Review Onprestressed Concrete Box Girder Bridge Superstructure

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Abstract- *The prestressed concrete box girder bridges have achieved a worldwide level of importance in freeway and bridge systems due to its structural efficiency, serviceability, better stability, pleasing aesthetics and economy of construction. The efficient dispersal of congested traffic, excellent riding characteristics, economic as well as aesthetic desirability has increased the popularity of box girder bridges these days in modern highway systems, so it should be capable to withstand static as well as dynamic loads specially, earthquake-induced load to achieve a structure that behave at the level of life safety under enormous earthquake.*

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 continuous and curved box-girder bridges is highly desired. The main objective of present article is giving a clear vision about PSC 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.

Keywords- Box girder, Continuous Bridge superstructure, Pre-stressing.

I. INTRODUCTION

In Structural Engineering, prestressed concrete box girder bridges have increased the popularity in modern highway system. 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.

With the benefit of applying box girders, deck slab have supporting system with large span to depth ratios excellently suited as it is composed of extreme strength prestressing steel.Dynamic analysis of bridges are essential to ensure overall structural performance and stability during severe ground shaking motion. The main objective of performing dynamic analysis is to provides an accurate measure of expected structural response for a given earthquake or any kind vibrations and to improve the response of bridges during earthquake forces.

A box girder is particularly well suited for use in curved bridge systems. 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. Flexure reinforcement is provided in the top and bottom flanges of the box girder as necessary 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. 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 in form of stirrups in web is also required at the anchorage locations to prevent cracking as well as shear.

For curved girder applications, torsional shear reinforcement in the form of additional stirrups is sometimes required.
The primary and secondary reinforcing steel is same. For temperature and shrinkage reinforcing steel is oriented longitudinally in the deck and webs and flanges in the box girder.

The most important factors affecting dynamic response are the basic flexibility of the structure and, more specifically, the relationship between the natural frequency of the structure and exciting frequency of the vehicle using finite element analysis with different radius of curvatures configurations.

II. 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. Box girder sections 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.

Fig:-1 Pres-stressed Concrete Trapezoidal Box Girder Bridges.

III. SUPERSTRUCTURE OF PRESTRESSED CONCRETE CONTINUOUS BOX GIRDER BRIDGES

Box girders are widely used in forming the superstructure of continuous highway as well as metro rail bridges due to their structural efficiency, better stability, serviceability, economy of construction and pleasing aesthetics. It can cover a range of spans from 25 m up to the largest non-suspended concrete decks built; of the order of 300 m.

IV.DYNAMIC BEHAVIOUR OF CONTINUOUS BOX GIRDER

As bridges is most important structure in modern highway & metro rail system. It should be capable to withstand static as well as dynamic loads. The dynamic characteristics of bridges are frequency, time period, displacement, mode shapes, base shear and damping ratio of its normal mode of vibration. These can be governed by the excitation of bridge, measure of response, analysis of data.
The recent studies on straight and curved box girder bridges are dealt with analytical formulations to better understand the complex behaviour of box girders such as

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.

2)Frequency: Natural Frequency of bridge superstructure should not fall in the range of vehicle frequency band to avoid resonance. It is clear from past studies that too short or long span bridges may not create vibration related problems.

3) Time Period: With the increase in span, time period goes on increasing.

4)Base Shear: As box girder section is enclosed and rigid section it has less base reaction as compared to other girder sections.

5) Torsional Effects
The torsional load causes the section to rotate rigidly, distortion of section as well as 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. Box girders are usually dominated by St. Venant torsion because the closed cross section has a high torsional stiffness.

V. LITERATURE REVIEW

As box section girder is considered to be one of the most suitable choices for bridge superstructure of continuous bridges, a thorough review is carried out over the past. Each and every facet should be considered for economical and safe structure. This chapter gives an overview of various studies on box girders. Analysis and optimization is carried out of box girder by varying different parametersto investigate the accuracy of existing elastic analysis methods such as finite element method, finite strip method and so on.The overall goal of this chapter is to critically evaluate the different methodologies so as to identify the appropriate approach for our future work.

5.1 Review of Literature

Cheung and Li (1991) extended the application of the spline finite strip method to free-vibration analysis of curved box-girder bridges to reduce the computational effort when compared to the finite-element method.

Huang and Wang (1996) analyzed thin-walled box girder bridges subjected to moving vehicle for obtaining the dynamic response and impact factor characteristics using free-vibration analysis considering torsion, bending moment as well as deflectionandto obtain their impact factor characteristics.

W.Y.Li et al. (1998) employed & compared three examples of box-girder bridges of various geometrical shapes to illustrate the accuracy and versatility of the finite strip method and the finite element method, this method yields substantial savings in both time and effort.

Khaled et al. (2003) conducted a parametric study on multi cell box girder bridges subjected to AASHTO truck loading and dead load and concluded as stiffer cross bracings can significantly improve the transverse shear distribution and reduce lifting upward at the abutments.

Samaan et al. (2007) presented a dynamic analysis of curved continuous multiple box girder bridges, using the finite element method, to evaluate their natural frequencies and mode shapes and experimental tests are conducted on two continuous twin-box girder bridge models of different curvatures to substantiate the finite-element model.

Gupta et al. (2010) conducted a detailed study of box girder bridge cross-sections namely Rectangular, Trapezoidal and Circular and also presented a parametric study for deflections, longitudinal and transverse bending stresses and shear lag for all cross-sections.

Chirag Garg and M.V.N Kumar (2014) analyzed the most effective positions of pre-stressed tendons by keeping constant loading and varying the positions of tendons using SAP2000 software. A combination of three moving vehicle loads i.e. H 20-44 Truck load, HS 220-44 Truck load, H 20-44 Lane load in two lanes of bridge deck is considered in this study. Conclusion was based on stress contours of the different load cases.

Vishal U. Misal (2014) carried out a study on design and cost analysis on pre-stressed concrete girder. IRC class AA, 70R loading are used for analysis. Comparison between I-girder and Box girder is done on the basis of results obtained from classical old theory and STAAD PRO software.

Miss P.R. Bhivgade (2014)analyzed pre-stressed concrete two lane simply supported box girder subjected to moving loads as per IRC:6, IS:1343, IRC: 18 specifications at various span/depth ratios, the deflections and stress criteria are checked SAP 2014 bridge wizard and pre-stressed with parabolic tendons in which full sections is utilized. This paper gives the basic principles for proportioning of concrete box girder.

Ms.Rubina Patil and Dr. R.S Talikoti (2014) performed a seismic analysis on balanced cantilever bridge by conventional methods and are then compared with the analysis carried out in SAP 2000 considering time dependent properties. In this paper the effect of time dependent properties on moment variation with time during construction and at various stages during the life span of the bridge is studied.

Nila P Sasidharan (2015)analyzed single-cell curved rectangular box girder using ABAQUS software and presents a parametric study by varying span and radius of curvature and by keeping the span to depth ratio constant

Abd. El-Hakim Khali et.al (2015) presented behaviour of box girder under pure torsion also introduced prestressing strengthening techniques, and concluded that the presence of transverse opening decreases the torsional capacity compared to beam without opening.

This review enhanced the knowledge about behaviour of box girder under static & dynamic loading as well as efficient prestressing techniques in box girder bridge superstructure to intensify structural performance of bridge superstructure.

VI. SUMMARY AND CONCLUSION

A concise review of different literatures on study & Analysis 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 showed that most important factors affecting dynamic response are the basic elasticity of the structure especially; relationship between the natural frequency of the structure and exciting frequency of the vehicle as well as amplitude of vibrations has major influence against occurrence of extreme vibrations of structure.

The various advantages provided by box girders are as follows:

i. Pre-stressed concrete girder whether continuous or simple requires much less steel than reinforced beam girder. Especially for large span, (Span > 25m) box girder is always suitable.
ii. Box girder shows better resistance to torsion of superstructure.
iii. As the depth increases the pre-stressing force decreases and the number of cables decreases.
iv. The most effective position of the tendons in box girder to increase the stability of bridge superstructure as shown in the Fig 2. below.

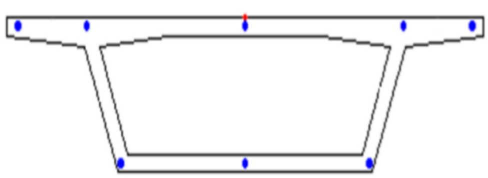

Fig:-2Most Effective Positions of Tendons in a Box Girder (Source: Chirag Garg 2014)

v. The radius of curvature and the reactions like BM, SF, and stresses are inversely proportional to each other. Hence, as radius of curvature increases the reactions are minimum.
vi. The natural frequency of vibration of PSC girder bridge superstructure hardly matches with the vehicle frequencies.
vii. Strengthening of box beam using external prestressed technique improves ductility behaviour, torsional capacity transversely while for longitudinal strengthening it is not that effective.
viii. Interiors of box girder bridges can be used to accommodate service such as gas pipes, water mains etc; and bottom flange to accommodate traffic with advantage of providing a non-corrosive atmosphere.

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