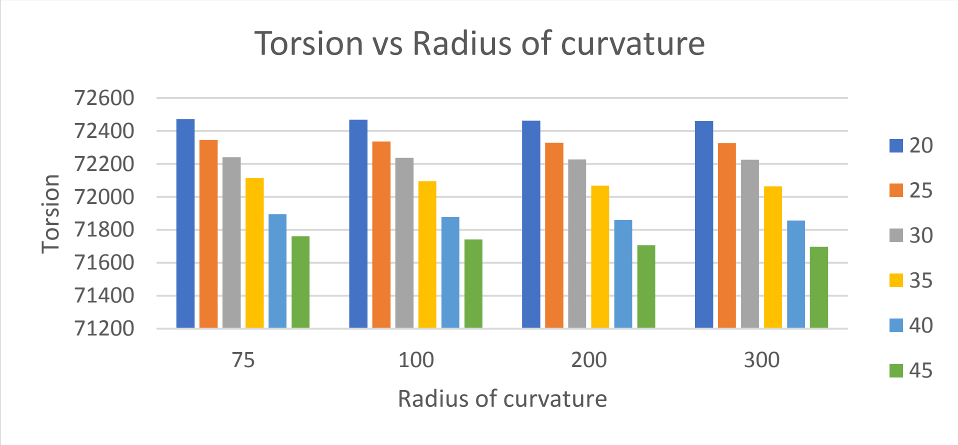

Fig. Variation in Torsion for various span lengths and radii

From the above figures, it is observed that there is no significant change in bending moments and shear forces for a span with different radii, but the torsional moments vary greatly due to the curvature effect. There is a tremendous increase in torsion with decreasing span radius.

b) Mid-span deflections

The maximum Mid-span deflection for various span lengths and radii is shown below.

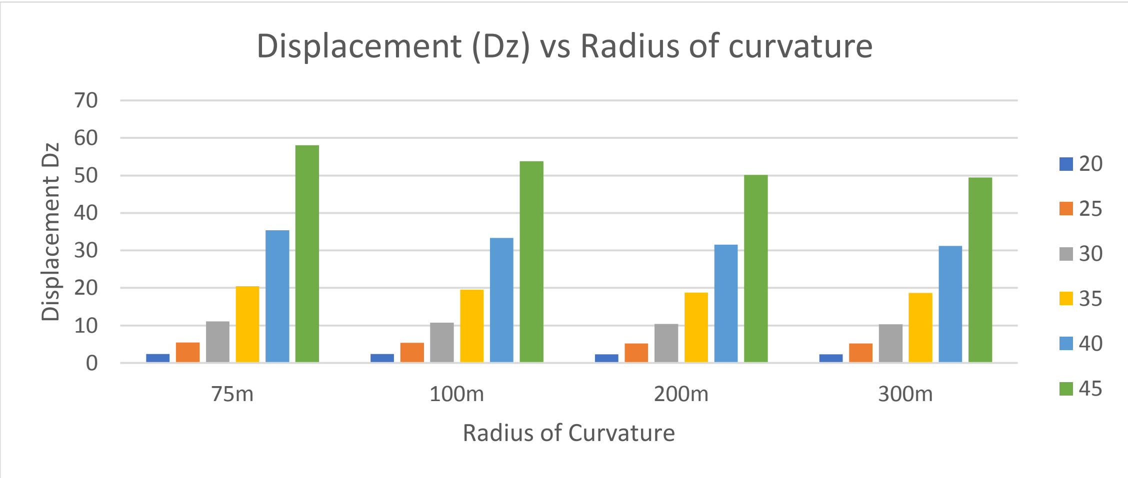

Fig. Variation in Mid-span deflection for various span lengths and radii

Due to the radius of curvature, a torsional moment occurs. The torsional moment caused the deflection at mid-span is more as compared to other locations. It can be observed that mid-span deflection increases with increasing span length and decreases in span radius.

6. CONCLUSIONS

In this paper numerous curved box girder superstructure models are analyzed for the various parameters such as span lengths, the radius of curvature, and loading are carried out using MIDAS Finite Element Analysis software to access the more accurate bending moments, shear, torsion, and mid-span deflections. The following are the findings of this investigation.

1. It can be observed that there is no significant change in bending moment and shear forces for a span length for different Radius of curvatures.

2. The torsional moment increases remarkably with a decrease in the radius of curvature of the box girder. Also, the torsional moment increases with a decrease in span length. Significant change can be seen in torsional moments when the radius is below 200m and fewer variations are observed as the radius increases above 200m.

3. It is observed that there are considerable variations in the mid-span deflection of curved box girder bridge

4. It can be observed that mid-span deflection is in negative correlation with radius of curvature Mid-span deflection increases with a decrease in radius of curvature and an increase in span length.

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