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Parametric Study on Behaviour of RC Box Girders

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Abstract*—Box girder nowadays has achieved a significant level of importance in bridge and construction of Metro works. The present study focus on behaviour of different types of RC box girder bridges keeping span length constant. This study would enable bridge engineers to better understand the behaviour of box girders with different variations in parameters such as curvature and shape. For the parametric study eight models of different shape and cells are analysed in finite element model software, SAP Bridge. The span length, and material property remains unchanged. The parameter that changes is the radius of curvature , cells & shape. The study is carried out on Aroor -Kumbalam railway bridge which is one of the longest railway bridge in Kerala spanning 1km. The main objective of this study is to analyse non composite straight and curved box girder bridges in the form of single and multi cell cross sections with using the three dimensional finite element analysis. Their behavior will be investigated and compared using SAP2000.

Keywords - Box girder bridge; Radius of curvature; SAP Bridge;

I. INTRODUCTION

The spanning of the bridge begin with simple slabs. When the width of the bridge deck is increased, the number of longitudinal beams to be used have also been increased which leads to reduction of stiffness in the transverse direction and relatively high transverse bending occurs. Under high transverse bending the webs could no longer be in their original position and to keep them in their original position, the bottom bulb of the webs are to be tied together. This leads to the evolution of box girder. The box girders can be of different forms and geometry. Analysis and design of box-girder bridges are very complex due to its three dimensional behaviour consisting of torsion, and bending in longitudinal and transverse directions. Analysis and design of the box girder can be separated into two parts i.e. longitudinal analysis (i.e. analysis along traffic direction) and transverse analysis (i.e. across traffic direction). In Longitudinal direction the bending moment, shear and torsion of the curved box girders differ with the different spans lengths and radius.

A box girder comprised of two web plates which gets joined by a common flange at top and bottom. Box girders can be classified according to their method of construction, use, and shapes. There are three box girder configurations commonly used in practice. It can be constructed and fabricated as single cell, multiple cell or multi cell. It may be monolithically builded with the deck (closed box girder), or the deck can be separately built later (open box girder). The box girder normally contains of either pre-stressed concrete, structural steel, or reinforced concrete. According to shape, box girders can be categorized as rectangular, trapezoidal and circular. A box girder is particularly most suited for use in curved bridge systems due to its high torsional rigidity. High torsional rigidity permit the box girders to effectively resist the torsional deformations encountered in curved thin-walled beams. Box girder webs may be vertical or inclined, which diminishes the width of the bottom flange. In bridges with small curvature, the curvature effects on bending, shear and torsional shear stresses can be neglected if they are within permissible range. Considering the 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 and examinations are possible due to availability of high capacity computational systems. It is required to investigate these bridges using finite element analysis with varying radius of curvatures configurations.

Box girders utilize a combination of primary mild steel reinforcement and high strength post-tensioning steel tendons to prevent tension and shear forces. Flexure reinforcement is imparted in the top and bottom flanges of the box girder as needed (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 adequate strength to resist all of the tension forces. To reduce these tensile stresses to acceptable levels, prestressing of the concrete is introduced and done through post-tensioning. Galvanized metal and polyethylene ducts are placed in the forms at the accurate location of the tendons. When the concrete has cured to an acceptable or permissible strength level, the tendons are installed in the ducts, tensioned, and then grouting shall be done.

The top flanges or decks of precast or cast-in-place segmental boxes are often seen transversely post-tensioned. The multi-strand tendons are grouted after stressing has been completed. The tendons anchor block-outs in the edges of top slab cantilever. These block-outs are then filled with concrete and covered or overlaid with a traffic barrier. For precast units, the top flange tendons are usually tensioned and grouted in the casting yard. Wide bridges have parallel twin boxes that a transversely post-tensioned.

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

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

II. ANALYSIS OF BOX GIRDER

SAP is a Powerful and Integrated Structural Analysis and Design Software. Modeling is done by using thin Shell Element The Shell element is a type of area object that is used to model membrane, plate, and shell behavior in planar and three-dimensional structures. The parametric modeler allows the user to build simple or complex bridge models and to make changes efficiently to maintain a total control over the design process. Lanes and vehicles can be described quickly and include width effects. Simple and practical Gantt charts are available to simulate modeling of construction sequences and scheduling. The SAP2000 14.2/Bridge module runs and compiled within the SAP2000 Plus or Advanced versions of SAP2000. It includes an easy to follow Wizard that outlines the steps necessary to create a bridge model. Unless otherwise specified, the finite element method is adopted to analyze bridge behavior.

III. BRIDGE DATA

The study is carried out on Aroor -Kumbalam railway bridge which is one of the longest railway bridge in Kerala spanning 1km. First Railway Bridge in India adopting segmental construction technology. Superstructure with pre-cast, pre-stressed, segmental type box girders.

Fig 3.1 Aroor-Kumbalam Railway Bridge

Concrete :

Grade: M45

Weight/unit volume: 25 kg/m^3

Modulus of Elasticity: 33541 MPa

Poisson's ratio: 0.15

Steel :

Grade: Fe 415

Weight/unit volume : 76.9729 kg/m^3

Modulus of Elasticity: 210000 MPa

Poisson's ratio: 0.3

IV. MODELLING DETAILS

In this study 8 models (among which four is straight and the other four are curved in plan) are analysed using finite element software SAP2000. These box girders are analysed to study the comparison of straight and curved box girder bridges in terms bending moment under different loading conditions along the length of the span. The box girder model is made using Bridge module with shell elements of SAP2000.

In the present work two different cross-sections namely Rectangular and Trapezoidal section are taken for modeling. Rectangular model has a bottom width of 4.8m and overhang length of 0.85m while Trapezoidal section has a bottom width of 3.2 m and overhang length of 0.5m. Both cross-section is modeled for straight and curved span of R230m as well both sections are modeled as single and multi cell.

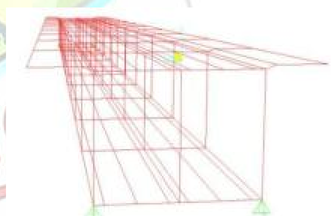

Fig 4.1 Rectangular section

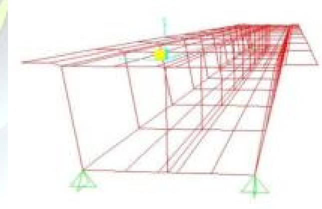

Fig 4.2 Trapezoidal section

A constant top slab thickness of 0.275m, bottom slab thickness of 0.32m and web thickness of 0.35m was considered throughout the bridge cross section. Simply support condition is assigned to bridge model using "Joint Restraints" icon that is available in the software by allocating roller support to one end and hinge to the other end.

V. LOADING ON BOX GIRDER

The main loads coming on bridge decks are permanent and temporary loads. The permanent loads include dead loads and

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superimposed dead loads. The temporary loads include vehicle live loads and impact forces. The loads that are to be considered on the superstructure of a typical box girder bridges are listed below.

Dead load :

The self-weight of the structure is applied to the structure as dead load. The finite element software is capable of generating self-weight of the structure.

Super imposed dead load :

The super imposed dead load is applied to the structure by assuming the thickness of wearing coat as 80mm with a unit weight of $22kN/m^3$.

Super imposed dead load = $0.6 \times 22000 = 13200\ N/m^2$

Moving load :

Width of span for both sections is taken as 4.8m, one lane of 25t loading-2008 as per IRS bridge rule.

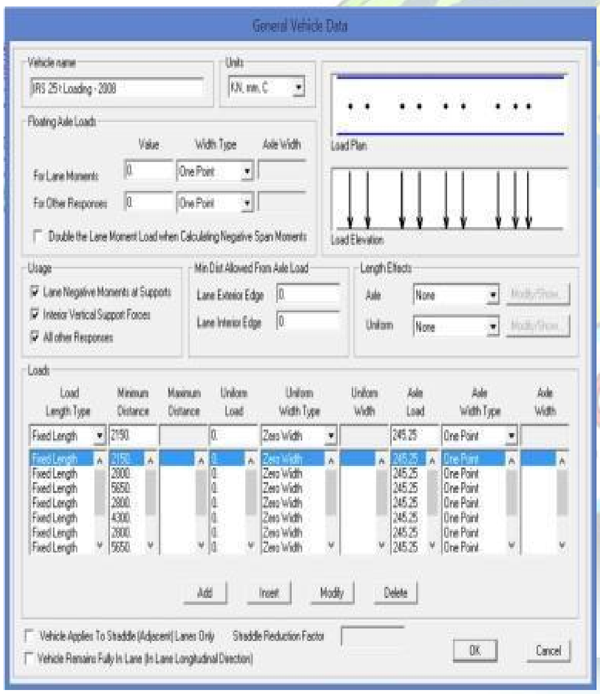

Fig 5.1 IRS 25t Loading-2008

VI. RESULTS

Bending moment due to dead load for trapezoidal section is 3% greater than that of rectangular section. Bending moment due to moving load for trapezoidal section is 2.5% lesser than that of rectangular section. Maximum bending moment of curved span due to dead load is 12718 kNm for a trapezoidal multi cell section. Maximum bending moment of straight span due to dead load is 12621 kNm for a trapezoidal multi cell section.

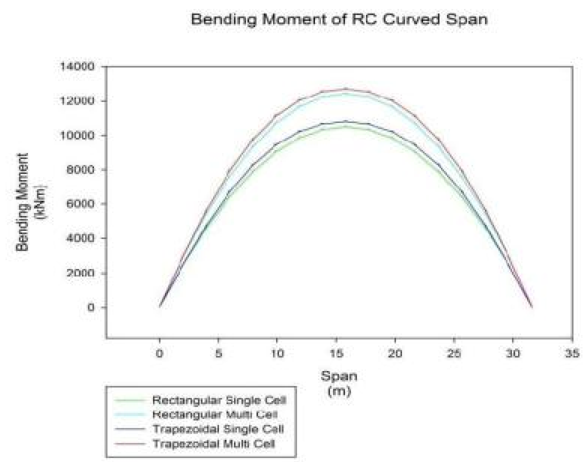

Fig 6.1 Bending moment of curved span due to dead load

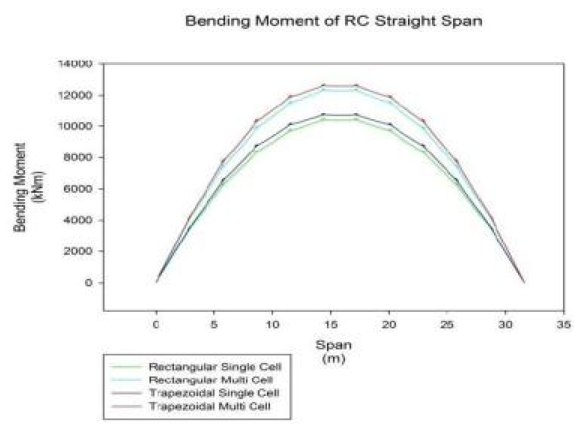

Fig 6.2 Bending moment of straight span due to dead load

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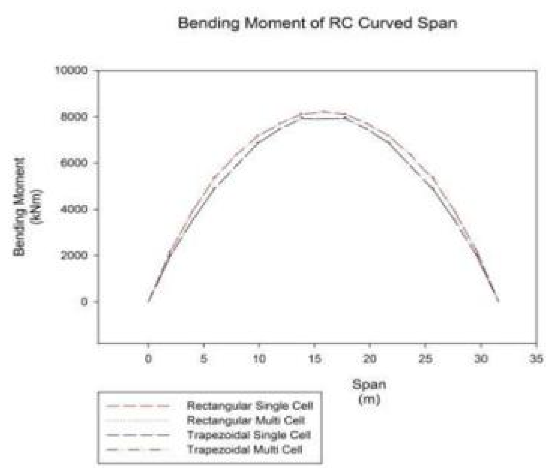

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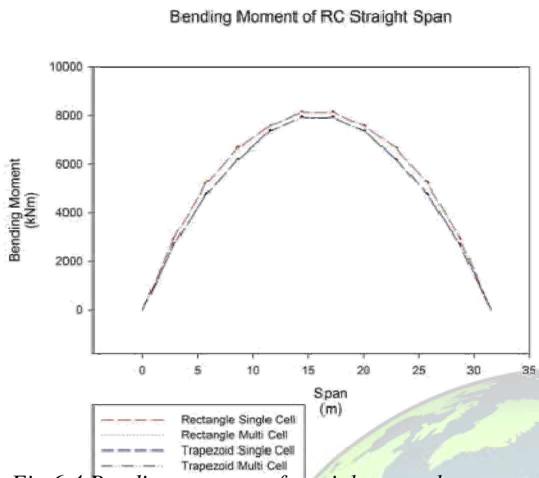

Fig 6.4 Bending moment of straight span due to moving load

Maximum bending moment of curved span due to moving load is 8212 kNm for a rectangular section. Maximum bending moment of straight span due to moving load is 8139 kNm for a rectangular section.

VII. CONCLUSIONS

The analysis of straight box girder and curved box girders with different shape are carried out in SAP Bridge software. According to this analysis the trapezoidal section of box girder is subjected to more bending moment than that of rectangular section for dead load, while in moving load trapezoidal section of box girder is subjected to less bending moment than that of rectangular section. There is a increase in bending moment for multi cell than that of single cell and also increase in bending moment for curved span than that of straight span.

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