ABHINAY SURATKAR, VISHAL SHUKLA

1,2Department of Mechanical Engineering, Priyadarshini College of Engineering, Nagpur, India
Email: abhi_suratkar@rediffmail.com, vivshukla@yahoo.com

Abstract—The design of an overhead crane with a double box girder has been investigated and a study 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 measurement 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, 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 method for an overhead crane is proposed.

I. 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 electrical consumption as well as the structural steel construction. The general procedure for design of EOT crane girders is accomplished through the use of codes and standards. Solid modeling of overhead crane box girder structure and finite element analysis has been done to find the displacements and stress values by analysis software’s.

II. 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.
III. 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. 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.

IV. NUMERICAL EXAMPLE OF DOUBLE BOX GIRDER EOT CRANE

A 10-ton-capacity overhead crane of overall length 12.5 m and total weight 14 tons was selected as a study object. 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.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Design Considerations</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rated Capacity</td>
<td>10000 Kg</td>
</tr>
<tr>
<td>2</td>
<td>Self-Weight of Crane</td>
<td>11250 Kg</td>
</tr>
<tr>
<td>3</td>
<td>Self-Weight of Trolley</td>
<td>2500 Kg</td>
</tr>
<tr>
<td>4</td>
<td>Span</td>
<td>12 Meter</td>
</tr>
<tr>
<td>5</td>
<td>Maximum Wheel Load</td>
<td>5000 Kg</td>
</tr>
<tr>
<td>6</td>
<td>Trolley Wheel Centre to Centre</td>
<td>2 Meter</td>
</tr>
<tr>
<td>7</td>
<td>Long Travel Speed</td>
<td>10M/min</td>
</tr>
</tbody>
</table>

V. SAMPLE CALCULATIONS

We assume the following section for Box Girder
• \( W_d = 1.5 \times 10000 = 15000 \text{Kg} = 147.150 \text{KN} \)
• \( W_i = 0.25 \times W_d = 3750 \text{Kg} = 37 \text{KN} \)
• \( W_c = 0.75 \times W_d = 11250 \text{Kg} = 110 \text{KN} \)
• \( W_{wn} = 1.07 \times \left( \frac{W_d + W_i}{4} \right) \)
  \( = 1.07 \times \left( \frac{147.150 + 37}{4} \right) \)
  \( = 49 \text{ KN per wheel} \)
• \( M_1 = \frac{W_g \times S}{8} \times (5 - 0.2) \)
  \( = 1.2 \times (147.150 + 37) \times (12000 - 1000)^2 \)
  \( = 8 \times 12000 \)
  \( = 278300 \text{ KN-mm} \)
• \( M_2 = 0.25 \times M_1 = 69575 \text{ KN-mm} \)
• \( W_g = (W_c - W_i) - 2 \times W_{ec} \)
  \( = (110 - 24.525) - 2 \times (11.772) \)
  \( = 62 \text{ KN} \)
• \( M_3 = \frac{(W_g \times S)}{8} \)
  \( = 1.1 \times \left( \frac{62 \times 12000}{8} \right) \)
  \( = 102 \text{ KN-mm} \)
• \( M_{max} = M_1 + M_2 + M_3 = 347977 \text{ KN-mm} \)
• \( Z = \frac{I_5}{S_0} = \frac{390943000}{500} = 7818860 \text{mm}^3 \)
• \( \sigma = \frac{M_{max}}{Z} = \frac{34797300}{7818860} = 44.50 \frac{\text{N}}{\text{mm}^2} = 455 \frac{\text{Kg}}{\text{cm}^2} \)

VI. 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.

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/mm². 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 50200N has applied on the top flange of the girder and a gravity force has applied. Average element size set to 0.1 and minimum element size set to 0.2. Later, a mesh is created. The number of nodes were created is 48291 and the elements were 25931. In this study, a tetrahedral type element is used. The solid meshed model is shown Fig.6.
VII. 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 53N/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 1.428mm.

CONCLUSION

In this study, the comparison between the analytical calculations and the finite element analysis results were investigated. In order to show how the finite element analysis of overhead crane bridge can be done one example is given. The maximum stress value is 53 N/mm² for a four-node tetrahedral element. Taking into account the safety factor, which is obtained from Finite Element Analysis are on higher side against the conventional standards as well as the stress values obtained from the finite element analysis is very much low than the allowable stress. The maximum displacement is on lower side against the allowable deflection. Thus from the above study, the design optimization of EOT crane Girder Bridge shall be proposed.

REFERENCES


