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Structural Analysis of Box Girder Bridge Structure

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Abstract-A box girder bridge is one in which the principal structural element is one or more closed cells, acting in bending. Box girders are used for highway bridges, railway bridges and footbridges – different structural forms are chosen for each of these applications. The objective of current research is to investigate the effect of different dimensional variables on strength of box Girder Bridge using techniques of Finite Element Analysis. The CAD modelling and FEA simulation of box Girder Bridge is conducted using ANSYS simulation package. The deformation obtained on the bridge structure is not uniform and found to be mostly at the zones of load application and reduces on other zones. The deformation pattern is almost uniform across length and width of the bridge structure. The bending stress distribution is also observed to be non-uniform and is maximum at the regions of load application. From the structural analysis conducted on box Girder Bridge structure the structural stability is established.

Keywords- Bridge, Design, Highways, Railways, Imperialist competitive Algorithm (ICA) Back tracking search Algorithm (BSA) Search group Algorithm (SGA).

I. 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.

II. LITERATURE REVIEW

Khaled et al. (2003) [1] 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) [2] 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) [3] 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.

Shi-Jun Zhou (2010) [4] this paper considered the interaction of the bending and shear-lag deformation of a box girder and established a finite-element method. A shearlag-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.

Priyanka Dilip P, Fahad P. P. [5] A box girder bridge is an evident bridge section in which main longitudinal girders are provided in the hollow box shape. The box girder are constructed using steel or the concrete after prestressing or they are also constructed in the form of composite or reinforced concrete section. The typical cross section of box girder is rectangular, square and trapezoidal. In this study, 240m span of two Lane Bridge is analysed and designed. A trapezoidal cross-section of post tensioned box girder bridge with two cells is analysed using different design loads using the IRC code for loads and load combinations i.e. IRC:6-2014 which includes different loads such as Super imposed dead load, Dead loads, moving loads, Prestresssing force. SAP 2000 is used to analyse the post tensioned box girder bridge using v 19 software. Post tensioning anchorages is carried out by the Freyssinet system.

Phani Kumar, S.V.V.K.Babu, D.Aditya Sai Ram [6] Bridge are used for connecting highway, roadways and railway in the whole world has high level of importance in construction sector. Prestress girder bridges are extremely popular in bridge engineering field as they are more stable, serviceable, economical and structurally efficient and gives aesthetic appearance. In this thesis, prestressed concrete TGirder and Box Girder bridges analysis and design are carried out. IRC:112-2011 is used for analyzing the bridges. IRC:112 is a new generation code. The design provisions given in new code differs from previous codes. The previous codes are IRC:18 for prestressed concrete structures and IRC:21 for reinforced concrete structures. IRC:112 based on limit state method and IRC:21 and IRC:18 are based on working stress method which is the main difference between IRC:21 and IRC:112-2011.

Sanket Patel, Umang Parekh [7] The bridges are used for different purposes from the very beginning of human civilization. Innumerable bridges of various kinds and of various materials have been built from times immemorial. Design of medium span highway bridge system requires careful selection of structural element in preliminary stage. The motive behind present study is to prepare some useful interface for preliminary design of bridge system. The most economical design can only be found by comparing few different designs. Particular set of conditions can be used to find the most economic design. Economy can be achieved by separately or simultaneously considering one or more of the following factors: span, superstructure cross section, cost of prestressing steel and concrete consumption. The parametric study of prestressed concrete girder bridge superstructure has been carried out.

Pragya Soni, Dr. P.S. Bokare [8] The bridging activity is as old as human civilization. Innumerable bridges of various kinds and of various materials have been built from times immemorial. Design of medium span highway bridge system requires careful selection of structural element in preliminary stage. The motive behind present study is to prepare some useful interface for preliminary design of bridge system.

III. OBJECTIVES

The objective of current research is to investigate the effect of different dimensional variables on strength of box Girder Bridge using techniques of Finite Element Analysis. The CAD modelling and FEA simulation of box Girder Bridge is conducted using ANSYS simulation package.

IV. METHODOLOGY

The methodology of FEA simulation is based on three different stages. In the 1st stage the CAD model of disc brake is developed. The design of single box Girder Bridge is developed using sketch and extrude tool in ANSYS design modeller.

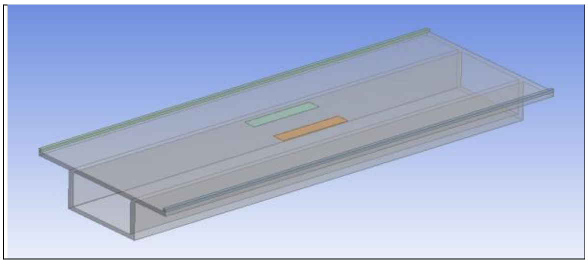

Fig 1. Single box girder bridge.

The design of box Girder Bridge is meshed using hexahedral element type. The selection of hexahedral element type is based on topological consistency of box Girder Bridge. The dimensions and geometry of box Girder Bridge is uniform throughout. The meshing of box Girder Bridge is on fine relevance, adaptive shape function and 1.2 growth rates. The meshed model of box Girder Bridge is shown in figure 2.

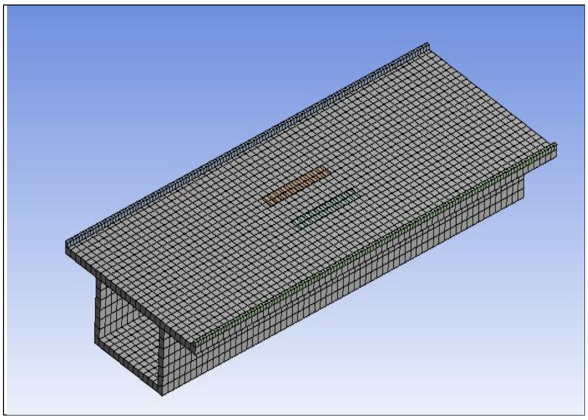

Fig 2. Meshed model of box Girder Bridge.

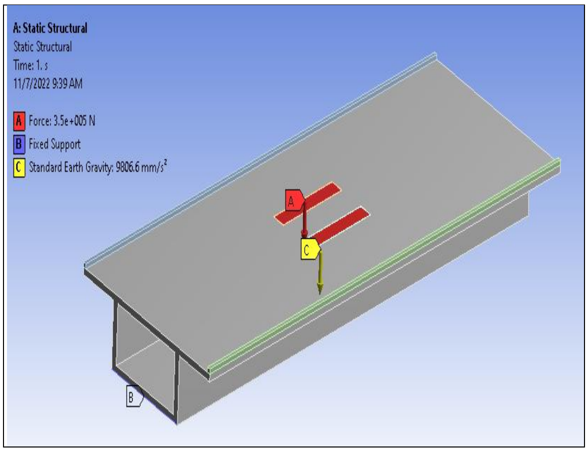

Fig 3. Applied loads and boundary conditions.

The structural loads and boundary conditions are applied on box Girder Bridge as shown in figure 3 above. The side edges of box girder bridge structures are applied with support and 2 surfaces on the top are applied with pressure which is based on IRC loading class 70R. After applying loads and boundary conditions, the simulation is run to determine total deformation, normal bending stress.

V. RESULTS AND DISCUSSION

From the FEA simulation, the total deformation plot is generated for box Girder Bridge. The maximum total deformation is obtained at the mid-centre and corner region of box Girder Bridge. The deformation obtained at this region is more than 4.5mm. The deformation value reduces as we move towards the sides and other regions of box Girder Bridge.

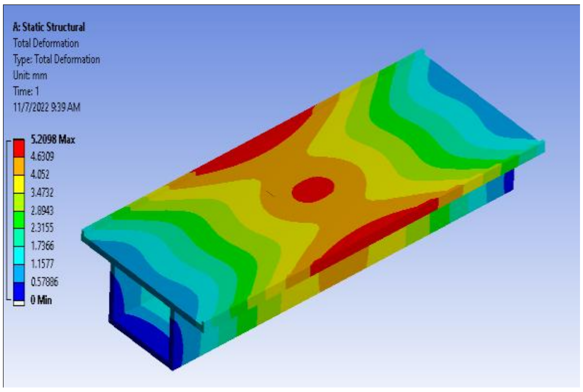

Fig 4. Total deformation plot.

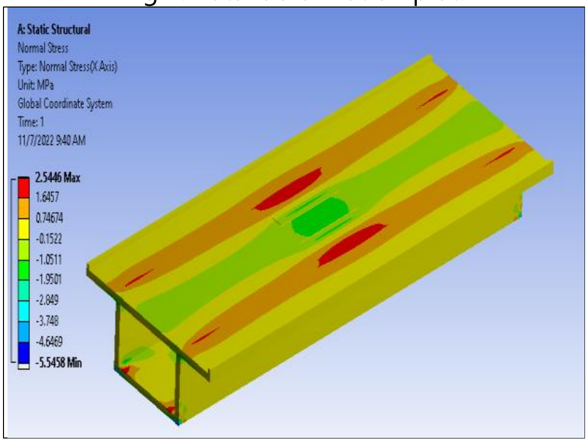

Fig 5. Bending stress plot of box girder bridge.

The bending stress plot is obtained for box girder bridge structure as shown in figure 5 above. From the plot, the maximum bending stress is obtained at the 2 small zones located at the centre. The maximum bending stress value reduces at the along the width of box girder bridge as shown in yellow and orange coloured regions.

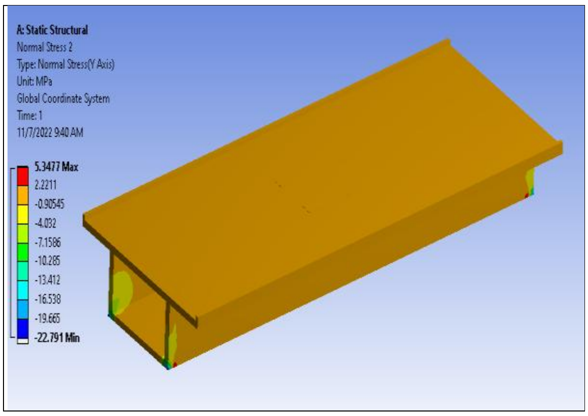

Fig 6. Vertical normal stress.

The vertical normal stress plot is generated for box girder bridge structure as shown in figure 6 above. The maximum vertical normal stress obtained from the analysis is at the bottom corner region of the bridge with magnitude of more than 2.21MPa. The normal stress however remains uniform for rest of the regions throughout.

VI. CONCLUSION

The structural analysis is conducted on single box girder bridge to evaluate the structural behaviour under IRC 70R loading conditions. From the FEA analysis the critical regions of high stresses and deformations are obtained. The deformation obtained on the bridge structure is not uniform and found to be mostly at the zones of load application and reduces on other zones. The deformation pattern is almost uniform across length and width of the bridge structure. The bending stress distribution is also observed to be non-uniform and is maximum at the regions of load application. From the structural analysis conducted on box Girder Bridge structure the structural stability is established.

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