USING FINITE ELEMENT METHOD FOR ANALYSIS OF SINGLE AND MULTICELL BOX GIRDER BRIDGES.

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Abstract –

Bridge construction today has achieved a world-wide level of importance. Bridges are the key elements in any road network Use of box girder is gaining popularity in bridge engineering fraternity because of its better stability, serviceability, economy, aesthetic appearance and structural efficiency. The structural behavior of box girder is complicated, which is difficult to analyze in its actual conditions by conventional methods. Finite element method analysis provides results to interpret the three dimensional behavior. The objective of this project is to deal with finite element analysis of Single and multicell box girder bridges.

In the present study single cell box girder with and without Diaphragm and Twin Cell With and without Diaphragm are studied. First it is analyzed by conventional method and then by finite element method. The comparison is made with respect to calculation along longitudinal and transverse direction. 2D plane frame analysis is also used to compare results in the transverse direction. This study aims to validate the conventional and finite element method.

It is also proposed to study the effect of end and intermediate diaphragm on different types of cell. It also incorporates the effect of temperature (Uniform and temperature gradient) on different types of cells. Comparison such as shear force, bending moment, deflection, natural frequency, natural time, distribution factor are prepared and the results are presented

1. INTRODUCTION

Bridge construction today has achieved a world-wide level of importance. Over the last few decades, the enormous growth in traffic volume has resulted into the congested roads, reduced speed and long traffic jams specially in urban dense areas. For smooth flow of traffic there is a growing need to place new highway in existing transportation corridors in order to minimize disruption and land acquisition.

Bridges are the key elements in any road network. Use of box girder is gaining popularity in bridge engineering fraternity because of its better stability, serviceability, economy, aesthetic appearance and structural efficiency. The variety of forms of the bridges demonstrates the combination of art and technology.

Bridge is a structure providing passage over an obstacle without closing the way beneath. The required passage may be for a road, a railway, pedestrian, a canal or a pipeline. The obstacles to be crossed may be a river, a road, a railway or a valley. A bridge basically consist of two parts namely the superstructure and the substructure. Depending upon the type of material, structural action, use etc. bridges are classified into various types. The choice of appropriate type of bridge and planning of its basic features constitute a crucial decision. The superstructure of any bridge may be analyzed and designed such that it satisfies the geometric and load carrying requirements. Figure 1.1 shows the components of a typical bridge.

2. LITERATURE REVIEW

Khaled M. Sennah and John B. Kennedy (1999) [1]

Presented an extensive parametric study using the finite-element method—in which 120 bridges of various geometries were analyzed. The parameters considered are: number of cells, number of lanes, span length, and cross bracings. Results from testing a simply supported three-cell bridge model are used to substantiate the analytical modeling. Based on the parametric study, moment and shear distribution factors are deduced for such bridges subjected to AASHTO truck loadings as well as dead load. Saint-Venant torsional stiffness for composite cellular cross sections used in this study is also investigated. Recommendations to enhance the torsional stiffness are formulated. An illustrative design example is presented.

Khaled M. Sennah and John B. Kennedy (1999) [2]

Summarizes the results from an extensive parametric study, using the finite-element method, in which simply supported curved composite multicell bridge prototypes are analyzed to evaluate the moment and deflection distributions between girders, as well as the axial forces expected in the bracing system, due to truck loading as well as dead load. Results from tests on four, 1/12 linear-scale, simply supported curved composite concrete deck-steel multicell bridge models are used to substantiate and verify the analytical modeling. The parameters considered in the study are cross-bracing system, aspect ratio, number of lanes, number of cells, and degree of curvature. Based on the data generated from the parametric study, expressions for moment and deflection distribution factors are deduced. Expressions for the maximum axial force in bracing members are also derived. An illustrative design example is presented.

Tushar V. Ugale, Bhavesh A. Patel and H. V. Mojidra(2006) [3]

Included methods available for analysis of Multi cell box girder and the parametric studies for alternatives of multi cell with three, four, and five cells have been incorporated. Study also includes effect on multi cell with and without inclined web. For analysis IRC-6 vehicle loading has been considered. The software modeling and FEM analysis carried out and obtained the coefficient of moment and shear distribution for each cell. The coefficients of live load distribution obtained for span: depth ratio varies from10:24. This paper is suggested to the most effective alternative for upcoming concrete box girder bridges. The conclusions of the authors are listed below.

i. Analysis performed on straight as well as inclined web girder. The inclined web girder suitable than straight girder.

ii. The coefficient of distribution shows that web lies away from the wheel position is less effective. So edge webs are normally provided such a way that wheel should locate exactly or near to web.

iii. The analysis of all sections shows that, Single Cell Box Girder Economical From 15 Up to 25m and Two Cell Box Girders Economical From 20 m Up to 28m and Three Cell Box Girders Economical From 22 Up to 35m, Four and Five Cell Box Girder is not so economical alternative for two lanes bridges. Effective when span is in between 30 to 50m Span more than 30 m, Prestress two and three cell Box Girder is economical alternative than RCC box section.

Vishal S. Jawanjal and Manoj Kumar (2006) [4]

Presented the Finite Element Analysis of simply supported box-girder bridge curved in plan with skewed supports. In this study the finite element analysis has been carried out using the 9-node degenerated shell element, however, the geometry of the bridge has been modeled with the help of STAAD Pro. In order to study the behavior of skewed-curved box-girder bridge, a 20m span Reinforced Concrete (RC) bridge has been considered and the degrees of curvature and skewness has been varied to study the effect of curvature and skewness on deflection, longitudinal bending stress and shear lag.

Ganesh Deshmukh (2000) [5]

Solved box girder by conventional analysis certain assumptions are made in the conventional analysis like transverse analysis one meter length is taken and the analysis is done by usual moment distribution method. In longitudinal direction girder does not consider longitudinal bending of the whole box where the top and bottom slab act as flanges of hollow box girder.

For the same box girder a three dimensional analysis using 3-D general shell element is carried out and the results are compared with the conventional analysis. 2D plane strain element is used to compare the results in transverse direction at the end section where bearings are provided.

A Ghani Razaqpur and hanging Li(1991) [6]

Developed a thin walled box-girder finite element that can model extension ,flexure, torsion, torsional warping ,distortion, distortional warping, and shear lag effects was developed using an extended version of Vlasov's thin walled beam theory. The element has two end nodes, but it has besides the six nodal degrees of freedom of a conventional beam element, additional degrees of freedom to account for torsional warping, distortion, distortional warping, and shear lag. The governing differential equations pertaining to each action was used to derive the exact shape functions and the stiffness matrix and nodal vector of the element. An orthogonalization procedure was employed to uncouple the various distortional and shear lag modes. A numerical example is solved that compares the proposed method with the facet-shell finite element analysis with good agreement between the two sets of results.

Kenneth W.Shushkewich (1988) [7]

Presented the actual three dimensional behavior of the box girder bridge as predicted by a folded plate, finite strip, or finite element analysis can be approximated by using some simple membrane equations in conjunction with a plane frame analysis. In plane frame analysis a unit length of the cross section is considered and supports are placed at the junction of webs and the bottom slab. The method allows reinforcing and prestressing to be proportioned for transverse flexure, as well as the stirrups to be proportioned for longitudinal shear and torsion in single celled, precast concrete, segmental box girder bridges. Three numerical examples are given to illustrate how the method can be applied to practical problems.

Khaled M. Sennah, Xuesheng Zhang and John B. Kennedy (2004) [8]

Presented a method for determining the dynamic impact factors for horizontally curved composite single- or multicell box girder bridges under AASHTO truck loading. The bridges are modeled as three-dimensional structures using commercially available software. The vehicle is idealized as a pair of concentrated forces, with no mass, traveling in two circumferential paths parallel to the curved centerline of bridges. An extensive parametric study is conducted, in which over 215 curved composite box girder bridge prototypes are analyzed. The key parameters considered in this study are: Number of cells, number of lanes, degree of curvature, arc span length, slope of the outer steel webs, number and area of bracing and top chord systems, and truck(s) speed and truck(s) positioning. Based on the data generated from the parametric study, expressions for dynamic impact factors for longitudinal moment, reaction, and deflection are proposed as function of the ratio of the arc span length to the radius of curvature. The results from this study would enable bridge engineers to design horizontally curved composite box girder bridges more reliably and economically. Furthermore, the results can be used to potentially increase the live-load capacity of existing bridges to prevent posting or closing of the bridge.

Babu Kurian and Devdas Menon (2005) [9]

Presented a large number of simply supported box- girder bridges have been analyzed by both Simple Frame Analysis (SFA) and three-dimensional finite element analysis for different load conditions and wheel contact areas, and the errors in SFA have been studied and quantified. The error is found to vary widely at the web-top flange junction as well as under the load (maximum sagging moment), depending on the eccentricity of loading, the wheel contact dimensions and the web-flange thickness ratio. Accordingly, a set of correction factors to the results of SFA have been proposed, which is expected to be of significant use in design practice. The use of the correction factors is demonstrated by means of two illustrative examples. The scope of the study is limited to the simplest case of a single-cell concrete box-girder bridge (simply supported with end diaphragms) without overhanging flanges

A.K. Dwivedi, Pradeep Bhargava and N.M. Bhandari (2006) [10]

Presented a finite element analysis to predict the nonlinear temperature distributions and their response for the design of concrete bridges, which takes into consideration the various meteorological, environmental, and other bridge parameters. The proposed model has been validated against the results obtained by an experimental program on a laboratory model of concrete box-girder bridge exposed to solar radiation. The proposed analytical model has been validated against the experimentally observed values on laboratory models of concrete box girder bridge section. Good agreement has been observed between the computed and experimental thermal profiles.

Based on the above literature study, the analysis regarding the box girder are carried out in such a way that, first the various cross sections of box girder are analyzed by conventional method which includes effect of with and without diaphragm in analysis. In next part the study done with effect of temperature on box girder bridges. Finally the comparison done for conventional and finite element analysis for various box girders.

3. CONCLUSIONS

In this study box girders with different cells incorporating the effect of diaphragm and along with the effect of temperature are studied. Based on the analysis by conventional method as well as finite element both these methods are studied carefully. Based on whole study the following conclusions are drawn.

i. 3D analysis represent the actual pattern of loading and also consider the geometry, the moments and shear force obtained are on the lower side than that of the conventional design.

ii. In transverse analysis it is revealed that the 3D Finite element analysis results are more precise, because the actual behavior is three dimensional and not the two dimensional.

iii. Results obtained along longitudinal and transverse directions by Finite element analysis and conventional analysis are 8 to 10%.

iv. Due to inclusion of diaphragm there is considerable variation in the distribution factor as compared to cell without diaphragm.

v. The variation in bending moment and shear force due to addition of diaphragm are seems to be 3 to 5%.

vi. Provision of diaphragm at end and at the center is advantageous in reducing the deflection and increasing the ultimate load capacity.

vii. Error in plane frame analysis such as contribution of intermediate diaphragm can be overcome in 3D Finite element analysis, which has the advantage of combining transverse action with longitudinal action.

viii. Section with (Single and Twin cell box girder) Diaphragm is preferred as the reduction in deflection and as the redistribution of moments takes place in cell.

ix. As the increase in cell the bending moment, deflection and distribution factor are decreases.

x. From the study it also proposed that the factor for distribution reinforcement in deck slab that is 0.3 times live load and 0.2 times live load are need some modification.

xi. The temperature distribution that critically affect the cross section of a concrete box girder of given geometry.

xii. Axial forces induced in the bridge cross section are significantly affected by uniform temperature distribution in web as the addition of diaphragm.

Stresses induced due to temperature gradients with as the increase in diaphragm are not significantly affected at the end of section.

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