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Finite Element Analysis Of 450T EOT Crane Box Girder

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Abstract —*FEA(finite element analysis) of double box girder has been done in this paper and a comparative study of results of finite element analysis and analytical calculation of a crane with 450 ton capacity and 27.2 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 modeling procedures. With regard to this, the creation of 3-D models for researching and analyzing the behavior 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 are performed. The crane design is modeled with solids, Loads and boundary conditions are applied to solid model. Assign material to the solid model. Finite Element meshes are generated from the solid model. After a comparison of the finite element analyses, and the conventional calculations, the analysis is found to give the most realistic results. As a result of this study, a design of an overhead crane box girder is within the permissible limit as per Indian standards.*

Keywords-EOT Crane Bridge, Optimal Box Girder, Duty factor, Impact factor, Rails, End Carriage, FEA

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 off weight; 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 to find the displacements and stress values by analysis software's. Further with respect to the design optimization of overhead EOT crane box girder has been proposed.

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.

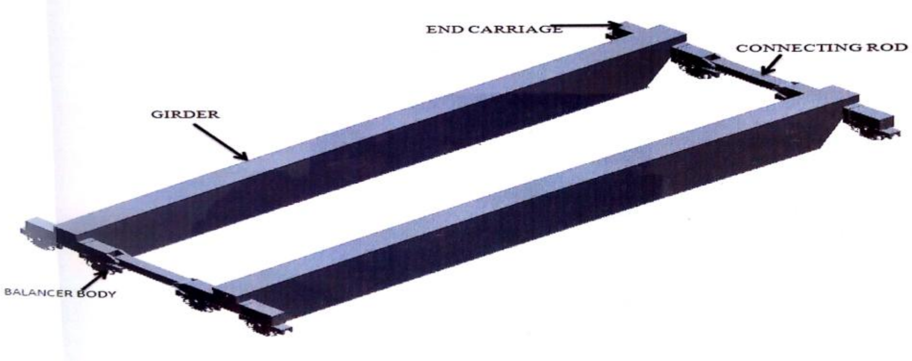


Figure 1 - EOT Crane Structure

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 and diaphragms are shown in Fig.2 and Fig.3. A 450-ton-capacity overhead crane of overall length 22.7 m is selected for design optimization. Initially the self-mass of crane girder is found to be 36.628 tons. 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.

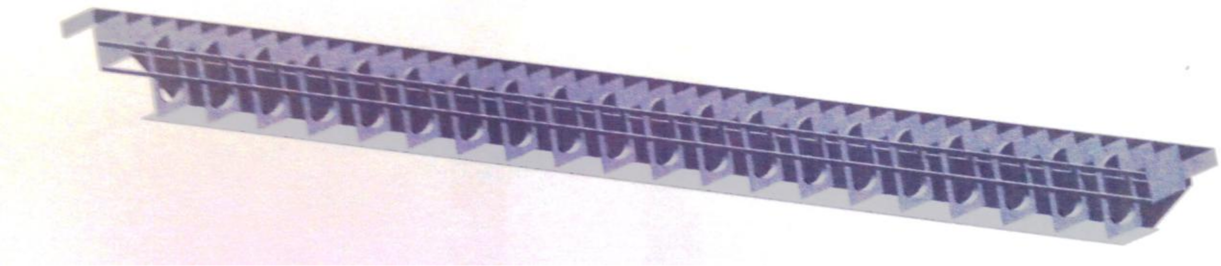


Figure 2-Main Girder Assembly

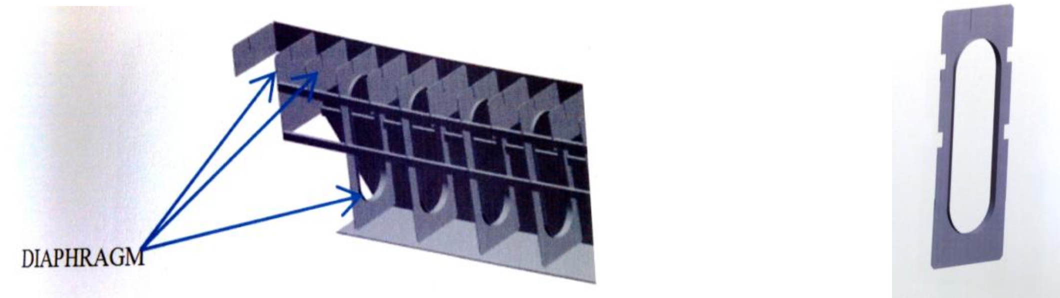


Figure3-Diaphragms

III. INTRODUCTION TO FINITE ELEMENT METHOD

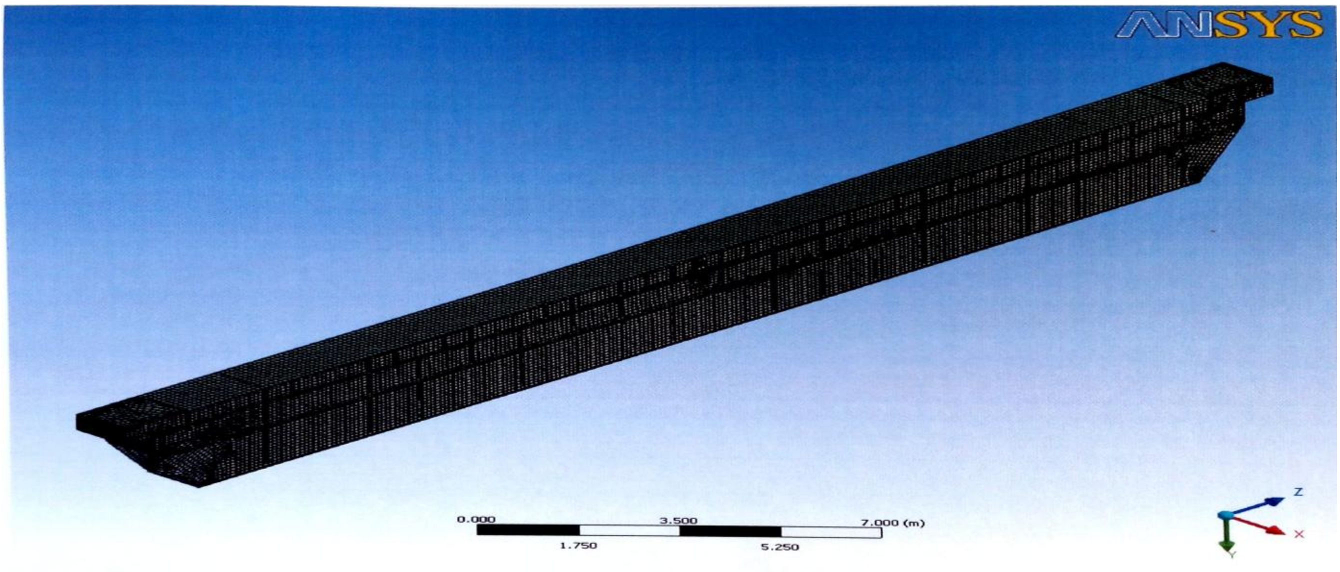
FEA has become common place in recent years. Numerical solution to even very complicated stress problems can now be obtained routinely using FEA, and the method is so important that even introductory treatments of mechanics of materials.FEA is a mathematical representation of a physical system comprising a part/assembly (model), material properties and applicable boundary conditions (collectively referred to as pre-processing), the solution of that mathematical representation (solving), and the study of results of that solution (post-processing).
The finite element analysis usually consists of three principal steps:

1. Pre-processing : In this process FEA software typically uses a CAD representation of the physical model and breaks it down into small pieces called finite 'elements'. This process is called as meshing. Higher quality of mesh, the better mathematical representation of physical model.
2. Analysis: FEA software constructs and solves a system of linear or nonlinear algebraic equations.
3. Post-processing: it is used to create graphical displays that show the distribution of stresses, strains, deformations, temperatures, and other aspects of the model.

IV. 3-D MODELING AND FEA OF OVERHEAD CRANE BRIDGE

Computer aided design (CAD) is the use of computer technology for the design of objects, real or virtual.CAD may be used to design curves and figures in two-dimensional ("2D") space or curves surfaces and solids in three-dimensional ("3D") objects. Modern CAD packages can also frequently allow rotations in three dimensions, allowing viewing of a designed object from any desired angle, even from the inside looking out. Among all CAD Software's I have selected PRO-ENGINEER developed by PTC, which is parametric, feature-based, associative solid modeling software in the market and is a very user friendly tool. 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. First, the crane bridge is modeled as a solid. Solid modeling of overhead double box Crane Bridge has been done as per technical specifications. The solid model is shown Fig.2.
For getting the results from stress analysis, the following tasks are performed as follows.

In Pre-processing, first of all adopt CAD model of main girder which is made in Pro-e wildfire 4.0 to ANSYS workbench 11.0. First assign the material for the each part of the box girder. I.S. 2062 material has applied to girder parts. Hex dominant method is selected for meshing of main girder having a size of 25mm. Later, a mesh s created. The numbers of nodes are created 1176296 and the elements are 48365. The solid meshed model is shown Fig.4



Figur4-Meshing of Girder

For Analysis displacement and load condition for the main girder assembly are applied after meshing in next step. The plates are as shown in Fig.5 are fixed and degree of freedom of the assembly is zero. Contact condition of box girder set to bonded (welded) has been set.

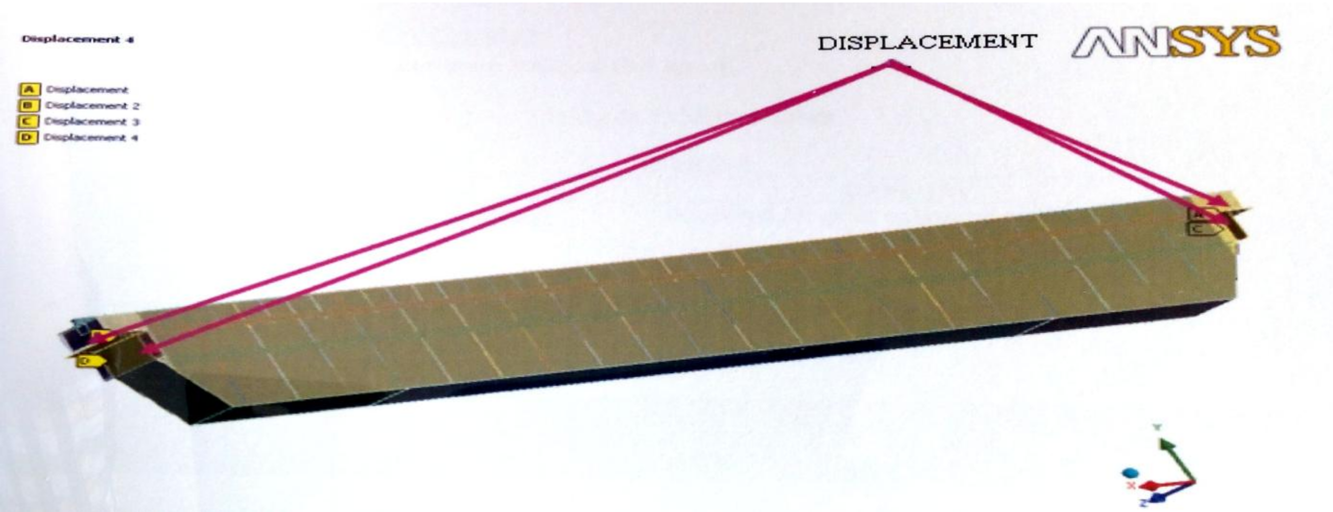


Figure5-Fixed support for Girder

we have taken two load conditions for main girder, in case-1 load is applied at centre of girder and in case-2 load is applied at extreme end of the girder.

Load Case-1: 3.62396e+006N load applied at centre of girder in down ward direction with zero degree of freedom as shown in Fig.6.

Vertical forces due to lifted loads

For a class II M5 crane, the Impact factor in vertical plane = 1.32, Duty factor = 1.06

Load in a vertical direction= impact factor × lifted load

= 1.32×450

= 594 T

Total load acting vertically downward

= (duty factor × load in vertical direction) + weight of crab assembly
= (1.06×594) +110
=739.64 T

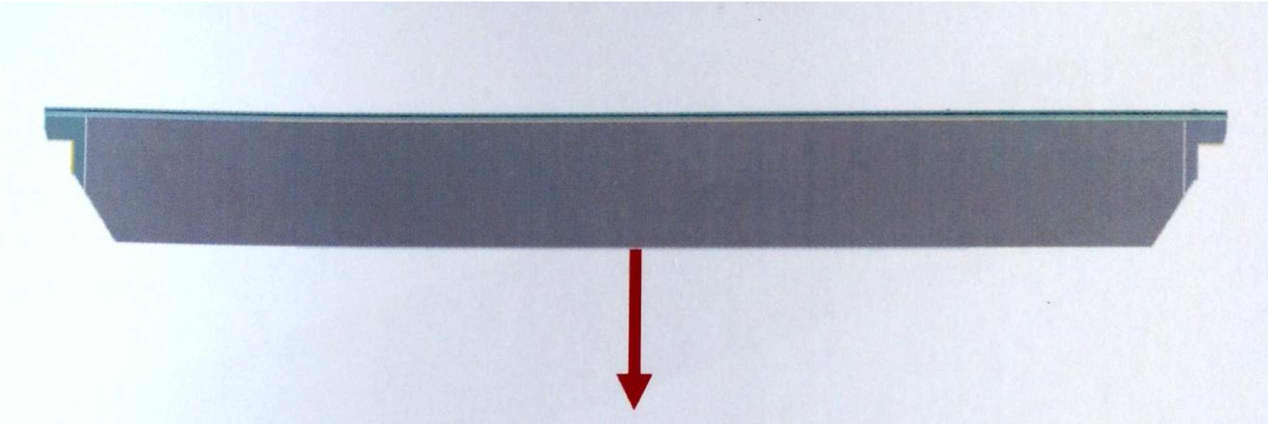


Figure6- load case-1

Load Case-2: 3.62396e+006N load applied at extreme end of the girder in down ward direction with zero degree of freedom. (either left or right)

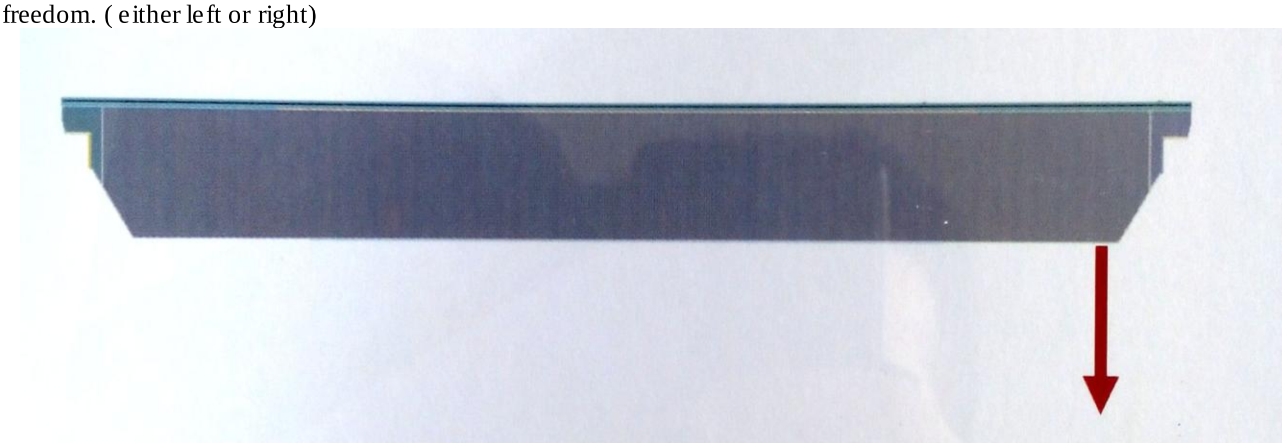


Figure7- load case-2

Self weight of girder is shown in Fig.8.

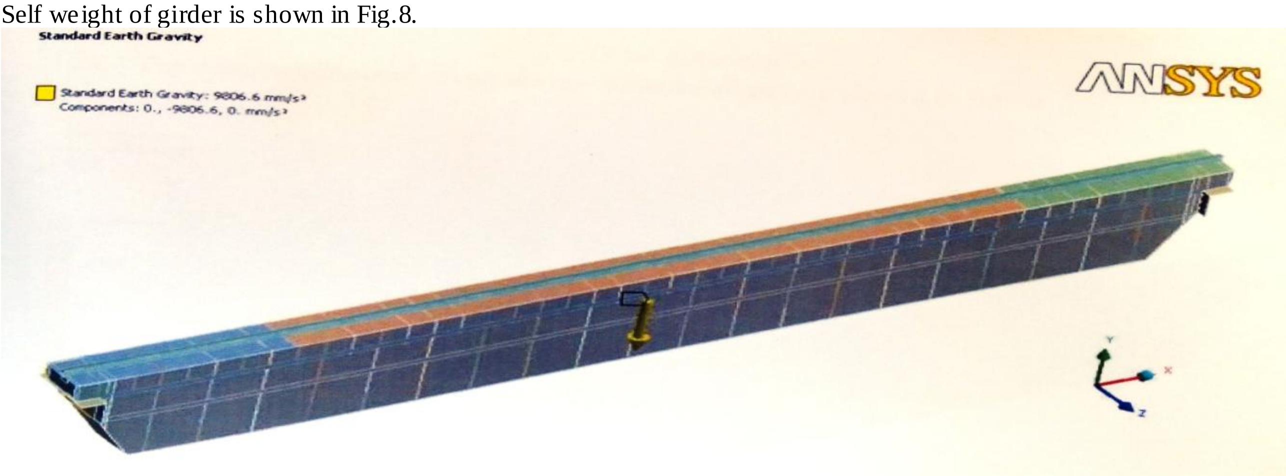


Figure8-self weight of girder

Horizontal force due to longitudinal travel of structure is shown in Fig.9.
For a class II M5crane, the horizontal forces due to crane travel in longitudinal direction are given as
$= \beta \times 0.01\,(v)^{1/2}$,
V=longitudinal travel speed of crane=40 m/min
Therefore β= 0.0632

Force value = 0.0632 × (lifted load + total weight of crane)
= 0.0632 × (450+276)
= 45.88 T
Considering the effect of duty factor
Total force= 1.06 × 45.88 = 48.63T

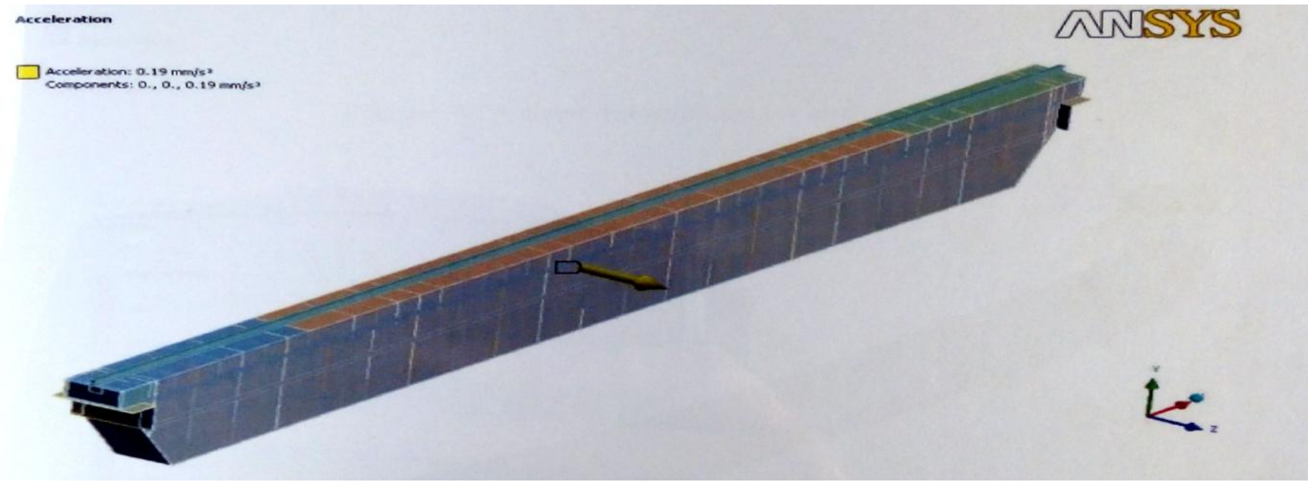


Figure9-Horizontal force applied as acceleration action on girder

V. Results From a 3-D Girder Model With a Hex dominant Element

Load of 3.62396e+006N has applied on the top flange of the girder and a gravity force had applied.
As per IS 2062 for mild steel the maximum permissible stress is 250Mpa and Factor of safety is taken as 1.4.
Allowable stress = maximum permissible stress / factor of safety
= 250/1.4
=178.57 M Pa
Hex dominant element is used for finite element analysis, using the girder solid model generated by means of ANSYS Workbench 11.0. It is clearly seen from the stress diagram that the maximum stresses is developed at the support. Girder maximum stress is 383.41 MPa Case-1 shown in Fig.10.and 490.24 MPa in Case-2 shown in Fig.11. Which is at edge of fixed plate so it is negligible, average stress on whole girder is 156.28 MPa.

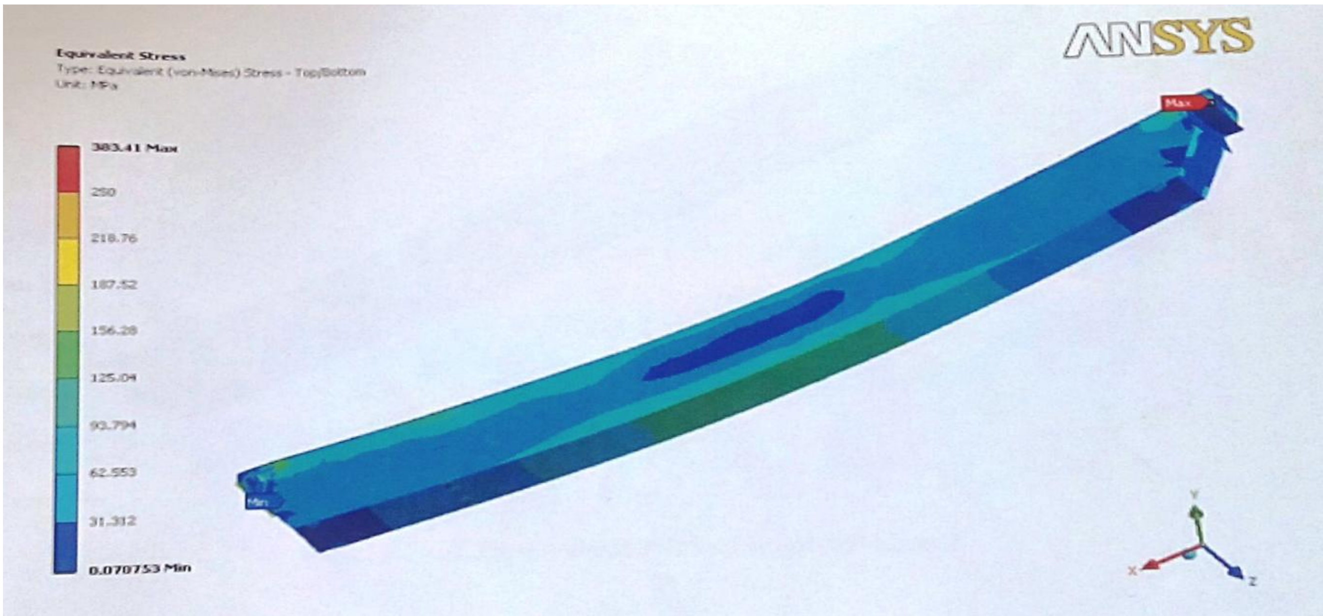


Figure10-Equivalent stress for girder Case-1

Figure11-Equivalent stress for girder Case-2

The span of crane is 27200mm, the maximum vertical deflection of the girder produced by the dead load, weight of the trolley and rated load shall not exceed 1/750 of the span of the crane for more than 12 meters.

So maximum vertical deflection = span × (1/750)

=27200 × (1/750)

=36.27mm

Maximum allowable deflection as per standard is 36.27mm.

The displacement of the modeled overhead crane girder is obtained from Finite Element Analysis, and is occurring at the mid span of the girder, illustrated in Fig.12 and Fig.13. Total deflection is 24.463 mm for Case 1 and 9.778 mm for Case 2 which is less than 36.26 mm achieved without compromising the strength and rigidity. We can reduce the overall mass of the girder. 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.

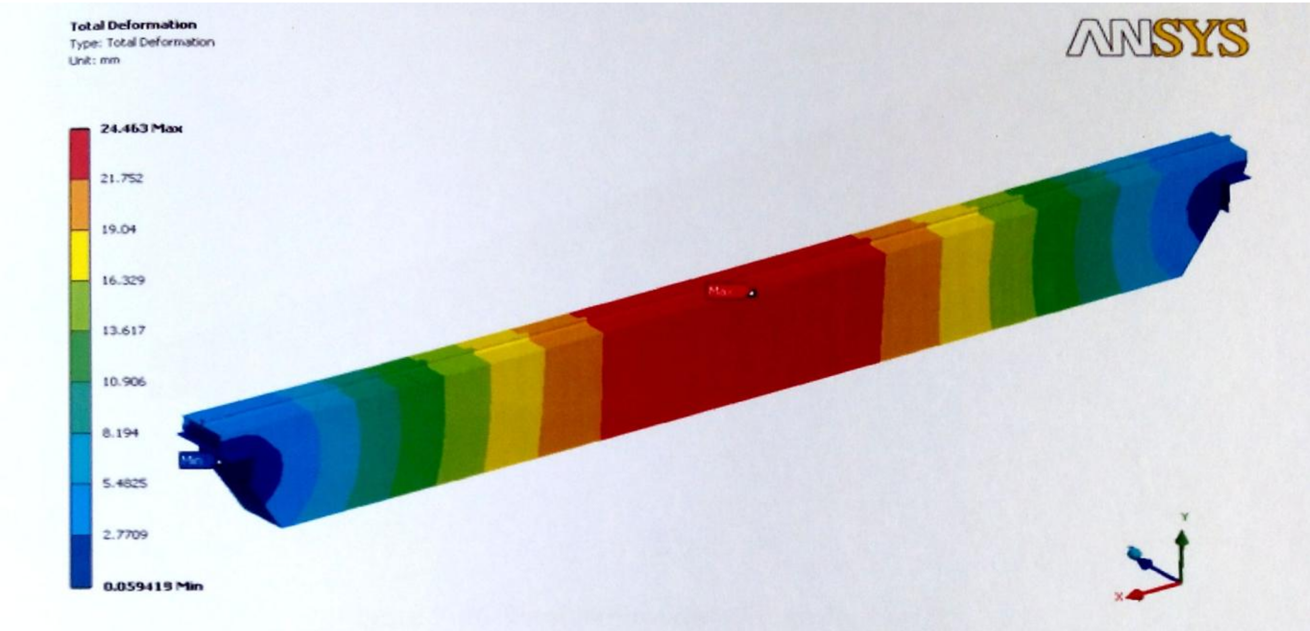


Figure12-Total deformation for girder Case-1

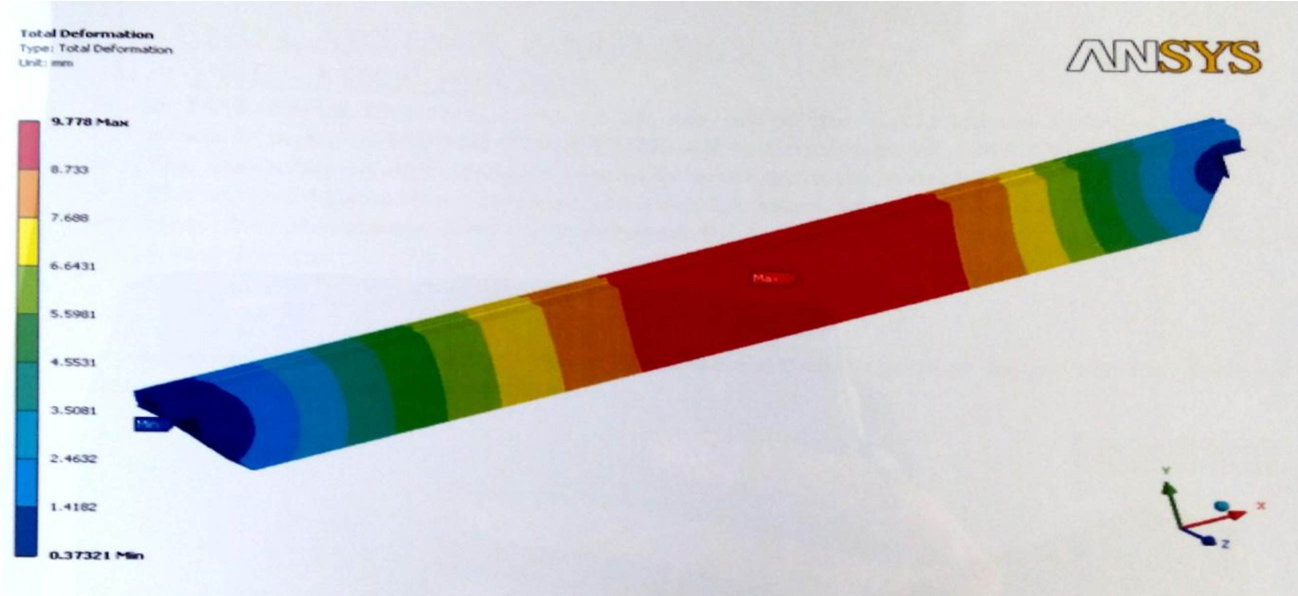


Figure13-Total deformation for girder Case-2

Table 1

Sr. No.	Description	Allowable Parameters as Per IS:3177 & IS:807	Results From FEA
1	Maximum Stress	178.57 MPa	156.28 MPa
2	Maximum deflection case 1	36.26 mm	24.463 mm
3	Maximum deflection case 2	36.26 mm	9.778 mm

Table 1 Comparison Between Allowable Values And Finite Element Results

VI. CONCLUSION

In this paper, the comparison between the analytical calculations and the finite element analysis results are investigated table 1. 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, I can state that the design optimization of EOT crane box girder had been safe.

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