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Design Optimization Of Overhead EOT Crane Box Girder Using Finite Element Analysis

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Abstract

The design optimization of an overhead crane with a double box girder has been proposed [6]. In this paper the design optimization of double box girder has been done and a comparative study of results of finite element analysis of a crane with 10 ton capacity and 12 m span length has been conducted. It is not possible for the real experimental studies to take into consideration the influence of the connections between the main beams and the rest parts of the construction, the influence of the longitudinal and transverse ribbings as well as the influence of the supports on the overall stressed state of the construction. Moreover, the researches that use for the majority of the test cases different strain measurements turn out to be quite hard and expensive. All these problems could be solved successfully by the use of computer modelling procedures. It is possible to perform 2D or 3D computer studies. The 2D computer studies give idea of the planar behaviour of the construction and lack the opportunity of showing the influence of supports or the connections of the construction. It is only the 3D models that could satisfy all the requirements for examining the general stressed state of the carrying metal construction. With regard to this, the creation of 3-D models for researching and analysing the behaviour of an overhead crane box girder, becomes the main goal of the present work. In the initial phase of the study, conventional design calculations proposed by Indian Standard Rules were performed. The crane design was modelled with solids, Loads and boundary conditions were applied to solid model. Assign material to the solid model. Finite Element meshes were generated from the solid model. After a comparison of the finite element analyses, and the conventional calculations, the analysis was found to give the most realistic results. As a result of this study, a design optimization for an overhead crane box girder has been done.

1. Introduction

A crane is a mechanical lifting device equipped with a winder, wire ropes and sheaves that can be used both to lift and lower materials and to move them horizontally. It uses one or more simple machines to create mechanical advantage and thus move loads beyond the normal capability of a human. Cranes are commonly employed in the transport industry for the loading and unloading of freight; in the construction industry for the movement of materials; and in the manufacturing industry for the assembling of heavy equipment. It serves a larger area of floor space within its own travelling restrictions than any other permanent type hoisting arrangement. The primary task of the overhead crane is to handle and transfer heavy payloads from one position to another. The escalating price of structural material is a global problem, which cannot be considered redundant. Overhead crane, which is associated with material handling in the industrial environment, utilizes structural steel for its girder fabrication. Light girder for overhead cranes saves material cost resulting into trim down the overall expenditure of the structural steel construction, civil construction as well as the electrical consumption. The general procedure for design of EOT crane girders is accomplished through the use of codes and standards. 3D-modeling of overhead crane box girder structure and finite element analysis has been done [6] to find the displacements and stress values by analysis software’s. Further with respect to [6] the design optimization of overhead eot crane box girder has been proposed.

2. Overhead Crane With Double Box Girder

Overhead travelling EOT crane consist of three primary motions i.e. hoisting, long travel and cross travel. A double girder EOT crane is built of welded box type construction with structural steel plate. A double box girder is fitted to end carriage assembly by means of nuts and bolts. A trolley assembly is placed on the rails which are welded to double box girder. The overhead EOT crane system is illustrated in Fig.1. The double box girders are subjected to transverse and lateral loads by the self-weight of the crane, the rated (hook) load, the self-weight of trolley and the dynamic loads. With a double box girder construction, the trolley runs above the girders. A typical section of box girder shown in Fig.2

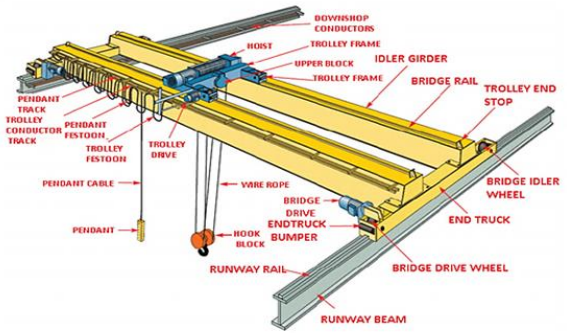


Fig. 1 Typical Double Box Girder Overhead EOT Crane Model

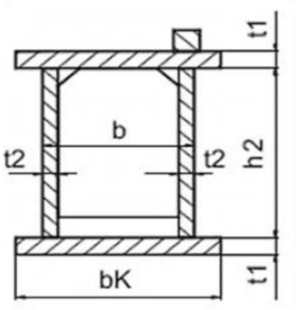


Fig. 2 Typical Section of Welded Box Girder

3. Introduction to Finite Element Method

The finite element method (FEM), sometimes referred to as finite element analysis (FEA), is a numerical technique used for finding the approximate solution to the complex engineering problems. It consist of two main parameters i.e. nodes and elements. The method essentially consists of assuming the piecewise continuous function for the solution and obtaining the parameters of the functions in a manner that reduces the error in the solution. The process of representing a physical domain with finite elements is referred to as meshing, and the resulting set of elements is known as the finite element mesh. The finite element method can analyze any geometry, and solves both stresses and displacements with respect to the known applied loads. In this study finite element meshing, is carried out by means of the Autodesk Inventor commercial package.

4. Numerical Example of Optimized Double Box Girder of Eot Crane

A 10-ton-capacity overhead crane of overall length 12.5m was selected for design optimization. Initially the self-mass of crane girder was found to be 7.3 tons. The configuration of the overhead crane is shown in Fig. 1.The overhead crane consists of two girders, two end carriage assemblies to connect them, and a trolley moving in the longitudinal direction of the overhead crane and wheels. The overhead crane is supported by two rails and the runway girders installed in building. In order to calculate the stress in the structure, the rules of I.S. 3177:1999, I.S. 807:2006 and I.S. 800:2007 are applied. The design considerations used in the box girder analysis are given in Table 1.

Sr. No.	Design Considerations	
1	Rated Capacity	10000 Kg
2	Self-Mass of End Trucks	11250 Kg
3	Span	12 Meter
4	Maximum Wheel Load	5000 Kg
5	Trolley Wheel Centre to Centre	2 Meter
6	Allowable Deflection	16mm
7	Safety Factor (S.F.) as per Class-III i.e. M3	1.5
8	Allowable Stresses	1695 Kg/cm^2

Notations Used:-

S : - Span
Tc : - Trolley Wheel Centre to Centre
W_d : - Design Load
Wg : - Self Mass of Girder
Wt : - Self Mass of Trolley
Wcr : - Self Mass of Crane
Wwm : - Maximum Wheel Load
Wec : - Self Mass of End Carriage
M1 :- Bending Moment due to Live Load
M2 :- Bending Moment due to Impact Load
M3 :-Bending Moment due to self-mass of Girder
Mmax : - Maximum Bending Moment
Z : - Section Modulus
σa : - Allowable Stresses
σb : - Maximum Bending Stresses
Ixx : - Moment of Inertia at X-axis.
Rc : - Rated Capacity
S.F. : - Service Factor
"ψ" : - Dynamic Coefficient Factor (ψ=1.32)
D.F : - Duty Factor (D.F.=1.06)

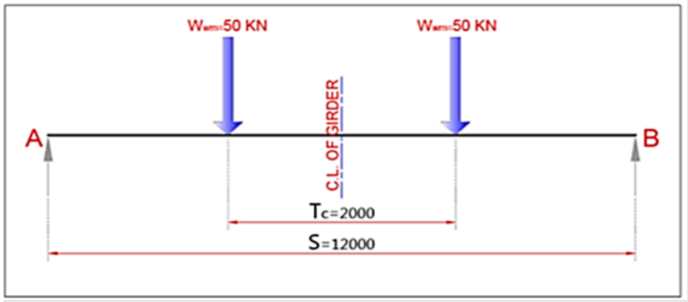
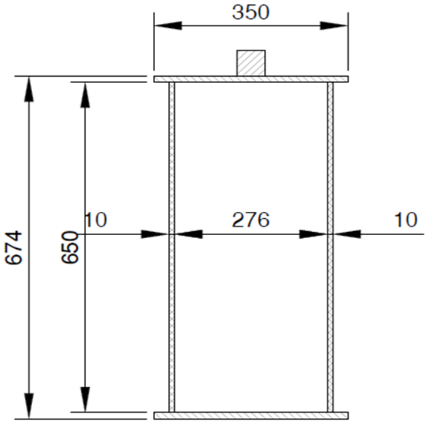


Fig. 3 Maximum Wheel Load Patter of Box Girder

5. Sample Calculations

We assume the following section for Box Girder



Sectional Properties Of Box Girder		
Sr. No.	**Description**	**Values**
1	I x-x (mm^4)	1671983000
2	I y-y (mm^4)	352216000
3	A (mm^2)	23900
4	Material	I.S. 2062 E 250B

- $W_t=(\frac{1}{5}$ x Rc+500Kg)

  = 2500Kg

  =24.52KN
- W_d=(Wt+Rc)*ψ

  =(24.52+98.1)*1.32

  =162 KN
- W_{cr}=0.7 x Wd=11560Kg=113.5KN

- $W_{wm}=1.06 \times \left(\frac{Wd+Wt}{4}\right)$

  $= 1.06 \times \left(\frac{162+24.52}{4}\right)$

  =49.42 KN per wheel
- $M_1=\psi \frac{(W_d+W_t) \times \{S-Tc/2\}^2}{8 \times S}$

$$=\frac{1.32 \times (162+24.52) \times (12000-1000)^2}{8 \times 12000}$$

=310322 KN-mm

- M_2=0.25 x M1=77580 KN-mm
- $W_g=(Wcr-Wt)-2 \times W_{ec}$

  =(113.5-24.52)-2 x (19)

  =50.98 KN =5196Kg
- $M_3=\left(\frac{Wg \times S}{8}\right)$

  $=1.1 \times \left(\frac{50.98 \times 12000}{8}\right)$

  =84117 KN-mm

- $M_{max}=M_1+M_2+M_3$= 472019KN-mm
- $Z=\left(\frac{Ix\text{-}x}{500}\right)=\left(\frac{1671983000}{349}\right)=4790782mm^3$
- $\sigma_b=\frac{Mmax}{Z}=\frac{472019000}{4790782}$ =98.52 N/mm^2

  =1005 Kg/cm^2

6. 3-D Modelling and Finite Element analysis of Overhead Crane Bridge

A 3-D model is a digital representation of the geometry of an existing or envisioned physical object. Designers may specify points, curves, and surfaces, and stitch them together to define electronic representation of the boundary of the object. Alternatively, they may select models of simple shapes, such as blocks or cylinders, specify their dimensions, position, and orientation, and combine them using assembly constraints, union, intersection or difference operators. The finite element method is a numerical procedure that can be applied to obtain approximate solutions to a variety of problems in engineering. Steady, transient, linear or nonlinear problems in stress analysis, heat transfer and fluid flow problems may be analyzed with finite element methods. The basic finite element analysis workflow depicted in Fig.4

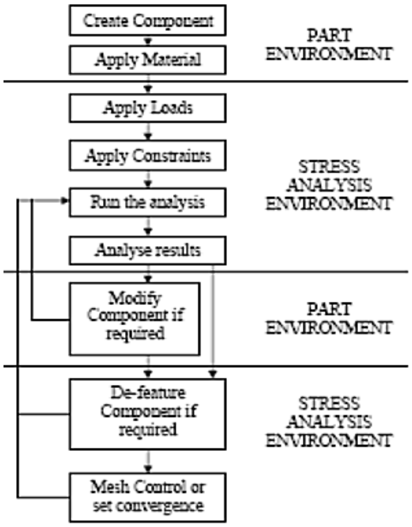


Fig.4 Finite Element Analysis Workflow

First, the crane bridge is modeled as a solid. Solid modeling of overhead double box crane bridge has been done as per above technical specifications. The solid model is shown Fig.5. For getting the results from stress analysis, the following task were performed as follows, first assign the material for the each part of the box girder, sets the safety factor as the yield strength, the maximum permissible yield strength value has been set to 165 N/mm^2. Maximum allowable deflection as per standard is 16mm. I.S. 2062 E 250B material has applied to girder parts. After assigning the material, the boundary conditions have been set as fixed constraint. Contact condition of box girder set to bonded (welded) has been set. Two remote load of 49290N has applied on the top flange of the girder and a gravity force has applied. Average element size is 105.064mm. Later, a mesh is created. The number of nodes were created is 3471 and the elements were 9498. In this study, a tetrahedral type element is used. The solid meshed model is shown Fig.6.

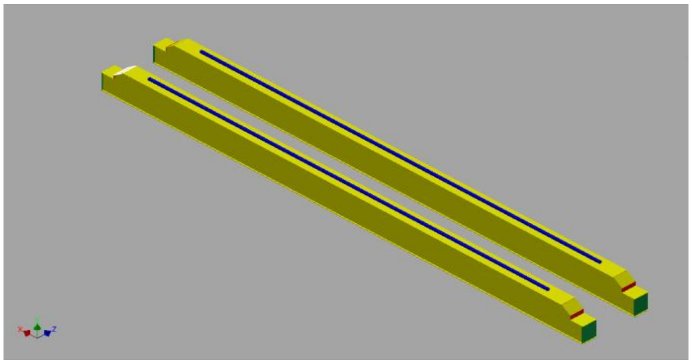


Fig.5 Solid Model of Double Box Girder

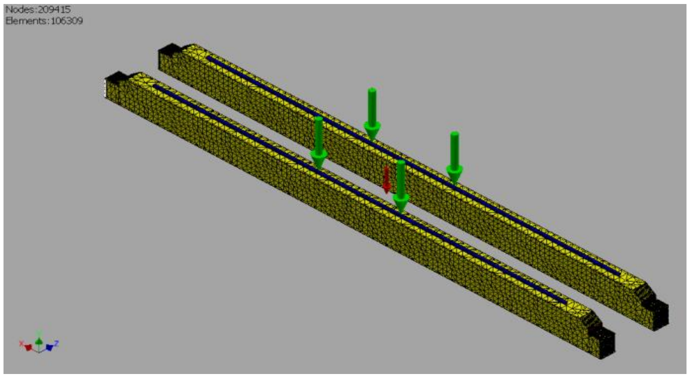


Fig.6 Solid Mesh Model of Double Box Girder

7. Results From a 3-D Girder Model With a Four-Node Tetrahedral Element

A four-node tetrahedral element was used for finite element analysis, using the girder solid model generated by means of Inventor software 2012. The maximum bending moment is occurring at the mid-span of the girder. Young's Modulus (E) is 220 GPa and the Poisson Ratio is 0.275 for finite element analysis. The maximum stress of the complete box girder is 110.03 N/mm2 to two decimal places from Fig. 7. It is clearly seen from the stress diagram that the maximum stresses is developed at the support. The displacement of the modeled overhead crane girder was obtained from Finite Element Analysis, and is occurring at the mid span of the girder, illustrated in Fig. 8. The value of maximum displacement of the girder is about 3.13mm.

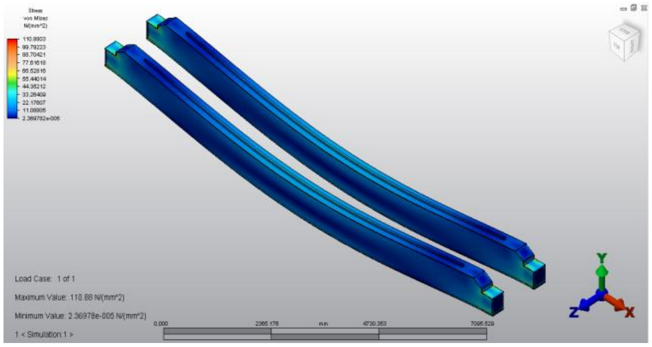


Fig.7 Maximum and Minimum values of Von Mises Stress

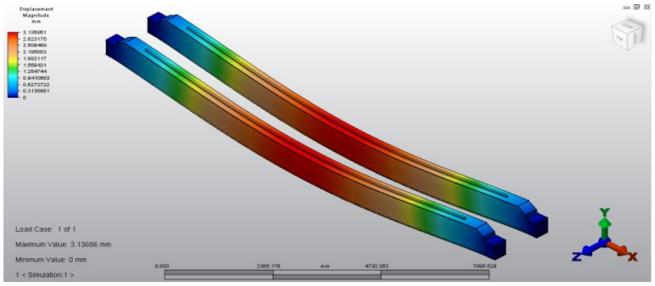


Fig.8 Maximum Displacement Value

Values of Finite Element Analysis for Re-Designed EOT Crane Box Girder			
Sr. No	**Description**	**Allowable Parameters as Per IS:3177 & IS:807**	**Results From FEA**
1	Maximum Stress	166 Mpa	110 Mpa
2	Minimum Safety Factor	1.5	1.96
3	Maximum Displacement in Y-Direction	16mm	3.13 mm

Table.2 Comparison between Allowable Values And Finite Element Results

8. Conclusion

In this paper, the comparison between the analytical calculations and the finite element analysis results were investigated table 2. From the above comparison between the allowable parameters of Indian Standard codes and the results of finite element analysis of re-designed box girder, it is clearly seen that the maximum stress & displacement which is obtained from the Finite Element Analysis are within the allowable limit of the Indian standard codes. The safety factor is on higher side against the Indian standard codes. Thus from the above results, we can state that the design optimization of EOT crane box girder has been achieved without compromising the strength and rigidity. We have reduced the overall mass of the girder by 29%. As the overall mass of the girder has reduced, the initial cost for the structural building, civil work and electrical consumption for the crane has also reduced.

9. Acknowledgement

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