Analysis of Piers and Box Girder in an Elevated Metro Bridge in Running Project

Aamir Khan[1] Prof. Kamni Laheriya[2]
[2]Professor & Head of Department
[1,2]Department of Civil Engineering
[1,2]SSSUTMS SEHORE (M. P.), India

Abstract— The parametric study on behavior 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. Also, it is noted that 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. As the span length to the radius of curvature ratio increases fundamental frequency decreases for three types of box girder bridges. The performance assessment of selected designed pier showed that, the Force Based Design Method may not always guarantee the performance parameter required and in the present case the pier achieved the target requirement. In case of Direct Displacement Based Design Method, selected pier achieved the behavior factors more than targeted Values. These conclusions can be considered only for the selected pier.

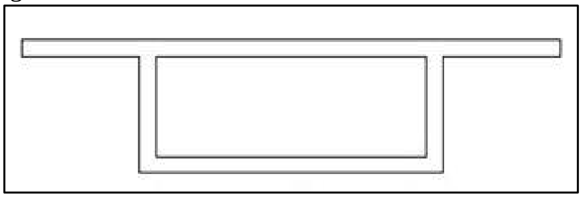
Keywords: Elevated Metro Structure, Bridge Pier, Box Girder Bridge, Direct Displacement Based Seismic Design, Performance Based Design, Force Based Design

I. INTRODUCTION

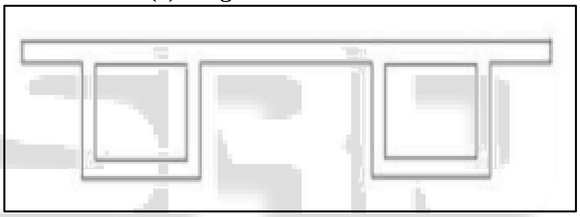
An elevated metro system has two major components pier and box girder. A typical elevated metro bridge model is shown in Figure 1.1 (a). Viaduct or box girder of a metro bridge requires pier to support the each span of the bridge and station structures. Piers are constructed in various cross sectional 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 and the use of horizontally curved in plan box girder bridges in modern metro rail systems is quite suitable in resisting torsional and warping effects induced by curvatures. The torsional and warping rigidity of box girder is due to the closed section of box girder. The box section also possesses high bending stiffness and there is an efficient use of the complete cross section. Box girder cross sections may take the form of single cell, multi spine or multi cell as shown in Figure.

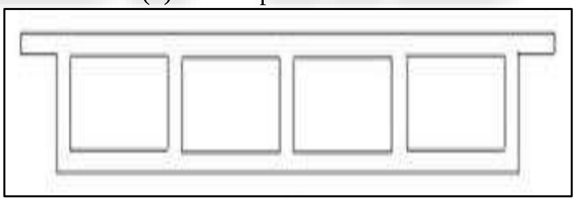
The performance assessment of selected designed pier showed that, the Force Based Design Method may not always guarantee the performance parameter required and in the present case the pier achieved the target requirement. In case of Direct Displacement Based Design Method, selected pier achieved the behavior factors more than targeted Values. These conclusions can be considered only for the selected pier it is noted that 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. As the span length to the radius of curvature ratio increases fundamental frequency decreases for three types of box girder bridges.



(a) Single Cell Box Girder



(b) Multi Spine Box Girder



(c) Multi Cell Box Girder

Fig. 1: Types of Box Girder

II. LITERATURE REVIEW

To provide a detailed review of literature related to Metro bridge pier and Box Girder Bridge in its entirety is too immense to address in this paper.

[Ramesh et al. (2006)] uncoupled in-plane and out-of-plane forces and neglected shear deformation to introduce a curved element with 6 degrees of freedom at each node. Their method is applicable to single and multi-cell sections.

[Moffat and Lim (2002)] presented a finite-element technique to analyse straight composite box-girder bridges will complete or incomplete interaction with respect to the distribution of the shear connectors.

[Chu and Jones (2001)] extended the developed finite-element formulation of curved box-girder bridges (Chu and Pinjarkar 1971) to the dynamic analysis of such bridges.

[Turkstra and Fam (2008)] demonstrated the importance of warping and distortional stresses in a single-cell curved bridge, in relation to the longitudinal normal bending stresses obtained from curved beam theory.

[Sargious et al. (2009)] studied the behaviour of end diaphragm with opening in single-cell concrete box-girder bridges supported by a central pier.

[Daniels et al. (2006)] presented the results of a finite-element study concerning the effect of spacing of the rigid interior diaphragms on the fatigue strength of curved steel box girders. The results showed that reducing the interior diaphragms spacing effectively controls the distortional normal and bending stresses and increases the fatigue strength of curved steel box girders.

[Jirousek and Bouberguig (2004)] presented an efficient macro-element formulation for static analysis of curved box-girder bridges with variable cross section.

[Templeman and Winterbottom (2009)] used the finite-element method to investigate the minimum cost design of concrete spine box beam bridge decks.

III. Design of Pier Using Force Based Design

A. *Design of Pier Using Direct Displacement Based Design*

The direct displacement based seismic design method proposed by Priestley et al. (2007) and IRS CBC 1997 Code is used to design of Pier Type B and the results are shown in Table 3.4. The performance level considered for the study is a Life Safety (LS) level.

1) *Reinforcement Details as per Direct Displacement Based Seismic Design*

Pier Type	Cross Section (m)	Diameter of Bar (mm)	Number of Bars	Diameter of Bar (mm)	Number of Bars	% of Reinforcement Required
1	0.276	1.5 x 0.7	604	32	#12	1.2 %
2	0.276	1.5 x 0.7	150	32	#12	0.8 %
3	0.276	1.5 x 0.7	86	32	#12	0.8 %
4	0.276	1.5 x 0.7	60	32	#12	0.8 %

Table 1:

The parametric study is carried to know the effect of displacement ductility on base shear for different Performance levels and the results are shown in Figure 3.2. The figure shows that as the displacement ductility level increases the base shear of the pier decreases and also the difference between different performance levels is about 40 %.

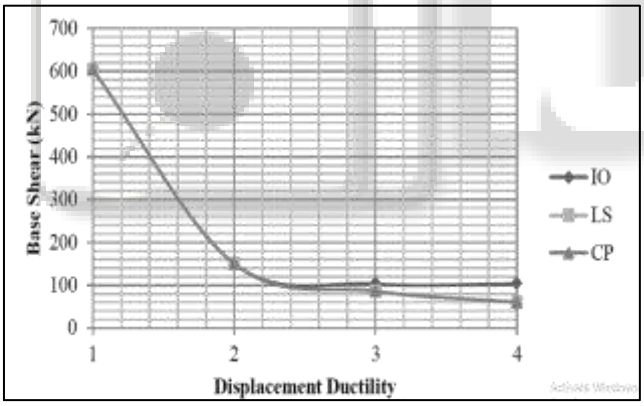


Fig. 2: Effect of displacement ductility on base shear for different Performance levels

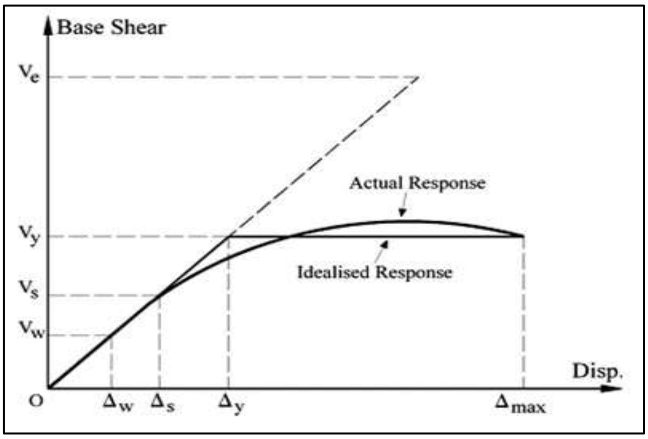


Fig. 3: Typical Pushover response curve for evaluation of performance parameters

The structure ductility, μ', is defined in as maximum structural drift (Δ´max) and the displacement corresponding to the idealised yield strength (Δy) as:

$$\mu = \Delta_{max} / \Delta_y$$

In Force Based Design, a force reduction factor (R) of 2.5 is used, and the design base shear is estimated to be 891kN in the FBD. The performance parameters of the section designed using FBD shows that the behavior factor R is found to be about 2.74. The same pier is designed using a DDBD method for target displacement ductility and drift, the performance parameters structural ductility and structural drift are found out for these cases. The design considers the target displacement ductility and drift at the design stage, and the present study shows that in both the examples the DDBD method achieves the behavior factors more than targeted Values. These conclusions can be considered only for the selected pier. For General conclusions large number of case studies is required and it is treated as a scope of future work.

IV. The Finite Element Model

The geometry of Box Girder Bridge considered in the present study is based on the design basis report of the Bahopal 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 and various geometric cases considered for this study are presented.

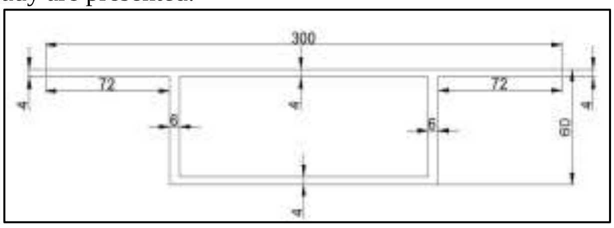


Fig. 4: Cross Section of Simply Supported Box Girder Bridge considered for study

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

Table 2: Geometries of Bridges used in Parametric Study

V. CONCLUSIONS

The performance assessment of selected designed pier showed that,

- 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.
- 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. An elevated metro system is the most preferred form of metro structure due to ease of construction and less cost compared to other types of metro structures. An elevated metro system has two major components pier and box girder. In this project, study has been carried out on these two major elements.

REFERENCES

[1] Abdelfattah, F. A. (1997). Shear lag in steel box girders. Alexandria Eng. J., Alexandria Univ., Egypt, 36 (1), 1110–1118.
[2] Armstrong, W. L. and Landon, J. A. (1973). Dynamic testing of curved box beam bridge. Fed. Hwy. Res. and Devel. Rep. No. 73-1, Federal Highway Administration, Washington, D.C.
[3] Balendra, T. and Shanmugam, N. E. (1985). Vibrational characteristics of multicellular structures. J. Struct. Engrg. , ASCE, 111 (7), 1449-1459.
[4] Bazant, Z. P. , and El Nimeiri, M. (1974). Stiffness method for curved box girders at initial stress. J. Struct. Div., 100 (10), 2071–2090.
[5] Buchanan, J. D., Yoo, C. H., and Heins, C. P. (1974). Field study of a curved box-girder bridge. Civ. Engrg. Rep. No. 59, University of Maryland, College Park, Md.
[6] Chang, S. T., and Zheng, F. Z. (1987). Negative shear lag in cantilever box girder with constant depth. J. Struct. Eng., 113 (1), 20–35.
[7] Chapman, J. C. , Dowling, P. J. , Lim, P. T. K. , and Billington, C. J. (1971). The structural behavior of steel and concrete box girder bridges. Struct. Eng., 49 (3), 111–120.
[8] Cheung, M. S., and Megnounif, A. (1991). Parametric study of design variations on the vibration modes of box-girder bridges. Can. J. Civ. Engrg., Ottawa, 18(5), 789-798.
[9] Cheung, M. S., and Mirza, M. S. (1986). A study of the response of composite concrete deck-steel box-girder bridges. Proc., 3rd Int. Conf. on Computational and Experimental Measurements, Pergamon, Oxford, 549-565.
[10] Cheung, M. S., Chan, M. Y. T., and Beauchamp, T. C. (1982). Impact factors for composite steel box-girder bridges. Proc., Int. Assn. for Bridges and Struct. Engrg. IABSE Colloquium, Zurich, 841-848.
[11] Cheung, Y. K., and Cheung, M. S. (1972). Free vibration of curved and straight beam-slab or box-girder bridges. IABSE Periodica, Zurich, 32(2), 41-52.
[12] Cheung, Y. K., and Li, W. Y. (1991). Free vibration analysis of longitudinal arbitrary curved box-girder structures by spline finite-strip method. Proc., Asian Pacific Conf. on Computational Mech., Pergamon, Oxford, 1139-1144.
[13] Chu, K. J. , and Jones, M. (1976). Theory of dynamic analysis of box-girder bridges. Int. Assn. of Bridge and Struct. Engrg., Zurich, 36(2), 121-145.
[14] Chu, K. J., and Pinjarkar, S. G. (1971). Analysis of horizontally curved box girder bridges." J. Struct. Div. , 97 (10), 2481–2501.