International Journal For Applied Research in Science and Engineering
Volume 4, Issue 1, August-2021 *ISSN (Online): 2456-124X*

DESIGN AND ANALYSIS OF COMPONENTS OF METRO RAILWAY BRIDGE

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Abstract- A metro system is an electric passenger railway transport system in an urban area with a high capacity, frequency and the grade separation from other traffic. Metro System is used in cities, agglomerations, and metropolitan areas to transport large numbers of people at high frequency. A typical elevated metro bridge model. Viaduct or box girder of a metro bridge requires pier to support the each span of the bridge and station structures. Piers are constructed in various cross sectional shapes like cylindrical, elliptical, square, rectangular and other forms. The piers considered for the present study are in rectangular cross section and it is located under station structure. Box girders are used extensively in the construction of an elevated metro rail bridge. The torsional and warping rigidity of box girder is due to the closed section of box girder. 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

Keywords- Elevated Metro Structure, Bridge, Direct Displacement Based Seismic Design

OBJECTIVE

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

VALIDATION OF THE FINITE ELEMENT MODEL

To validate the finite element model of box girder bridges in SAP 2000, a numerical example from the literature (Gupta et al., 2010) is considered. Figure 4.1 shows the cross section of simply supported Box Girder Bridge considered for validation of finite element model. Box girder considered is subjected to two concentrated loads (P = 2 X 800 N) at the two webs of mid span. Span Length assumed in this study is 800 mm and the material property considered are Modulus of elasticity (E) =2. 842GPa and Modulus of rigidity (G) =1. 015GPa.

The mid span deflection of the modelled box girder bridge is compared with the literature and it is presented in the Table 4.1. From the Table 4.1, it can be concluded that the present model gives the accurate result.

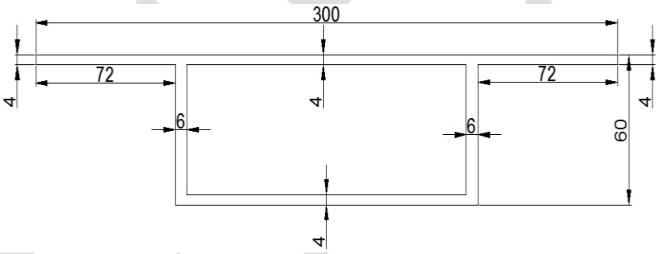


Figure 4.1: Cross Section of Simply Supported Box Girder Bridge

Table 4.1: Mid Span Deflection of Simply Supported Box Girder Bridge

Parameter	Gupta et al. (2010)	Present Study
Mid Span Deflection (mm)	4.92	4.91

CASE STUDY OF BOX GIRDER BRIDGES

The geometry of Box Girder Bridge considered in the present study is based on the design basis report of the Bangalore Metro Rail Corporation (BMRC) Limited. In this study, 60 numbers of simply supported box girder bridge model is considered for analysis to study the behaviour of box girder bridges. The details of the cross section considered for this study is given in Figure 4.2 and various geometric cases considered for this study are presented in Table 4.2. The material property considered for the present study is shown in Table 4.3.

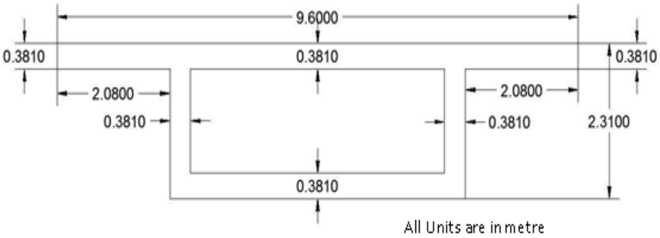


Figure 4.2: Cross Section of Simply Supported Box Girder Bridge considered for study

Table 4.2: Geometries of Bridges used in Parametric Study

Span Length (m)	Radius of Curvature (m)	Theta (radian)	Number of Boxes
Radius of Curvature			
31	8	0.0000	1,2,3
31	100	0.3100	
31	150	0.2067	
31	200	0.1550	
31	250	0.1240	
31	300	0.1033	
31	350	0.0886	
31	400	0.0775	
Span Length			
16	120	0.1333	1,2,3
19	120	0.1583	
22	120	0.1833	
25	120	0.2083	
28	120	0.2333	
31	120	0.2583	
Span Length to Radius of Curvature Ratio			
12	120	0.1000	1,2,3
24	120	0.2000	
36	120	0.3000	
48	120	0.4000	
60	120	0.5000	
72	120	0.6000	

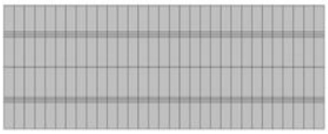
Table 4.3: Material Properties

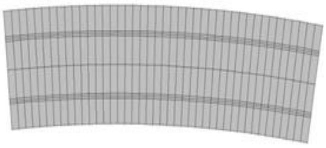
Properties of Material	Value
Weight per unit volume	235400 N/m^3
Mass per unit volume	24000 N/m^3
Modulus of Elasticity (E)	32500 x 10^6 N/m^2
Poisson's Ratio (υ)	0.15
Coefficient of thermal expansion (A)	1.170 x 10^{-5} / °C
Shear Modulus (G)	1.413 x 10^{10} N/m^2
Specific Concrete Compressive Strength (fc′)	45 x 10^6N/m^2

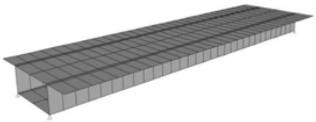
The moving load analysis is performed for live load of two lane IRC 6 Class A (Tracked Vehicle) loading for all the cases considered by using SAP 2000. The longitudinal stress at the top and bottom, shear, torsion, moment, deflection and fundamental frequency is calculated and compared with Single Cell Box Girder (SCBG), Double Cell Box Girder (DCBG) and Triple Cell Box Girder (TCBG) bridge cases for various parameters viz., radius of curvature, span length, and span length to the radius of curvature ratio.

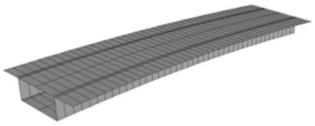
FINITE ELEMENT MODELLING

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).









3D Model 3D Model

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

PARAMETRIC STUDY

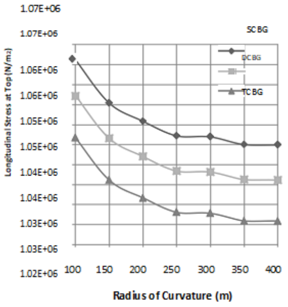
The parametric study is carried out to investigate the behaviour (i.e., the longitudinal stress at the top and bottom, shear, torsion, moment, deflection and fundamental frequency) of box girder bridges for different parameters viz. radius of curvature, span length, span length to radius of curvature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



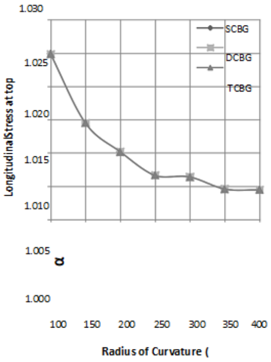


Figure 4.4: Variation of Longitudinal Stress **Figure 4.5:** Variation of α
Longitudinal Stress at top with with Radius of Curvature at Top of Box Girder
Radius of Curvature of Box
Girder

The variation of longitudinal stress at the bottom with radius of curvature of box girder bridges is shown in Figure 4.6. 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 4.7 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.

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.

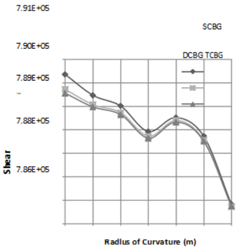


Figure 4.8: Variation of Shear Force with Radius of Curvature of Box Girder

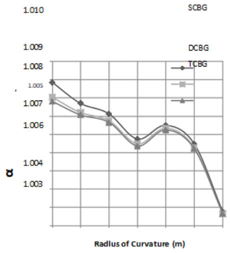


Figure 4.9: Variation of α $_{\text{Shear Force}}$ with Radius of Curvature of Box Girder

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 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.

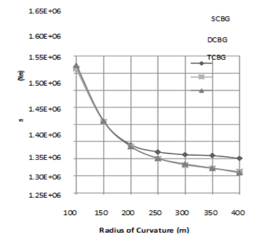


Figure 4.10: Variation of Torsion with Radius of Curvature of Box Girder

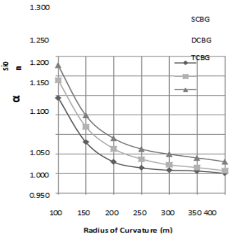
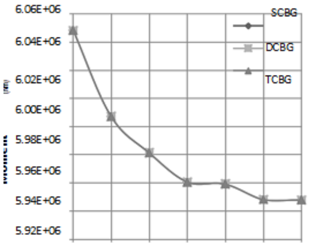
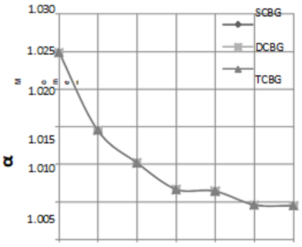


Figure 4.11: Variation of α $_{\text{Torsion}}$ with Radius of Curvature of Box Girder

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.





The variation of deflection with radius of curvature of box girder bridges is shown in Figure 4.14. 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 4.15 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 %

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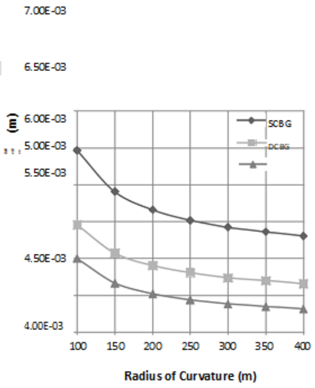


Figure 4.14: Variation of Deflection with Radius of Curvature of Box Girder

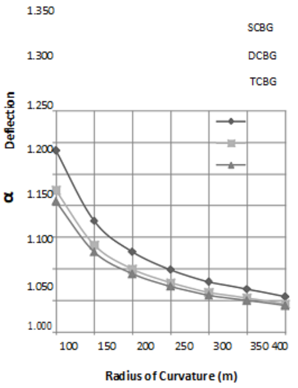
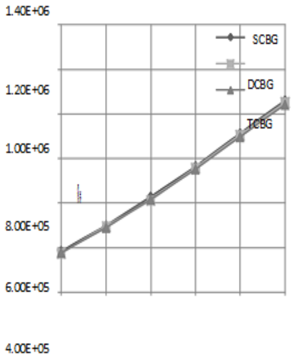


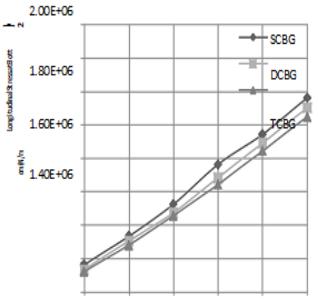
Figure 4.15: Variation of α $_{\text{Deflection}}$ with Radius of Curvature of Box Girder

The variation of frequency with radius of curvature of box girder bridges is shown in Figure 4.16. 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 4.17 represents a non- dimensional 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 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 Figure 4.18. 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 Figure 4.19. 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 %.





The variation of shear force with a span length of box girder bridges is shown in Figure 4.20. 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 4.21. 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 %.

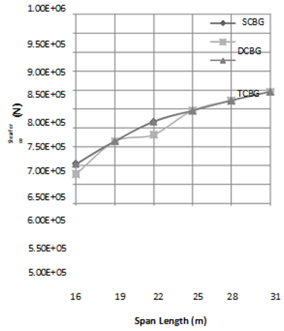


Figure 4.20: Variation of Shear Force with Span Length of Box Girder

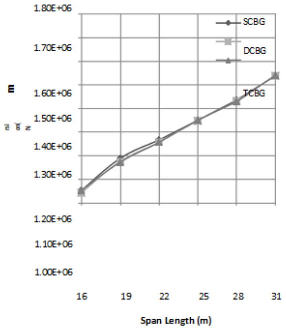


Figure 4.21: Variation of Torsion with Span Length of Box Girder

The variation of moment with a span length of box girder bridges is shown in Figure 4.22. 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 4.23. As the span length increases, deflection of box girder increases for each type of Box Girder Bridge. 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 %.

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. As discussed in this work the among various types of the metro structures, the pre-cast superstructure elements in the elevated viaduct considering the construction ease and safety. As the precast elements give the feasibility in the construction avoiding the interference to the traffic and gives an easy hand to the civil engineer to control the quality of the work. The following points can be drawn:

- 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

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