International Conference on Science, Engineering & Management Trends

International Journal of Science, Engineering and Technology
ISSN: 2348-4098, P-ISSN: 2395-4752

Study and Analysis of Single Cell Box Girder in a Metro Bridge Under Various Radius of Curvature

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Abstract- The population of the Ahmedabad metropolis, India's economic hub, has grown dramatically over the last two decades. To meet traffic demands, Metro Rail Transport began operations. Ahmedabad Metro Rail Corporation is building some phases of an elevated metro rail system. A typical box girder bridge consists of various structural elements. The current study focuses on the parametric analysis of single cell box girder bridges that are curved in plan. The parametric study used five box girder bridge models with constant span length and varying curvature. In order to validate the finite element modeling method, a box Girder Bridge example from the literature is chosen for the validation study. The example box girder is modelled and analysed in SAP 2000, and the results are found to be reasonably consistent with those reported in the literature. The response ratio is expressed as a parameter. The responses show that parameters such as torsion, bending moment, and deflection increase as the curvature of the bridges increases.

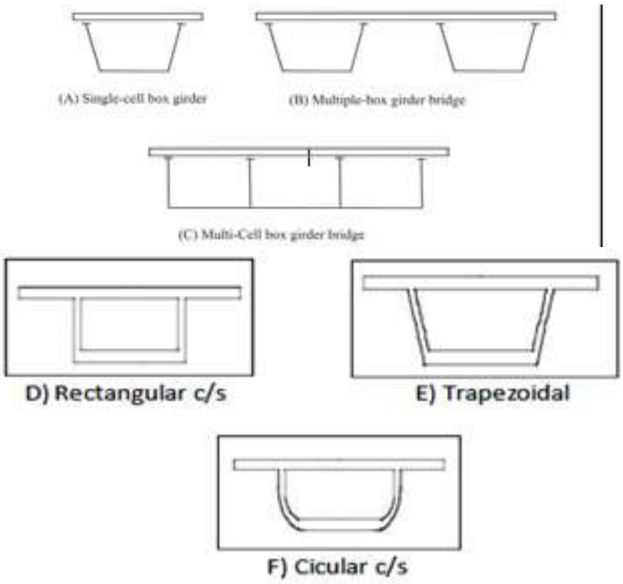
Keywords- Elevated Metro Structure, Box Girder Bridge, Direct Displacement Based Seismic Design, Performance Based Design, Force Based Design

I. INTRODUCTION

Due to their superior stability, serviceability, structural efficiency, cost-effectiveness, and attractive appearance, box girders have become widely used in freeway and bridge systems. Because box-girder bridges exhibit three-dimensional behaviors such as torsion, distortion, and bending in both longitudinal and transverse directions, their analysis and design are extremely complex. A standard box girder bridge built as part of the Metro Rail Project in Ahemedabad. There are numerous ways to categorize box girders based on their shapes, uses, and construction methods. Single-, double-, or multi-cell box girders are all possible. The deck can be built separately later known as an open box girder or it can be built monolithically with the deck known as a closed box girder. Alternatively, box girders can be round, trapezoidal, or rectangular.

Single-cell box grider (B) Multiple box grider bridge (C) Multi-cell grider bridge

International Journal of Science, Engineering and Technology
ISSN: 2348-4098, P-ISSN: 2395-4752



D) Rectangular c/s (E) Trapezoidal (F) Circular c/s

Fig. 1: Different types of box girder bridges

II. LITERATURE REVIEW

P.K. Gupta et.al. 2010 issued a technical note on parametric study on behavior of box-girder bridges using finite element method. It present study of box girder bridge cross-sections namely Rectangular, Trapezoidal and Circular has been carried out in the present investigation.SAP-2000 has been used to carry out linear Analysis of these box girders. Three dimensional 4-noded shell elements have been employed to analyze the complex behavior of different box-girders. The linear analysis has been carried out for the Dead Load (Self Weight) and Live Load of Indian Road Congress Class 70R loading, for zero eccentricity as well as maximum eccentricity at mid-span. The paper presents a parametric study for deflections, longitudinal and transverse bending stresses and shear lag for these cross-sections. In the paper, results of linear analysis of three box girder bridge cross-sections namely Rectangular, Trapezoidal and Circular of varying depths have been presented.

J. Rimal et.al. 2002 worked on the thermal behavior of a Composite Box-girder Railway Bridge, The behavior of a composite box-girder railway bridge subject to environmental thermal effect such as solar radiation, air temperature and wind speed, was presented. The temperature measure of temperatures was performed on the railway bridge in Kralovske Porici.

Sisodiya,et.al 2014 presented finite element analyses for single box girder skew bridges that were curved in plan. The bridge that could be analyzed by this method may be of varying width, curved in any shape, not just a circular shape and with any support conditions. They used rectangular elements for the webs and parallelogram or triangular elements for top and bottom flanges. Such an approach is impractical, especially for highly curved box bridges.

III. METHODOLOGY & ANALYSIS

The method has become an important part of engineering analysis and design because nowadays finite element computer programs are used practically in all branches of engineering. A complex geometry, such as that of continuous curved steel box girder bridges, can be readily modeled using the finite element technique. The method is also capable of dealing with different material properties,

International Journal of Science, Engineering and Technology
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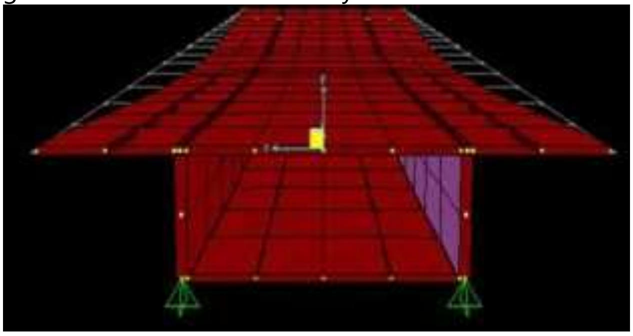
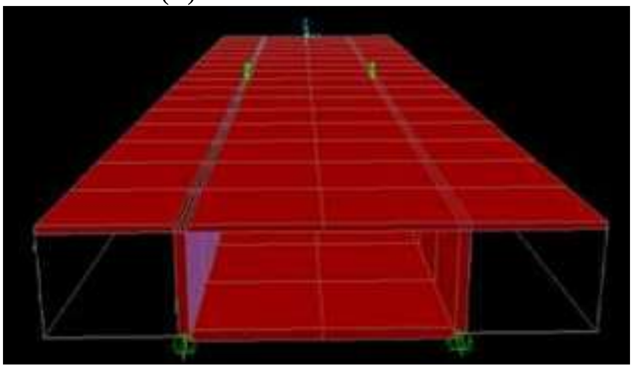
relationships between structural components, boundary conditions, as well as statically or dynamically applied loads. The linear and nonlinear structural response of such bridges can be predicted with good accuracy using this method. In the current research, various structural elements are modelled using finite element method. Program SAP2000 that was utilized throughout this study for the structural modeling and analysis and finally the description of the models of the straight and curved box bridges is presented.

Finite Element Model Using Sap 2000

The cross section of the simply supported box beam bridge model used for the validation study. It is subjected to two equal concentrated load (P=2x800N) at the two webs of mid span. Length of Span is considered as 800mm, Modulus of elasticity (E) as 2.842GPa and Modulus of rigidity (G) as 1.015GPa. The model is Modelled in SAP refer Figure 3.2. The rectangular box girder is modelled with Bridge Wizard having Shell elements. The boundary condition is taken is simply supported. It is assigned with point loads along the negative Z direction. Static analysis is conducted for the model.



(A) Model without load



(B) Model with load

Figure 2: Single cell rectangular box girder bridge modelled in SAP 2000

The bending moment, shear force and deflection at quarter span and mid span are monitored. The comparison of the values obtained and the values reported in literature, Gupta et. al (2010) are presented in the Table 1. The table shows that percentage error in the values obtained for BM, SF and deflections are very negligible. Hence the finite element model can be considered as validated. The same modelling approach is followed for further studies on modeling of straight and curved box girder bridges.

Second moment of area of the

Table 1: Comparison of responses obtained in present study and Gupta et. al (2010

International Journal of Science, Engineering and Technology
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Second moment of area of the concrete section	Ic	4.45 m^4
Section modulus bottom	Wb 3	3 m^3
Section modulus top	Wz	5.3m^3
Perimeter concrete box girder	u	22.66m

Parameters	Location	Present Study	Gupta et.al(2010)	% Error
Bending Moment (KN-m)	L/4th of span	0.16	0.16	0
	Mid span	0.32	0.32	0
Shear Force (KN)	L/4th of span	0.8	0.8	0
	Mid span	0.8	0.8	0
Deflection (mm)	Midspan	4.35	4.91	12.87

Table 2: Material Property of Trapezoidal Box Girder Relation between maximum torsion to the ratio of span to radius of Curvature

IV. RESULT AND DISCUSSION

From the relation, T = GθI/L
where,
T = Torsional Moment
G = Bulk Modulus
θ = Subtended angle
I = Polar Moment of Inertia L = Span length
From the relation the graph from Figure 3 shows that as θ increases the Torsion increases. Thus with increase in θ, R will decrease for constant span. In comparison to straight model the curved models have much higher values of torsional moments.

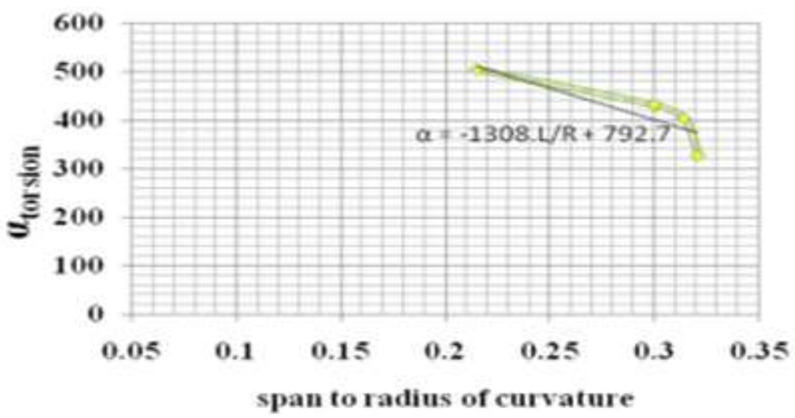

Figure 3: Variation of αtorsion with the radius of curvature Maximum Torsion can also be expressed in terms of L/R ratio by the following Linear Equation
α torsion= -1308.L/R +792.7
where,
α torsion = (max. torsion, curved/max. torsion, straight)

L/R = span to radius of curvature

V. CONCLUSIONS

- Under IRC class A loading, for bottom face of left overhang part of girder, the longitudinal stress is increased by 12% as the radius of curvature is increased from 205m to 210m and it is increased by 17.5% as radius of curvature is increased from 210m to 220m radius of curvature, 5.2% when the radius of curvature is increased from 220m to 306m.
- For top face, the longitudinal stress for all the curved models increases about 6% from straight model.
- Under IRC class A loading, the longitudinal stress increase of 12%, 25% and 1% are observed between the models 205R to 210R, 210R to 220R and 220R to 306R for the bottom face of central cross section.
- For top face the longitudinal stress for all the curved models increases fairly 6% from straight model
- Under IRC class A loading, for bottom face of right overhang part of girder, the longitudinal stress is increased 16% from 205R to 210R and it is decreased by 28% both from 210R to 220R and 210R to 306R. For top face, longitudinal stress increases by 2% from 205R to 210R and by 33% from 210R to 220R and also from 210R to 306R.
- The fundamental mode is same for all the five models of bridges; as the mass and stiffness remains almost the similar.

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