AN OVERVIEW ON BOX GIRDER BRIDGES

Savio John[1], Reshma Prasad.[2]

[1]PG Student, Department of Civil Engineering, FISAT, Angamaly, India
[2]Assistant Professor, Department of Civil Engineering, FISAT, Angamaly, India

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Abstract - *Bridge construction nowadays has achieved a worldwide level of importance. The efficient dispersal of congested traffic, economic considerations, and aesthetic desirability have increased the popularity of box girder bridges these days in modern highway systems, including urban interchanges. Box girders are prominently used in freeway and bridge systems due to its structural efficiency, serviceability, better stability, pleasing aesthetics and economy of construction. The box girders are efficient form of construction for bridges because it minimizes weight, while maximizing flexural stiffnes and capacity. Box girder have high torsional stiffness and strength, compared with an equivalent member of open cross section. Although significant research has been underway on advanced analysis for many years to better understand the behaviour of all types of box-girder bridges, the results of these various research works are scattered and unevaluated. Hence, a transparent understanding of more recent work on straight and curved box-girder bridges is highly desired. The main objective is give a clear vision about non composite straight and curved box girder bridges. This study would enable bridge engineers to better understand the behaviour of box girders with different variations in parameters such as curvature and shape.*

Key Words: Box girder, Bridge, Stiffness

1 INTRODUCTION

A box girder consists of two web plates which are joined by a common flange at top and bottom. Box girders can be classified in so many ways according to their method of construction, use, and shapes. There are three box girder configurations commonly used in practice. Box girders can be constructed as single cell, multiple cell or multicell. It may be monolithically constructed with the deck (closed box girder), or the deck can be separately constructed afterwards (open box girder). The box girder normally comprises of either pre-stressed concrete, structural steel, or reinforced concrete. According to shape, box girders may be classified as rectangular, trapezoidal and circular. A box girder is particularly well suited for use in curved bridge systems because of its high torsional rigidity. High torsional rigidity allows box girders to effectively resist the torsional deformations encountered in curved thin-walled beams. Box girder webs may be vertical or inclined, which reduces the width of the bottom flange. In bridges with light curvature, the curvature effects on bending, shear and torsional shear stresses can be ignored if they are within permissible range. Treating horizontally curved bridges as straight ones with certain limitations is one of the methods to simplify the analysis and design procedure. But, presently higher level investigations are possible due to availability of high capacity computational systems. It is required to examine these bridges using finite element analysis with different radius of curvatures configurations.

Box girder structures use a combination of primary mild steel reinforcement and high strength post-tensioning steel tendons to resist tension and shear forces. Flexure reinforcement is provided in the top and bottom flanges of the box girder as necessary (bottom flange at midspan in areas of positive moment and top flange over supports in areas of negative moment). However, because of the design span lengths, mild steel reinforcement does not have sufficient strength to resist all of the tension forces. To reduce these tensile stresses to acceptable levels, prestressing of the concrete is introduced through post-tensioning. Galvanized metal and polyethylene ducts are placed in the forms at the desired location of the tendons. When the concrete has cured to an acceptable strength level, the tendons are installed in the ducts, tensioned, and then grouted.

The top flanges or decks of precast or cast-in-place segmental boxes are often transversely post-tensioned. The multi-strand tendons are grouted after stressing. The tendons anchor in block-outs in the edges of top slab cantilever wings. These block-outs are then filled with concrete and covered with a traffic barrier. For precast units, the top flange tendons are generally tensioned and grouted in the casting yard. Wide bridges may have parallel twin boxes transversely post-tensioned. When this is the case, only about one-half of the transverse post-tensioning is stressed before shipment. The remainder of the post-tensioning is placed through ducts in adjacent box girders and the closure strip and stressed across the entire width of the bridge. Special “confinement” reinforcement is also required at the anchorage locations to prevent cracking due to the large transfer of force to the surrounding concrete.

Stirrups in the web are provided to resist standard beam action shear. For curved girder applications, torsional shear reinforcement is sometimes required. This reinforcement is provided in the form of additional stirrups.

The secondary (temperature and shrinkage) reinforcing steel is oriented longitudinally in the deck and webs and flanges in the box girder. The primary and secondary reinforcing steel for the deck portion of the girder is same as that for a standard concrete deck.

2 DISTINCTIVE FEATURES

A box girder has high torsional stiffness and strength, compared with an equivalent member of open cross section due to its distribution of longitudinal flexural stresses across the section remains more or less identical. The increase in flange width of box girder makes it possible to use large span/depth ratios. This is an advantage if construction depth is limited. Also it can lead to more slender structures which are mainly considered more aesthetical. The space enclosed within in the girder may be used for the passage of services such as gas pipes, cables, water mains etc. Maintenance of a box girder can be easier, because the interior space can be made directly accessible. Box girders are generally aesthetic. The shape of the box girder can vary a lot. This makes them easier to design for aerodynamic shapes, which is an advantage especially for long span bridges.

3 GENERAL BEHAVIOUR OF CURVED BOX GIRDER

The curved beam theory was developed by Saint-Venant (1843). Vlasov (1965) developed the thin-walled beam theory which marked the birth of all research efforts published to date on the analysis and design of straight and curved box-girder bridges. The recent studies on straight and curved box girder bridges are dealt with analytical formulations to better understand the complex behaviour of box girders.

3.1 Bending Effects

The bending load will cause the section to deflect rigidly (longitudinal bending) and deform (bending distortion). The box girders have large span to depth ratio and due to that transverse load causes significant bending stresses in the girder. The bending distortion occurs when transverse loads are applied to the open box.

3.2 Torsional Effects

The torsional load causes the section to rotate rigidly (Mixed torsion) and deform the section (Torsional distortion). In curved box girder bridges, the transverse loads acting on the girder causes twisting about its longitudinal axis because of the bridge curvature. Uniform torsion occurs if the rate of change of the angle of twist is constant along the girder and warping is constant and unrestrained. If there is a variation of torque or if warping is prevented or altered along the girder, longitudinal torsional warping stresses develop. In general there are two types of torsion that act on cross-sections. Shear flow around the cross-section develops Saint-Venant torsion, while the other one is warping due to bending deformation in the cross-section. Box girders are usually dominated by St. Venant torsion because the closed cross section has a high torsional stiffness.

4 LITERATURE REVIEW

Various literature reviewed on box girders is presented in this section. A number of works have been carried on optimization of box girder by varying different parameters. A review of literatures is summarized in brief by various scholars and researchers on box girder.

There are several literature studies on straight and curved box girder bridges dealing with systematic formulations to have a clear understanding the behaviour of these complex structural systems. Some experimental studies are undertaken by a few authors to investigate the accuracy of existing elastic analysis methods such as finite element method, finite strip method and so on.

W.Y.Li et al. (1998) employed three examples of box-girder bridges of various geometrical shapes to illustrate the accuracy and versatility of the finite strip method. This work points out that compared to the finite element method, this method yields substantial savings in both time and effort, since only a few number of unknowns are generally required in the analysis.

Khaled et al. (2003) conducted a parametric study on multi cell box girder bridges using finite element method and the bridges are subjected to AASHTO truck loading and dead load. In this study, a parametric study of multiple steel box girder bridge was conducted by an experimentally calibrated finite-element model and the shear distribution characteristics under dead load and AASHTO live loadings are determined. Based on the results obtained from this study it was found that the presence of solid end diaphragms at the abutment supports coupled with a minimum of three bracing systems, equally spaced along the span with a maximum spacing of 7.5 m, and significantly enhances the transverse shear distribution. Another conclusion from this study is that stiffer cross bracings can significantly improve the transverse shear distribution and reduce lifting upward at the abutments.

Ayman et al. (2004) conducted a detailed investigation of warping related stress of composite steel concrete box girder bridges of different radius of curvature and span length. This paper points out that there can be a large subset of bridges where the warping effect is small enough which may be ignored in structural calculations. This is particularly useful to designers, because warping calculations are complicated and time-consuming.

Gupta et al. (2010) conducted a parametric study on behaviour of box girder bridges under different depth of the cross section.Three dimensional 4-noded shell elements have been employed for discretization of domain and to analyse the complex behaviour 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. The paper presents study on various parameters for deflection, longitudinal and transverse bending stresses and shear lag for the cross-sections considered. The Finite element computational model are validated by comparing few obtained results with the published paper. Analysis of box girder bridges with four noded shell elements and its effectiveness is mentioned. From the journal it was concluded that increase in depth of box girder rsults in reduced deflection. Similarly with increase in depth the bending stress distribution also decreases.

Shi-Jun Zhou (2010) this paper considered the interaction of the bending and shear-lag deformation of a box girder and established a finite-element method. A shear-lag-induced stiffness matrix was defined and the stiffness matrices considering the effect of the shear lag was formulated. At each node of the beam element, two shear-lag degrees of freedom are used as boundary conditions for the box girders. The proposed formulations is then applied to analyse the effects of the shear lag on the deflection, the internal forces, and the shear-lag coefficients in the simply supported, cantilever and continuous box girders under concentrated and uniformly distributed loads. The results obtained using the proposed procedure was in good agreement with using different methods such as the analytical method, the finite-stringer method, the finite shell element method through variational principle, and the model tests. The proposed method is dependable and more effective for the analysis of the shear lag in the actual box-girder structures.

Nikolaos Pnevmatikos & Vassilis Sentzas (2012) this paper focuses on the seismic response of the curved and post-tensioned concrete box girder bridges. It investigates influence of curvature and its response of a bridge subjected to earthquake. Parametric analysis of different radius of curvature is analyzed and the internal forces, torsion moment, axial and shear along the bridge are found out. Two types of connections are carried out for investigation, the monolithic connection and deck connection with bents and abutments with bearing. The response spectrum seismic analysis was performed. Diagrams relating the curvature with the torsion moment have been obtained from the results of analysis. These diagrams can be used by engineers for preliminary design of such kind of bridges.

5 SUMMARY AND CONCLUSION

A concise review of different literatures presented shows that that there are a number of published work on study of box girder bridges with different variations in parameters such as shape, span, depth, material used, method of construction, cell configuration, curvature and so on. Due to rapid advancement of computers and development of various analytical methods, complex model of curved beams have become easy to analyze and hence engineers have started to adopt the curved beams into use. Results based on curvature are scattered and unevaluated, hence there is a future scope of research on this area. Seismic and dynamic analysis can be considered in future studies

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