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Research Paper

Parametric Behaviour of Box Girder Bridges under Different Radius of Curvature & Varying Spans

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ABSTRACT

A box girder flyover is a transport system in an urban area with a high capacity, frequency and the grade separation from other traffic. Box girder flyover is used in crowded cities, crossover junctions, and metropolitan areas to transport large numbers of people. An elevated carriage way system is more preferred type of transport system due to ease of construction and also it makes urban areas more accessible without any construction difficulty. Here the present study focuses on the analysis of box girder, of an elevated box girder structural system. From the parametric study on behavior of box girder bridges by using FEM techniques showed that, as curvature decreases, responses such as longitudinal stresses at the top and bottom sections, shear stress, torsional moments, Bending moment and deflection decreases for three types of box girder bridges and there is not much variation for fundamental frequency of three types (SCBG, DCBG & TCBG) of box girder bridges due to the same span length. It is observed that as the span length increases, longitudinal stresses at the top and bottom, shear stresses, torsional stresses, bending moment and deflection increases for these three types of box girder bridges. As the span length is increased, the fundamental frequency decreases for these three types of box girder bridges. Also, it can be significantly noted that as the span length to the radius of curvature ratio is increased response parameters such as longitudinal stresses at the top and bottom, shear stresses, torsional stresses, bending moment and deflection get increased for three types of box girder bridges. As the span length to the radius of curvature ratio is increased the fundamental natural frequency decreases for these three types of box girder bridges.

Keywords: *Elevated Bridge Structure, Box Girder Bridge, Radius of Curvature, Dynamic Analysis, Finite Element Modelling, Radius of Curvature.*

INTRODUCTION

Urban cities in India have experienced phenomenal growth in population in the last two decades. To meet the traffic demands, Flyovers, Tunnels & Elevated Highways etc. have been constructed. The viaduct of a bridge has box girders of single cell, double cell, multi cell etc. There are different structural elements for a typical box girder bridge. Box girders have gained wide acceptance in freeway and bridge systems due to their structural efficiency, ease of construction, better stability, serviceability, economy of construction and pleasing aesthetics. Analysis and design of box-girder bridges are very complex because of its 3D behaviors consisting of torsion, distortion and bending in longitudinal and transverse directions. A typical box girder bridge is shown below in fig.1.01

Fig-1.01: Box girder bridge for vehicular traffic movement

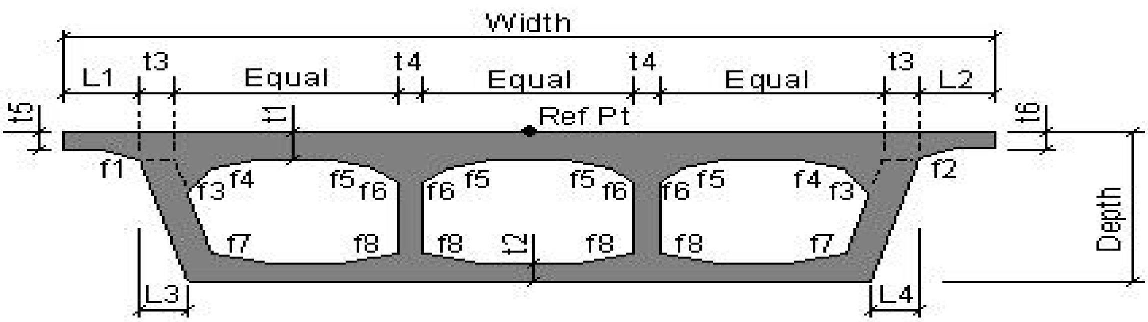
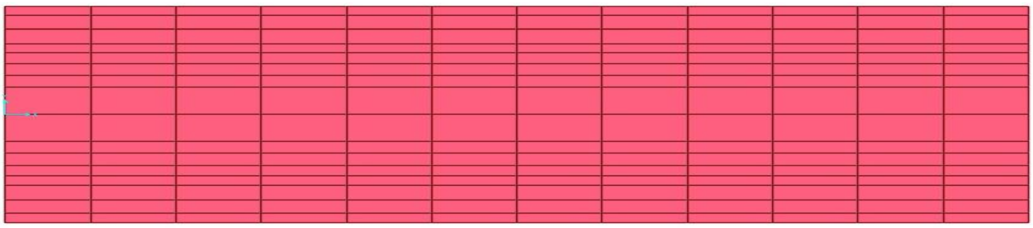
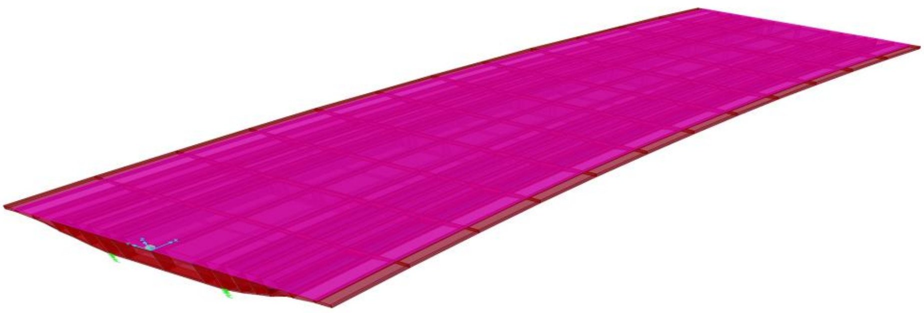


Fig-1.02:Multi cell box girder showing geometric parameters

FINITE ELEMENT MODELLING

The finite element modelling methodology adopted for validation study is used for the present study. The modelling of Box Girder Bridge is carried out using Bridge Module in CSI BRIDGE. The Shell element is used in this finite element model to discretize the bridge cross section. At each node it has six degrees of freedom: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes. The typical finite element discretized model of straight and curved simply supported box Girder Bridge in CSI BRIDGE is shown in Fig-3.04.





PARAMETRIC STUDY

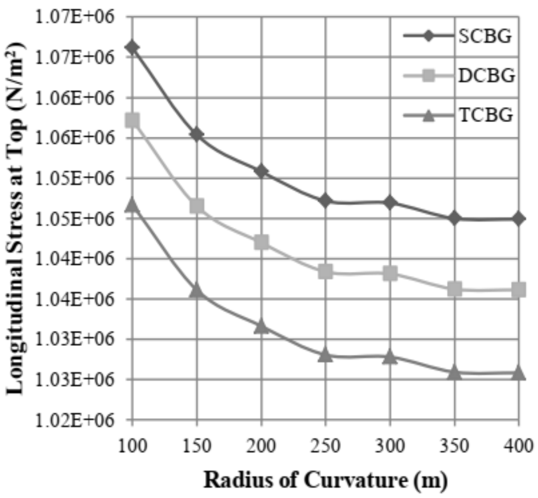
The parametric study is carried out to investigate the behaviour (i.e., the longitudinal stress at the top and bottom, shear, torsion, moment, deflection and fundamental frequency) of box girder bridges for different parameters viz. radius of curvature, span length, span length to radius of curvature ratio and number of boxes.

Radius of Curvature

Two-lane 31 m Single Cell Box Girder (SCBG), Double Cell Box Girder (DCBG) and Triple Cell Box Girder (TCBG) Bridge are analysed for different radius of curvatures to illustrate the variation of longitudinal stresses at the top and bottom, shear, torsion, moment, deflection and fundamental frequency with radius of curvature of box girder bridges.

To express the behaviour of box girder bridges curved in plan with reference to straight one, a parameter **'α'** is introduced. **'α'**is defined as the ratio of response of the curved box girder to the straight box girder.

The variation of longitudinal stress at top with radius of curvature of box girder bridges is shown in Figure 3.06. As the radius of curvature increases, the longitudinal stress at the top side of the cross-section decreases for each type of Box Girder Bridge. Variation of Stress between radius of curvature 100 m and 400 m is only about 2 % and it is same for all the three cases. Stress variation between each type of box girder is only about 1 %. Figure 3.07represents a non-dimensional form of the stress variation for all the three types of box girder. It shows that stress variation pattern is same for all the three types of box girder.



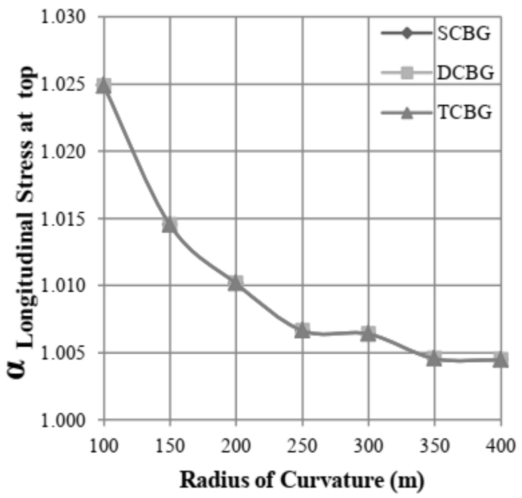
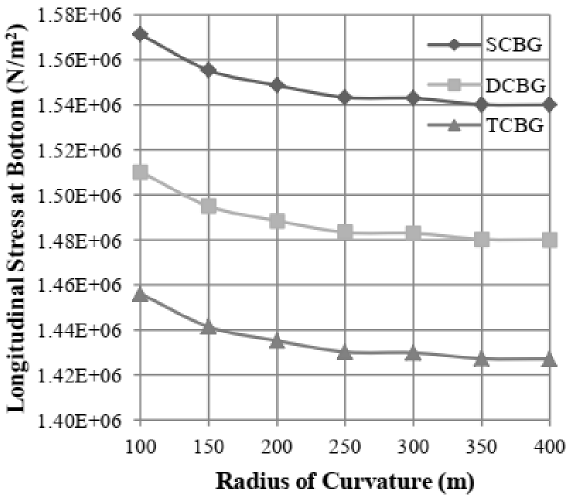


Fig-3.06: Variation of Longitudinal Stress with Radius of Curvature at Top of Box Girder
Fig-3.07: Variation of 'α' Longitudinal Stress at top with Radius of Curvature of Box Girder

The variation of longitudinal stress at the bottom with radius of curvature of box girder bridges is shown in above Figure 3.08. As the radius of curvature increases, the longitudinal stress at the bottom side of the cross section decreases for each type of Box Girder Bridge. Variation of stress between radius of curvature 100 m and 400 m is only about 2 % and it is same for all the three cases. Variation of stress between each type of box girder is about 4 %. Figure3.09 represents the non-dimensional form of the stress variation for all the three types of box girder. It shows that stress variation pattern is same for all the three types of box girder.



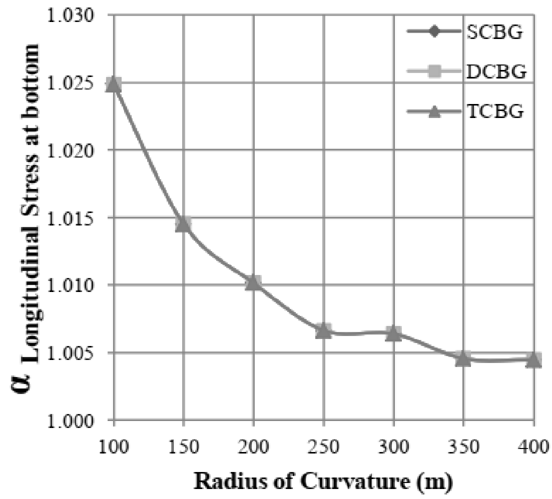
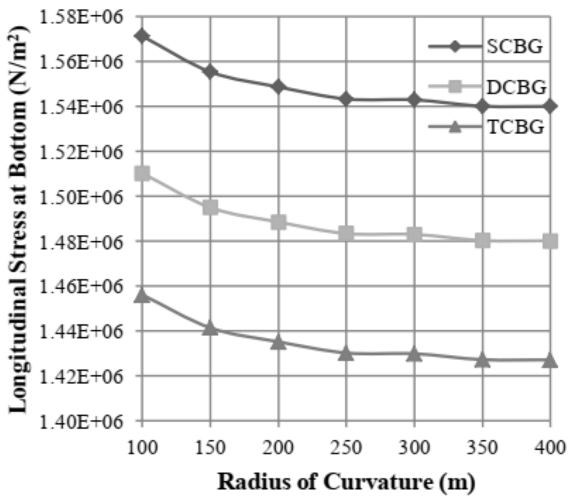


Fig-3.08: Variation of Longitudinal Stress withRadius of Curvature at Bottom of Box Girder,
Fig-3.09: Variation of 'α' Longitudinal Stress at bottomwith Radius of Curvature of Box Girder

The variation of longitudinal stress at the bottom with radius of curvature of box girder bridges is shown in above Figures. As the radius of curvature increases, the longitudinal stress at the bottom side of the cross section decreases for each type of Box Girder Bridge. Variation of stress between radius of curvature 100 m and 400 m is only about 2 % and it is same for all the three cases. Variation of stress between each type of box girder is about 4 %. Figure represents the non-dimensional form of the stress variation for all the three types of box girder. It shows that stress variation pattern is same for all the three types of box girder.



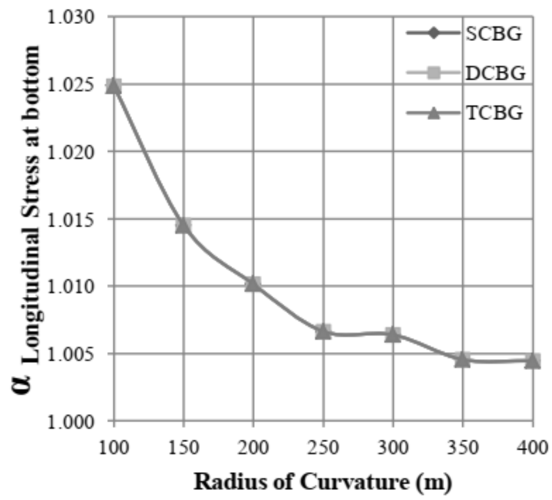
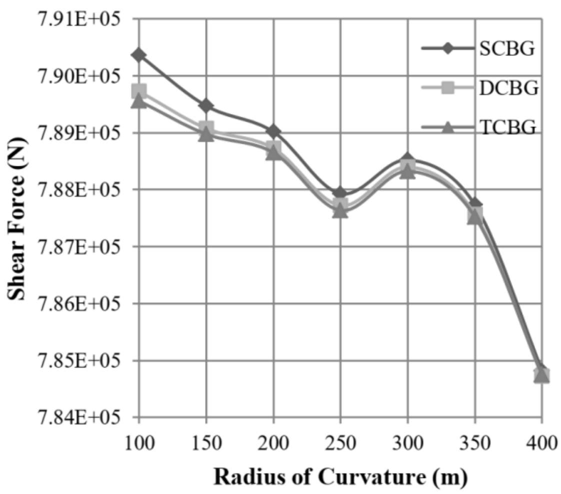


Fig-3.10: Variation of Longitudinal Stress withRadius of Curvature at Bottom of Box Girder
Fig-3.11: Variation of 'α' Longitudinal Stress at bottomwith Radius of Curvature of Box Girder

The variation of shear force on the radius of box girder bridges is shown in the above Figure. As the radius of curvature increases, the shear force of box girder bridge decreases till radius of curvature 250 m and then it is having a slight increase up to 300 m and then decreases from a radius of curvature 300 m for each type of Box Girder Bridge. Variation of shear force between radius of curvature 250 m and 300 m is only about 0.07 % and it is same for all the three cases. Variation of shear force between radius of curvature 100 m and 400 m for each type of box girder is only about 0.7 %. Figure 3.11 represents the non-dimensional form of theshear force variation for all the three types of box girder. It shows that the shear force variation pattern is almost same for DCBG and TCBG and for SCBG; it is 1 % more than DCBG and TCBG.



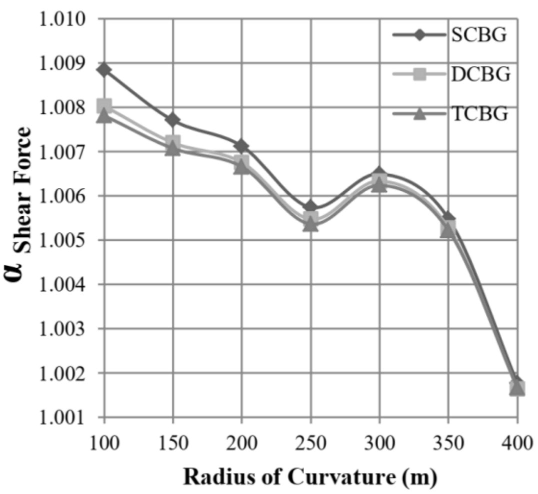
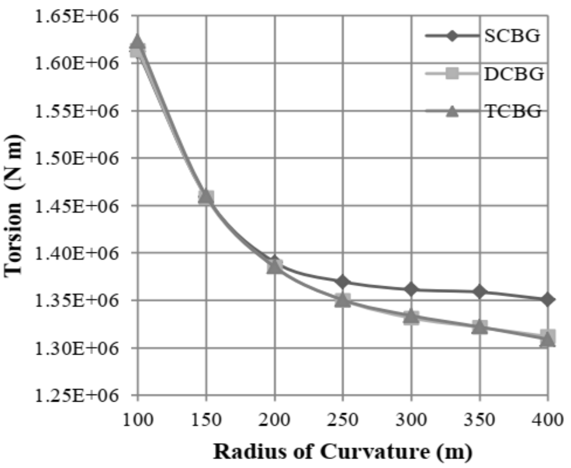


Fig-3.12: Variation of Shear Force with Radius of Curvature of Box Girder
Fig-3.13: Variation of 'α'Shear Forcewith Radius of Curvature of Box Girder

The variation of torsion with radius of curvature of box girder bridges is shown in the above Figure. As the radius of curvature increases, torsion decreases for each type of Box Girder Bridge. Variation of torsion between radius of curvature 100 m and 400 m is about 16-19% for all the three cases and it shows that the radius of curvature having a significant effect in torsion of box girder bridges. Variation of torsion between DCBG and TCBG is very small and variation of torsion between SCBG and others is about 3 %. Figure 3.13 represents a non- dimensional form of the torsion variation for all the three types of box girder. It shows that torsion variation pattern is same and has 3% variation between the three types of box girder.



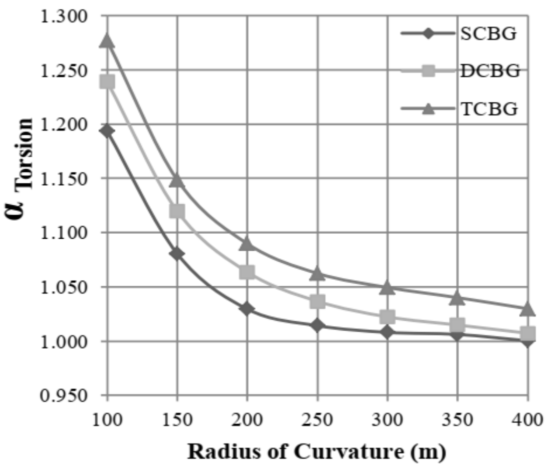
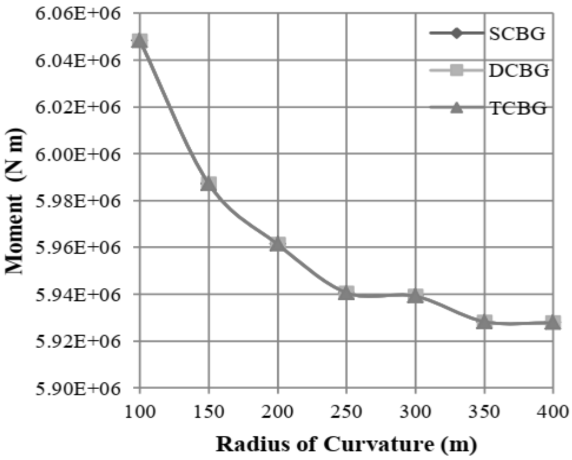


Fig-3.14: Variation of Torsion with Radius of Curvature of Box Girder
Fig-3.15: Variation of 'α' Torsion with Radius of Curvature of Box Girder

The variation of moment with radius of curvature of box girder bridges is shown in above Figure. As the radius of curvature increases, moment decreases for each type of Box Girder Bridge. Variation of moment between radius of curvature 100 m and 400 m is about 2 % for all the three cases. Variation of the moment is very small between three types of box girder. Figure 3.10 represents a non-dimensional form of the moment variation for all the three types of box girder. It shows that moment variation pattern is same between the three types of box girder.



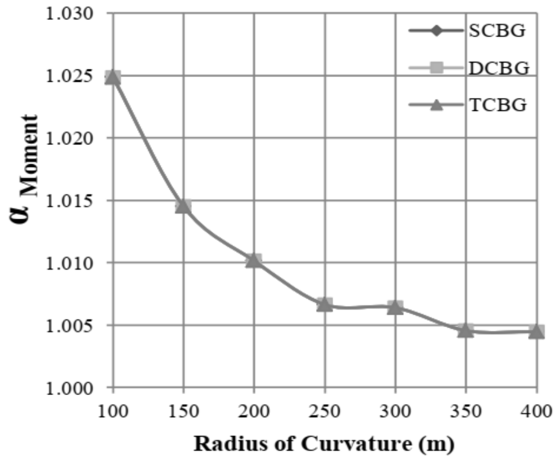
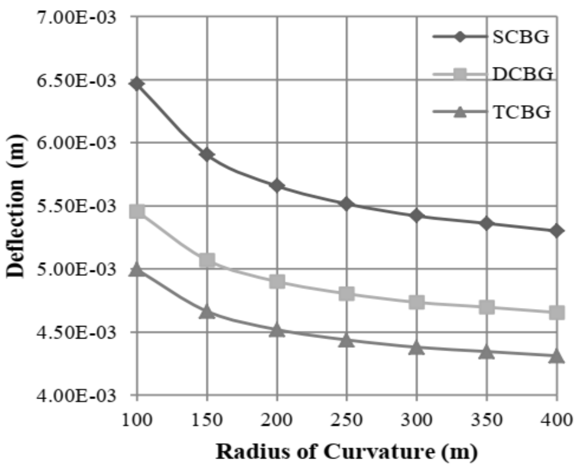


Fig-3.16: Variation of Moment with Radius of Curvature of Box Girder
Fig-3.17: Variation of 'α' Moment with Radius of Curvature of Box Girder

The variation of deflection with radius of curvature of box girder bridges is shown in above Figure. As the radius of curvature increases, deflection decreases for each type of Box Girder Bridge. Variation of deflection between radius of curvature 100 m and 400 m is about 13-18 % for all the three cases. Variation of deflection between three types of box girder is about 15 % and this indicates that the effect of radius of curvature on deflection is significant. Figure 3.17 represents a non-dimensional form of the deflection variation for all the three types of box girder. It shows that the deflection variation pattern is same between the three types of box girder and has a variation of about 5 %.



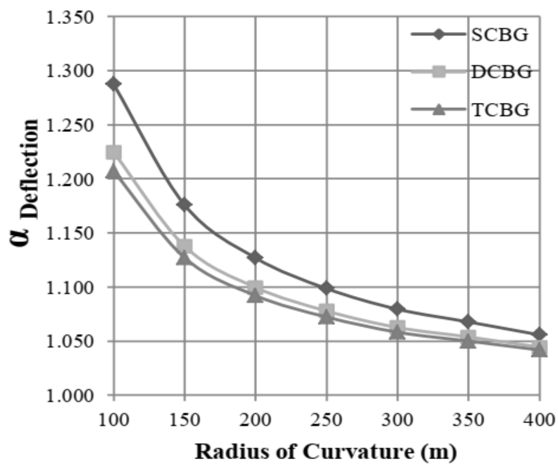
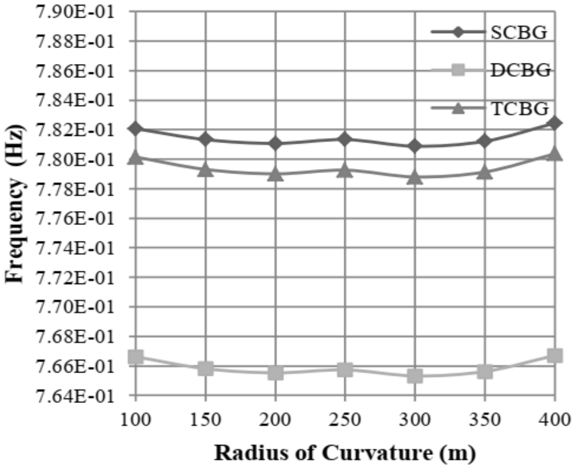


Fig-3.18: Variation of Deflection with Radius of Curvature of Box Girder
Fig-3.19: Variation of 'α'Deflection with Radiusof Curvature of Box Girder

The variation of frequency with radius of curvature of box girder bridges is shown in above Figure. As the radius of curvature increases, the variation of frequency is almost same for all the three cases of Box Girder Bridge. Variation of frequency between three types of box girder is only about 1%. This is due to the same span length. Figure 3.19 represents a nondimensional form of the frequency variation for all the three types of box girder. It shows that frequency variation pattern is same between the three types of box girder and has a variation is only about 0.5 %.



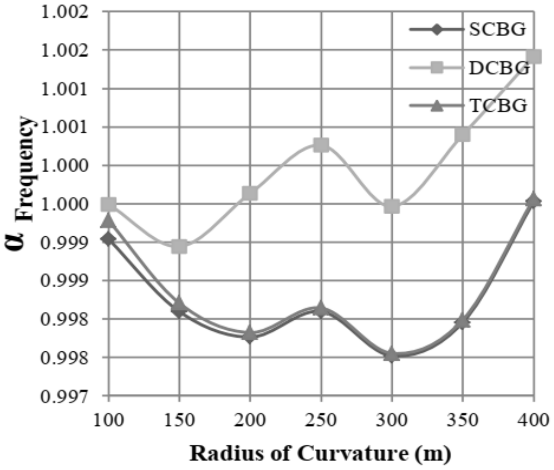
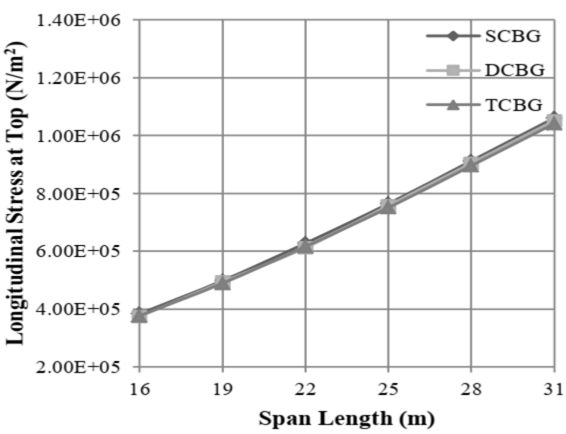


Fig-3.20: Variation of Natural Frequency with Radius of Curvature of Box Girder
Fig-3.21: Variation of 'α' Frequency with Radius of Curvature of Box Girder

Span Length

Two lanes with 120 m radius of curvature Single Cell Box Girder Bridge (SCBG), Double Cell Box Girder Bridge (DCBG) and Triple Cell Box Girder Bridge (TCBG) are analysed for different span length to illustrate the variation of longitudinal stresses at the top and bottom, shear, torsion, moment, deflection and fundamental frequency with a span length of box girder bridges.

The variation of Longitudinal Stress at the top with a span length of box girder bridges is shown in above Figure. As the span length increases, longitudinal stress at top of box girder increases for each type of Box Girder Bridge. Variation of longitudinal stress at top of box girder between span length 16 m and 31 m is about 64 % for all the three cases and it shows that effect of span length on longitudinal stress at top is significant. Variation of longitudinal stress at top between three types of box girder is only about 2 %. The variation of Longitudinal Stress at the bottom with a span length of box girder bridges is shown in above Figure. As the span length increases, longitudinal stress at bottom of box girder increases for each type of Box Girder Bridge. Variation of longitudinal stress at bottom of box girder between span length 16 m and 31 m is about 64 % for all the three cases and it shows that effect of span length on longitudinal stress at the bottom is also significant. Variation of longitudinal stress at bottom between three types of box girder is about 5 %.



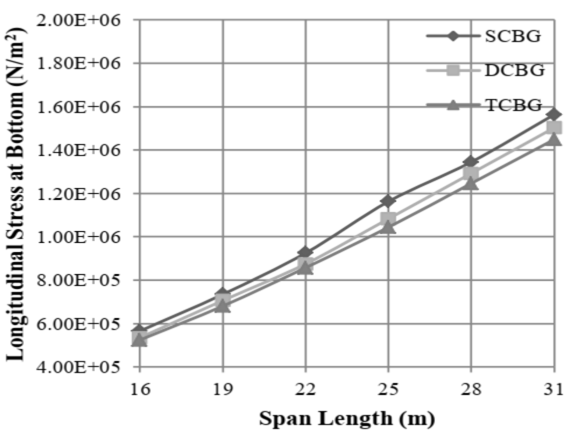
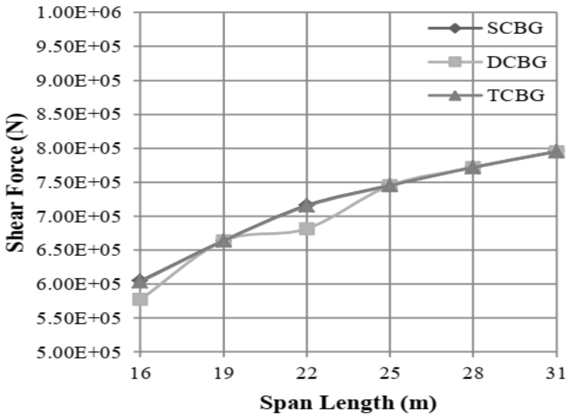


Fig-3.22: Variation of Longitudinal Stress attop with Span Length at Top of Box Girder
Fig-3.23: Variation of Longitudinal Stress atbottom with Span Length at Bottom of Box Girder

The variation of shear force with a span length of box girder bridges is shown in above Figure. As the span length increases, Shear Force of box girder increases for each type of Box Girder Bridge. Variation of the shear force of box girder between span length 16 m and 31 m is about 25 % for all the three cases and it shows that effect of span length on shear force is significant. Variation of shear force between three types of box girder is about 5 %.The variation of torsion with span length of box girder bridges is shown in Figure 3.23. As the span length increases, torsion of box girder increases for each type of Box Girder Bridge.

Variation of torsion of box girder between span length 16 m and 31 m is about 32 % for all the three cases and it shows that effect of span length on torsion is significant. Variation of torsion between three types of box girder is only about 0.8 %.



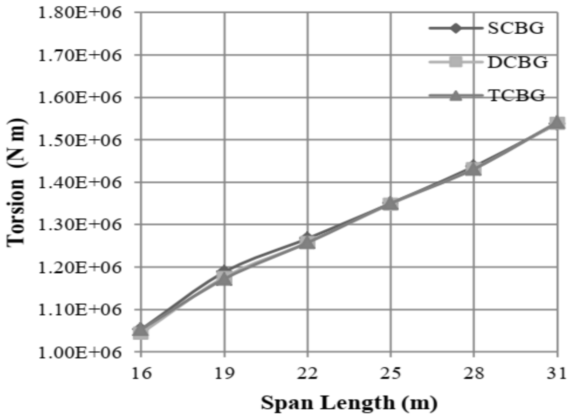
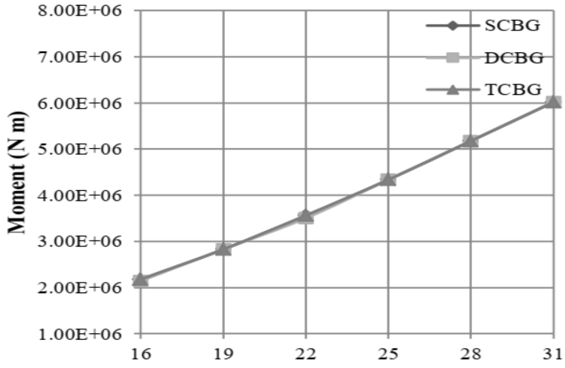


Fig-3.24: Variation of Shear Force with Span Length of Box Girder
Fig-3.25: Variation of Torsion with Span Length of Box Girder

The variation of moment with a span length of box girder bridges is shown in above Figures. As the span length increases, moment of box girder increases for each type of Box Girder Bridge. Variation of moment of box girder between span length 16 m and 31 m is about 64 %for all the three cases and it shows that effect of span length on the moment is significant. Variation of moment between three types of box girder is only about 1.5 %.The variation of deflection with a span length of box girder bridges is shown in Figure 3.25.As the span length increases, deflection of box girder increases for each type of Box GirderBridge. Variation of deflection of box girder between span length 16 m and 31 m is about 75% for all the three cases and it shows that effect of span length on deflection is significant. Variation of deflection between three types of box girder is about 13 %.



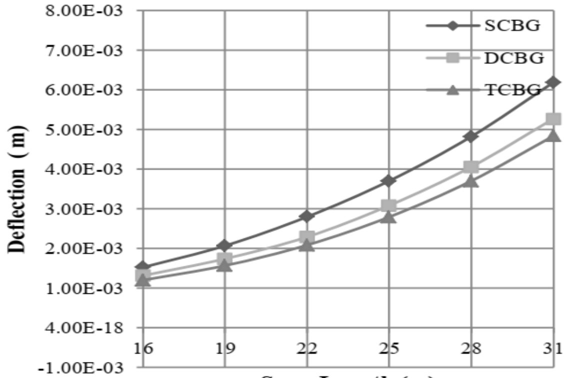


Fig-3.26: Variation of Moment with Span Length of Box Girder
Fig-3.27: Variation of Deflection with Span Length of Box Girder

The variation of frequency with a span length of box girder bridges is shown in above Figure. As the span length increases, frequency of box girder decreases for each type of Box Girder Bridge. Variation of frequency of box girder between span length 16 m and 31 m is about 66% for all the three cases and it shows that effect of span length on frequency is significant. Variation of frequency between three types of box girder is only about 2 %.

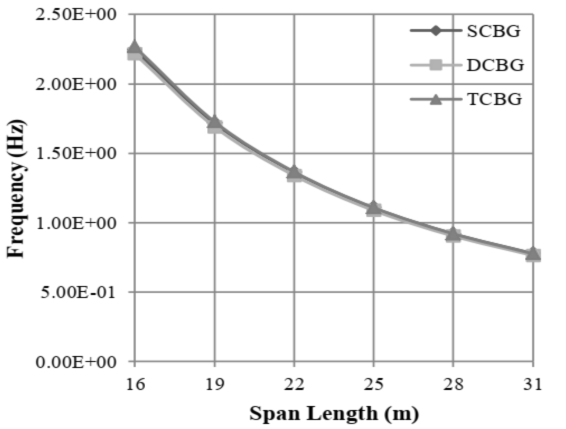
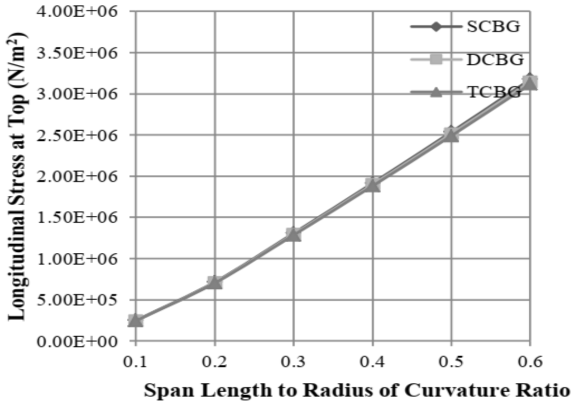


Fig-3.28:Variation of Frequency with Span Length of Box Girder

Span Length to Radius of Curvature Ratio

Two lanes with 120 m radius of curvature Single Cell Box Girder Bridge (SCBG), Double Cell Box Girder Bridge (DCBG) and Triple Cell Box Girder Bridge (TCBG) are analysed for different span length to the radius of curvature of ratio to illustrate the variation of longitudinal stresses at top and bottom, shear, torsion, moment, deflection and fundamental frequency with a span length of box girder bridges.

The variation of Longitudinal Stress at the top with span length to the radius of curvature of ratio of box girder bridges is shown in Figure 3.29. As the span length to the radius of curvature of ratio increases, longitudinal stress at the top of box girder increases for each type of Box Girder Bridge. Variation of longitudinal stress at the top of box girder between span length to the radius of curvature of ratio 0.1 – 0.6 is about 92 % for all the three cases and it shows that effect of span length to the radius of curvature of the ratio on longitudinal stress at the top is significant. Variation of longitudinal stress at top between three types of box girder is only about 1 %.The variation of Longitudinal Stress at the bottom with a span length of box girder bridges is shown in Figure 3.30. As the span length to the radius of curvature of ratio increases, longitudinal stress at bottom of box girder increases for each type of Box Girder Bridge. Variation of longitudinal stress at the bottom of box girder between span length to the radius of curvature of ratio 0.1 – 0.6 is about 92 % for all the three cases and it shows that effect of span length to the radius of curvature of the ratio on longitudinal stress at the bottom is also significant. Variation of longitudinal stress at bottom between three types of box girder is about 4 %.



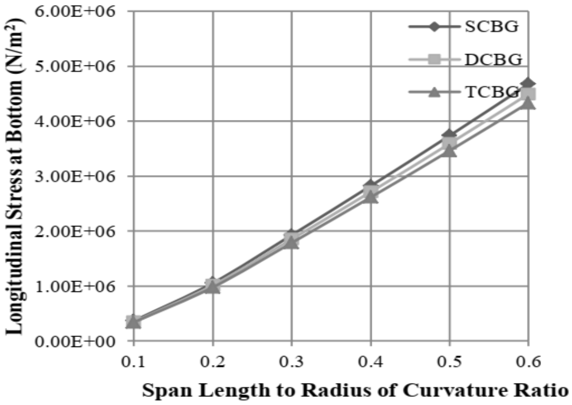
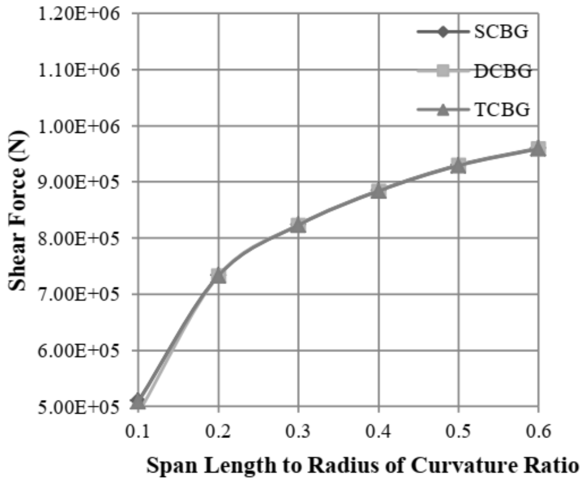


Fig-3.29: Variation of Longitudinal Stress at top with(L/R) Ratio of Box Girder
Fig-3.30: Variation of Longitudinal Stress at bottom with(L/R) Ratio of Box Girder

The variation of shear force with a span length of box girder bridges is shown in above Figure. As the span length to the radius of curvature of ratio increases, Shear Force of box girder increases for each type of Box Girder Bridge. Variation of the shear force of box girder between span length to the radius of curvature of ratio 0.1-0.6 is about 47 % for all the three cases and it shows that effect of span length to the radius of curvature of the ratio on shear force is significant. Variation of shear force between three types of box girder is about 4 %. The variation of torsion with span length of box girder bridges is shown in above Figure. As the span length to radius of curvature of ratio increases, torsion of box girder increases for each type of Box Girder Bridge. Variation of torsion of box girder between span length to the radius of curvature of ratio 0.1 - 0.6 is about 80 % for all the three cases and it shows that effect of span length to the radius of curvature of ratio on torsion is significant. Variation of torsion between three types of box girder is only about 1 %.



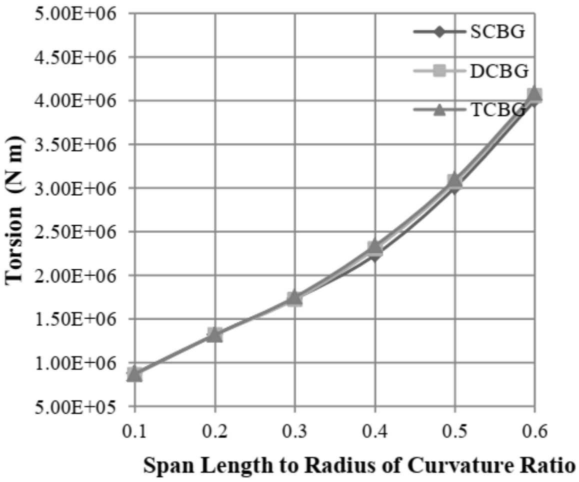
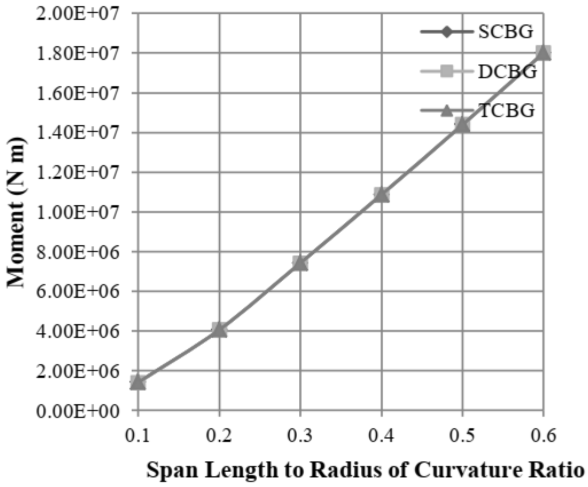


Fig-3.31: Variation of Shear Force with (L/R) Ratio of Box Girder
Fig-3.32: Variation of Torsion with (L/R) Ratio of Box Girder

The variation of moment with a span length of box girder bridges is shown in above Figure. As the span length to the radius of curvature of ratio increases, moment of box girder increases for each type of Box Girder Bridge. Variation of moment of box girder between span length to the radius of curvature of ratio 0.1 – 0.6 is about 92 % for all the three cases and it shows that effect of span length to the radius of curvature of ratio on the moment is significant.

Variation of moment between three types of box girder is only about 1.5 %.

The variation of deflection with a span length of box girder bridges is shown in Figure 3.32. As the span length to radius of curvature of ratio increases, deflection of box girder increases for each type of Box Girder Bridge. Variation of deflection of box girder between span length to the radius of curvature of ratio 0.1 – 0.6 is about 98 % for all the three cases and it shows that effect of span length to the radius of curvature of ratio on deflection is significant. Variation of deflection between three types of box girder is about 5-12 %.



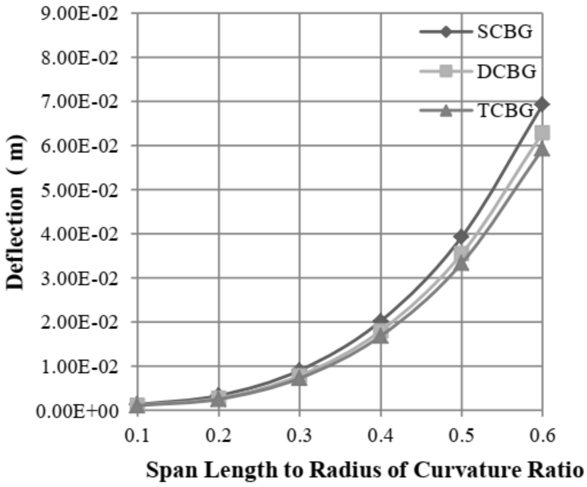


Fig-3.33: Variation of Moment with (L/R) Ratio of Box Girder
Fig-3.34: Variation of Deflection with (L/R)Ratio of Box Girder

The variation of frequency with a span length of box girder bridges is shown in above Figure. As the span length to the radius of curvature of ratio increases, frequency of box girder decreases for each type of Box Girder Bridge. Variation of frequency of box girder between span length to the radius of curvature of ratio 0.1 – 0.6 is about 95 % for all the three cases and it shows that effect of span length to the radius of curvature of ratio on frequency is significant. Variation of frequency between three types of box girder is about 3 %.

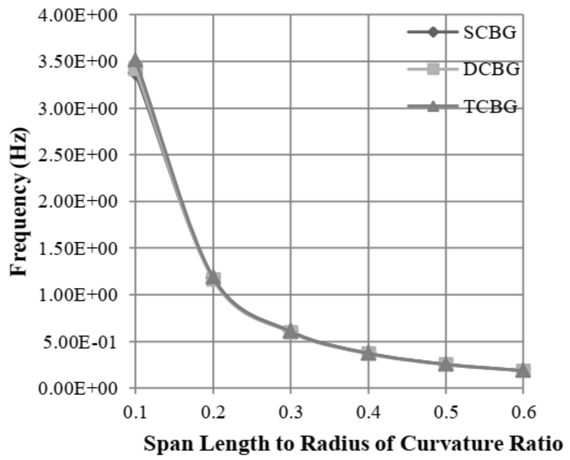


Fig-3.35: Variation of Frequency with (L/R) Ratio of Box Girder

RESULTS INTERPRETATION

In this chapter, parametric study on behaviour of box girder bridges is carried out by using finite element method. The numerical analysis of finite element model is validated with model of Gupta et al. (2010). The parameter considered in this chapter to present the behaviour of SCBG, DCBG and TCBG bridges are radius of curvature, span length and span length to the radius of curvature ratio. Theses parameters are used to evaluate the response parameter of box girder bridges namely longitudinal stresses at the top and bottom, shear, torsion, moment, deflection and fundamental frequency of three types of box girder bridges.

The results obtained from this parametric study are presented and discussed briefly in this chapter. From the parametric study it is found out that as the radius of curvature increases, responses parameter longitudinal stresses at top and bottom, shear, torsion, moment and deflection are decreases for three types of box girder bridges and it shows not much variation for fundamental frequency of three types of box girder bridges due to the constant span length.

It is observed that as the span length increases, responses parameter longitudinal stresses at the top and bottom, shear, torsion, moment and deflection are increases for three types of box girder bridges and fundamental frequency decreases for three types of box girder bridges. It is noted that as the span length to the radius of curvature ratio increases responses parameter longitudinal stresses at top and bottom, shear, torsion, moment and deflection are increases for three types of box girder bridges and as span length to the radius of curvature ratio increases fundamental frequency decreases for three types of box girder bridges.

SUMMARY AND CONCLUSIONS

SUMMARY

A flyover system is a transport system in an urban area with a high capacity, frequency and the grade separation from other traffic. An elevated system is the most preferred form of bridge structure due to ease of construction and less cost compared to other types of elevated structures. An elevated bridge system has two major components pier and box girder. In this project, study has been carried out on these two major elements.

In the first part of this study, the performance assessment on designed pier by Force Based Design and Direct Displacement Based Design is carried out. The design of the pier is done by both force-based design method and direct displacement based design method. In the second part, parametric study on behaviour of box girder bridges is carried out by using finite element method. The numerical analysis of finite element model is validated with model of Gupta et al. (2010). The parameter considered to present the behaviour of Single Cell Box Girder, Double Cell Box Girder and Triple Cell Box Girder bridges are radius of curvature, span length and span length to the radius of curvature ratio. These parameters are used to evaluate the response parameter of box girder bridges namely longitudinal stresses at the top and bottom, shear, torsion, moment, deflection and fundamental frequency of three types of box girder bridges.

CONCLUSIONS

The parametric study on behaviour of box girder bridges showed that,

- ❖ As the radius of curvature increases, responses parameter longitudinal stresses at the top and bottom, shear, torsion, moment and deflection are decreases for three types of box girder bridges and it shows not much variation for fundamental frequency of three types of box girder bridges due to the constant span length.
- ❖ As the span length increases, responses parameter longitudinal stresses at the top and bottom, shear, torsion, moment and deflection are increases for three types of box girder bridges and fundamental frequency decreases for three types of box girder bridges.
- ❖ As the span length to the radius of curvature ratio increases responses parameter longitudinal stresses at the top and bottom, shear, torsion, moment and deflection are increases for three types of box girder bridges and as span length to the radius of curvature ratio increases fundamental frequency decreases for three types of box girder bridges.

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