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A DETAILED STUDY ON MAJOR ELEMENTS OF METRO BRIDGE

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ABSTRACT: The parametric study on behaviour of box girder bridges showed that, as curvature decreases, responses such as longitudinal stresses at the top and bottom, shear, torsion, moment and deflection 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, longitudinal stresses at the top and bottom, shear, torsion, moment and deflection increases for three types of box girder bridges. As the span length increases, fundamental frequency decreases for three types of box girder bridges.

India is created a world-class Metro Rail Transit System (MRTS) as an integral part of community infrastructure development in the country. It is a cheap mode of transport, MRTS helps in low energy consumption, is ecofriendly, runs on electricity thus minimising the air and sound pollution and reduces the number of accidents. There are metro systems in the following busiest cities in India they are Delhi, Mumbai, Chennai, Bengaluru, Hyderabad, Jaipur and Kochi. The general problem of impact is extremely complex. Impact load is a high force or shock applied over a short time period when two or more bodies collide. A common case of impact, vehicle collision with a traffic barrier involves large displacements, material non-linearity, elastic and plastic instability under high strain rates. Vehicle collision with bridges can have serious repercussions with regard to both human life and transportation systems. When earthquakes occur, a structure undergoes dynamic motion. This is because the structure is subjected to inertia forces that act in opposite direction to the acceleration of earthquake excitations. These inertia forces are called seismic loads. Since earthquake motions vary with time and inertia forces vary with time and direction, seismic loads are not constant in terms of time and space.

Keywords: Metro Structure, Pier, Girder Bridge, Direct Displacement Based Seismic Design, Performance Based Design, Force Based Design

I. SIGNIFICANCE & OBJECTIVE

A force based seismic design approach is conventionally used to design the metro bridge pier. During a seismic loading, the behaviour of elevated bridges relies mostly on the ductility and the displacement capacity of the pier. It is important to check the ductility of such single piers. Force based methods do not explicitly check the displacement capacity at the design stage. The codes are now moving towards a performance-based (displacement-based) design approach which considers the design as per the target performances at the design stage. The behaviour of a box girder curved in plan is significantly different from a straight bridge and it is dependent on many parameters. A limited number of studies have been conducted on this aspect.

- To study the performance of a pier designed by Force Base Design Method (FBD) and Direct Displacement Based Design (DDBD) Method.
- To study the parametric behaviour of a Curved Box Girder Bridges

II. 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 SAP 2000. 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 SAP 2000 is shown in figure 4.3(a) and 4.3(b).

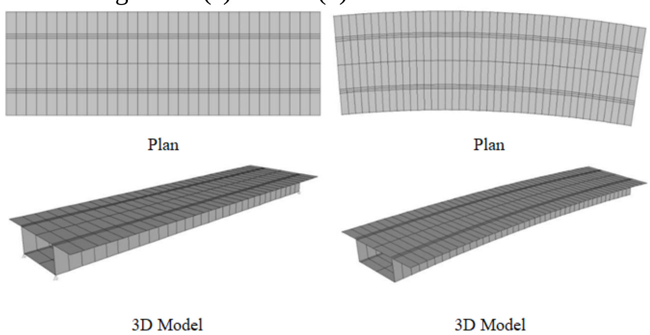

Figure 4.3(a): Discretized model of simply supported Straight Box Girder Bridge in SAP 2000

Figure 4.3(b): Discretized model of simply supported Curved Box Girder Bridge in SAP 2000

III. 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 4.4. 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 4.5 represents 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.

Variation Analysis

The variation of shear force on the radius of box girder bridges is shown in Figure 4.8. 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 4.9 represents the non-dimensional form of the shear 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.

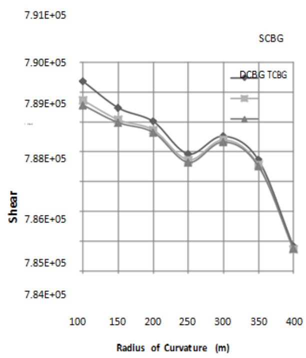

Figure 4.8: Variation of Shear Force with Radius of Curvature of Box Girder

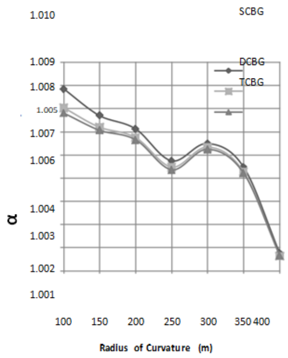

Figure 4.9: Variation of α $_{Shear\ force}$ with Radius of Curvature of Box Girder

The variation of torsion with radius of curvature of box girder bridges is shown in Figure 4.10. 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 4.11 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.

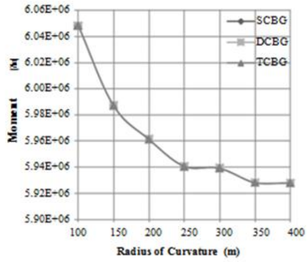

Figure 4.12: Variation of Moment with Radius of Curvature of Box Girder

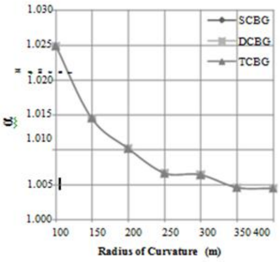

Figure 4.13: Variation of α $_{Moment}$ with Radius of Curvature of Box Girder

The variation of moment with radius of curvature of box girder bridges is shown in Figure 4.12. 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 4.13 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.

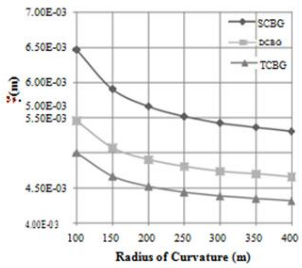

Figure 4.14: Variation of Deflection with Radius of Curvature of Box Girder

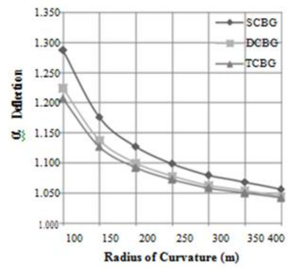

Figure 4.15: Variation of α $_{Deflection}$ with Radius of Curvature of Box Girder

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 4.25. 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 4.26. 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 %.

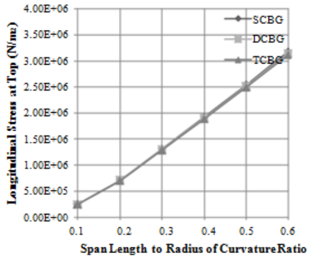

Figure 4.25: Variation of Longitudinal Stress at top with(L/R) Ratio of Box Girder

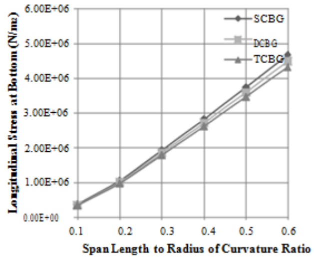

Figure 4.26: Variation of Longitudinal Stress at bottom with(L/R) Ratio of Box Girder

The variation of shear force with a span length of box girder bridges is shown in Figure 4.27. 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 Figure 4.28. 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 %.

SUMMARY

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

CONCLUSIONS

The increased vulnerability of structures to accidental loads demands the efforts to improve the resistance of a structures, for that it require some additional or alternate structural forms as a retrofitting methods to overcome the adverse effect. Metro rail supporting structure were analysed for various accidental load cases that may happen and different retrofitting methods were suggested. Metro pillar is safe to some extend against impact loading, and earthquake. But if a vehicle having weight and speed more than 30ton and 150km/hrs respectively in the case of impact loading the deformation will exceeds the permissible limit. The performance assessment of selected designed pier showed that,

- Force Based Design Method may not always guarantee the performance parameter required and in the present case the pier just achieved the target required.
- In case of Direct Displacement Based Design Method, selected pier achieved the behaviour factors more than targeted Values.

In the case of seismic load, if any strong earthquake occurs, it will cause more vibrations and provision of a damper will reduces the effect to some extent by absorbing the vibration and thereby reduces the deformation. As the stand-off distance increases, effect of blast will be reduces, for that barrier width can be increased therefore the distance at which a vehicle with explosive can be parked closest to the metro pillar will increases to avoid suspicion. To reduce the after effect of blast some alternate structural forms are necessary.

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