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Dynamic and Modal Analysis of Gantry Crane System Subjected Under Moving Load Condition

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ABSTRACT

Dynamic response of any structure under moving loads is an important problem in Engineering. Generally in the construction of structures gantry cranes are preferred for lifting heavy loads, it is one of the essential industrial equipment for material handling. This paper presents investigation of dynamic behavior of gantry crane system under moving load condition. Dynamic analysis of gantry crane system includes longitudinal and transverse deflections. ANSYS coding was developed for dynamic analysis at different speeds of moving load condition. Dynamic analysis and modal analysis are carried out for rectangular and I cross sections of gantry crane system with suitable material at different speeds and modes. Results obtained from the analysis of both the cross sections were compared and finally we have found I Cross Section is better than the rectangular cross section for gantry crane system under moving load condition.

Keywords:— *Gantry crane, Moving load, Vertical deflection, Horizontal deflection*

I. INTRODUCTION

Material handling is loading, moving and unloading of materials. To do it safely and economically, different types of tackles, gadgets and equipments are used, when the material handling is referred to as mechanical handling of materials. Since primitive men discovered the use of wheels and levers, they have been moving materials mechanically. Any human activity involving materials need material handling. However, in the field of engineering and technology, the term material handling is used with reference to industrial activity. In any industry, be it big or small, involving manufacturing or construction type work, materials have to be handled as raw materials, intermediate goods or finished products from the point of receipt and storage of raw materials, through production processes and up to finished goods storage and dispatch points. Material handling as such is not a production process and hence do not add to the value of the product. It also costs money; therefore it should be eliminated or at least reduced as much as possible. However, the important point in favours of material handling is that it helps production. Depending on the weight, volume and throughput of materials, mechanical handling of materials may become unavoidable. In many cases, mechanical handling reduces the cost of manual handling of materials, where such material handling is highly desirable. All these facts indicate that the type and extent of use of material handling should be carefully designed to suit the application and which becomes cost effective. Material handling uses different equipment and mechanisms called Material Handling Equipment. And extent of use of material handling should be carefully designed to suit the application and which becomes cost effective. In many industries Cost and time analysis criteria for minimizing the time this gantry crane beam was used to suit their interim applications.

II. Problem Identification

Vibrations are a serious problem in crane systems that are required to perform precise motion in the presence of structural flexibility. The moving load condition is one of the fundamental problems in any type of cranes (ex: gantry crane system). Crane response with respect to trolley motion i.e. moving load causes unwanted crane deflections in the vertical and horizontal planes. These unwanted deflections demand to concentrate on different cross sections and material of gantry crane beams subjected to dynamic and modal analysis under moving load conditions at different speed in order to minimize the deflections & stress concentrations.

III. Objective of the Work

Dynamic Analysis

- Finding longitudinal and transverse deflections for both rectangular and I cross sections

Static Analysis

- To determine Von Misses stresses
- To determine the deformation

Modal Analysis

- Natural frequencies and deformation behavior can be predicted for gantry crane system by using modal analysis

Buckling Analysis

- Buckling analysis can be performed for both rectangular & I cross sections of gantry crane beam

IV. Methodology

- Create a gantry crane in ANSYS work bench software by giving moment of inertia and area of cross sections.
- ***Material property:*** define mild steel properties as gantry crane system material.
- Divide the entire span of the beam into ten equal numbers of elements by using meshing.
- ***Defining boundary conditions:*** apply moving load on gantry crane beam by giving ANSYS coding as an input.
- ***Solve:*** ANSYS software solves the modal with given mesh and loading condition with respect to the time intervals along the span of beam.
- ***Time history post processor:*** view the horizontal and vertical deflections in time history post processor.

V. Specifications of Gantry Crane

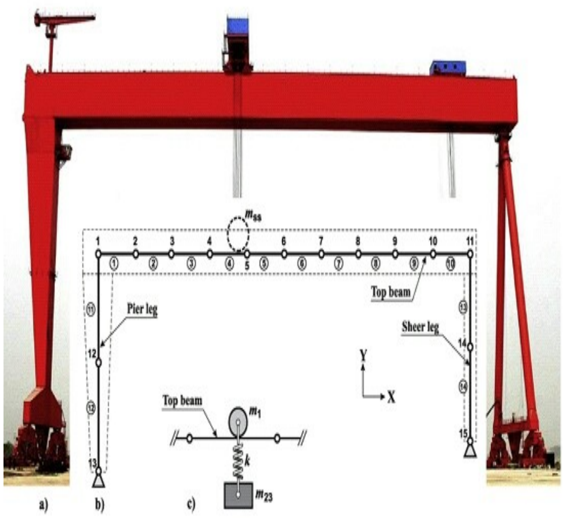

Figure 1: Gantry Crane Model

1. Rectangular cross section beam:

- cross sectional area $A_{(1\ to\ 10)}=0.09m^2$
- moment of inertia $I_{(1to10)}=0.041m^4$

2. I- cross section beam:

- cross sectional area $A_{(1to\ 10)}=0.094m^2$
- moment of inertia $I_{(1\ to\ 10)}=0.046m^4$
- $A_{11}=0.085m^2$
- $I_{11}=0.036m^4$
- $A_{12}=0.07m^2$
- $I_{12}=0.024m^4$
- $A_{(13\&14)}=0.048m^2$
- $I_{(13\&14)}=0.01m^4$

VI. Material Specification

The study focuses dynamic analysis for gantry crane system under moving load conditions for three different materials with the crane dimensions of 15m height and 40m length such as FE410, Mild Steel, and RST. Each and every technical detail of three materials was tabulated.

Table 1: Material Specifications of Gantry Crane

S. No	Mate-rial	Young's Modulus(Gpa)	Density(kg/m3)
1	FE410	200	7650
2	Mild Steel	210	7850
3	RST	207	7780

VII. Static Model of Gantry Beam

In this study CATIA v5 software is used to create model of Gantry crane beam and each and every dimension is taken from reference [3].The finite element solver ANSYS 18.2 is used to analyze the model.

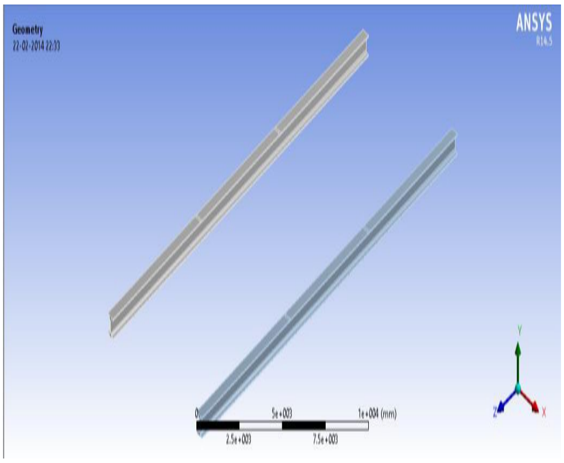

Figure 2: Static Model of Gantry Crane Beam

VIII. Meshing Model

SOLID173 is a higher order 3-D 10-node solid element that exhibits quadratic displacement behavior. The element is defined by 10nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. The element supports plasticity, hyper elasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastic and plastic materials, and fully incompressible hyper elastic materials.

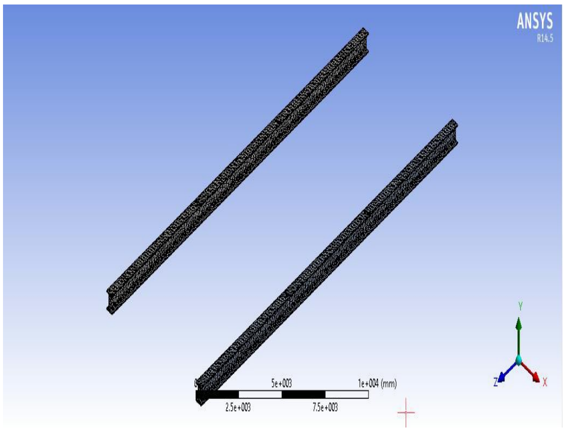

Figure 3. Meshing Model of Gantry Crane Beam

IX. Loading and Boundary Conditions

After applying the mesh to the crane model, the boundary condition has been applied to the model as the total Load of 52tons acting on the crane, support area to the crane which requires generating the stresses and deformation on the crane mode.

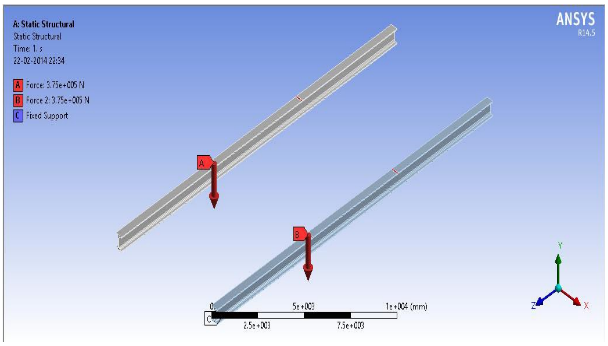

Figure 4. Loads Distribution of Gantry Beam

X. Results and Discussion

A. Dynamic analysis:

Dynamic analysis was done to determine the vertical and horizontal deflections for both rectangular & I sections at different speeds 2, 4, 6, 8, 10 m/s.

1. Rectangular section:

a. Vertical deflection:

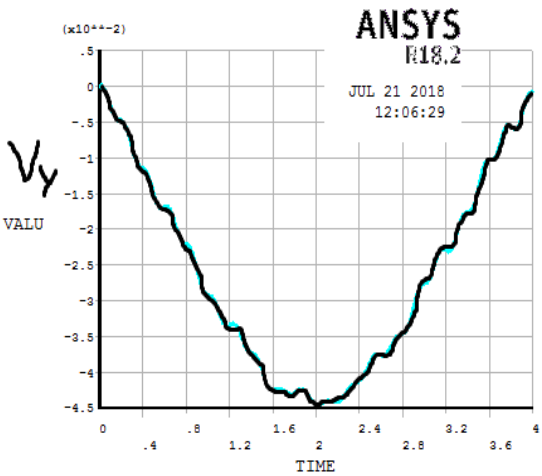

Figure 5: Vertical Deflection of Gantry Beam

Under moving load condition the vertical deflections for rectangular section at different speeds 2, 4, 6, 8, 10 m/s are constant. The maximum vertical deflection obtained is 4.5×10^{-2} m.

b. Horizontal deflection:

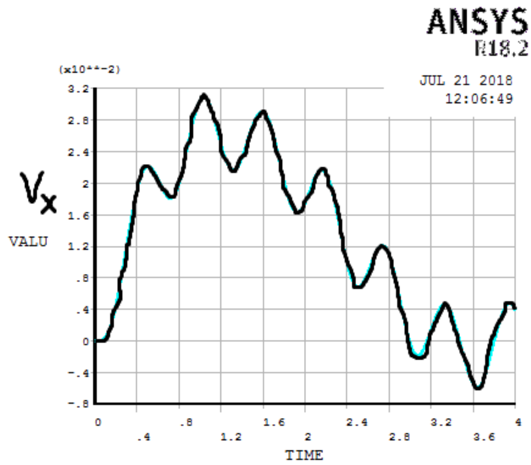

Figure 6: Horizontal Deflection of Gantry Beam

Under moving load condition the horizontal deflections for rectangular section at different speeds 2, 4, 6, 8, 10 m/s are varying. The maximum horizontal deflection obtained at speed 10 m/s is 3.2×10^{-2} m.

1. I Cross Section:

a. Vertical deflection:

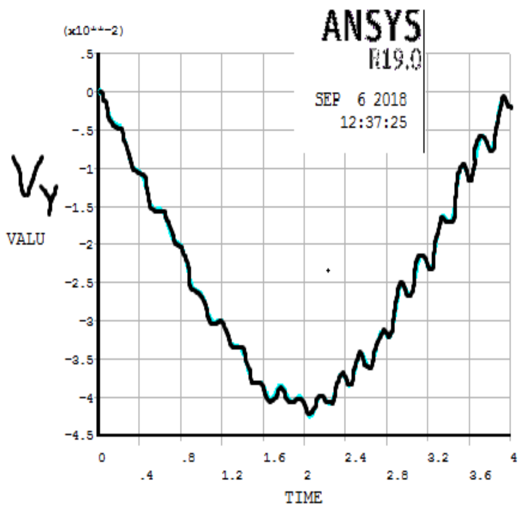

Figure 7: Vertical Deflection of Gantry Beam

Under moving load condition the vertical deflections for I cross section at different speeds 2, 4, 6, 8, 10 m/s are constant. The maximum vertical deflection obtained is 4.1×10^{-2} m.

b. Horizontal deflection:

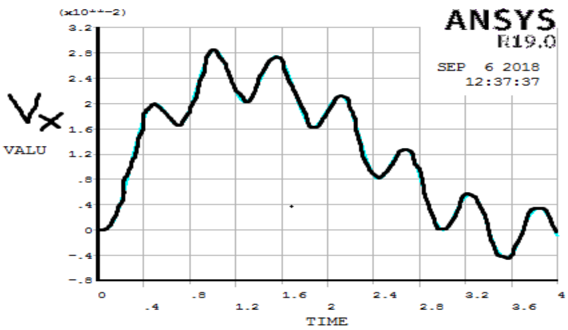

Figure 8. Horizontal Deflection of Gantry Beam

Under moving load condition the horizontal deflections for I cross section at different speeds 2, 4, 6, 8, 10 m/s are varying. The maximum horizontal deflection obtained at speed 10 m/s is 2.85×10^{-2} m.

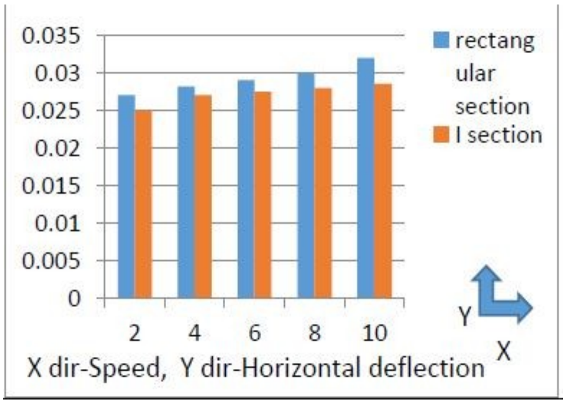

Figure 9: Graphical Representation of Deflections

After comparing the horizontal deflections of both rectangular and I cross sections at different speeds 2, 4, 6, 8, 10 m/s, I cross section gives the less deflections values then the rectangular section.

Comparison of dynamic analysis results for both rectangular and I cross sections:

Vertical deflections (Vy)

Table 2: Vertical deflections comparison

S.no	Speed	Rectangular (m)	I section (m)
1	2,4,6,8,10	4.5×10^{-2}	4.1×10^{-2}

From the above table we concluded that I cross section gives the less vertical deflections than rectangular cross section.

Horizontal deflections (Vx)

Table 3: Horizontal Deflection Comparison at Different Speeds

S.No	speed	Rectangular(m)	Isection(m)
1	2	$2.7\text{X}10^{-2}$	$2.5\text{X}10^{-2}$
2	4	$2.82\text{X}10^{-2}$	$2.7\text{X}10^{-2}$
3	6	$2.9\text{X}10^{-2}$	$2.75\text{X}10^{-2}$
4	8	$3.0\text{X}10^{-2}$	$2.8\text{X}10^{-2}$
5	10	$3.2\text{X}10^{-2}$	$2.85\text{X}10^{-2}$

B. Modal analysis:

The modal analysis is the basic technique used for analysis of dynamic character. Mode shapes and natural frequencies were examined through this approach. In this paper modal analysis was done for both rectangular and I cross sections of gantry crane system for different modes 1, 2, 3, 4, 5 and the natural frequencies at different modes have been obtained.

1. Rectangular section

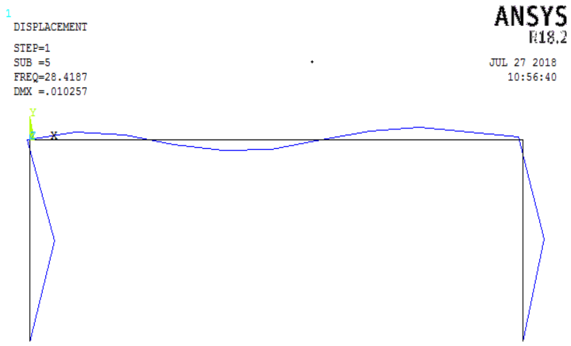

Figure 10: Modal Analysis of Rectangular Section

The maximum natural frequency for rectangular section was found at mode 5 and the value is 28.41 as shown in above figure.

2. I cross section

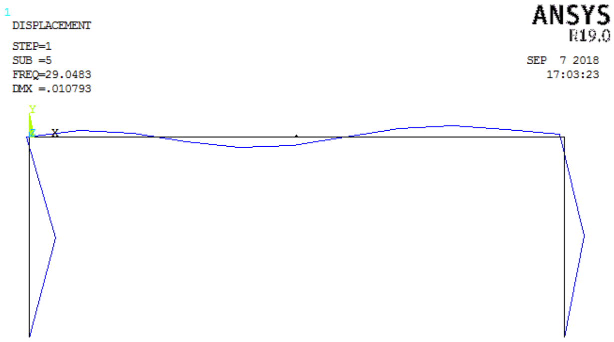

Figure 11: Modal Analysis of I Cross Section

The maximum natural frequency for I cross section was found at mode5 and the value is 29.04 as shown in above figure.

Comparison of Modal analysis results for both rectangular and I cross sections:

Table 3: Modal Analysis Frequencies Comparison

S. No	Mode	Rectangular	I section
1	1	1.72705	1.77218
2	2	4.92967	5.12712
3	3	14.6858	15.3778
4	4	23.114	23.5377
5	5	28.4187	29.0483

Natural frequencies of Rectangular and I section crane beams were compared.

1. Graphical Representation

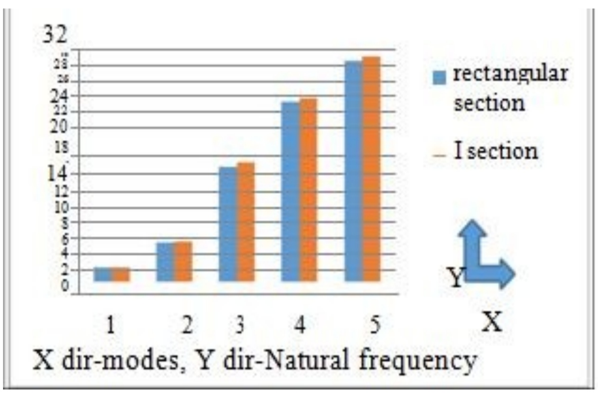

Figure 12: Graphical representation of frequencies of both sections

From the above table we concluded that I cross section has more natural frequency than rectangular cross section under same conditions.

C. Static analysis:

Static analysis was used to find stress and deformation of model with didn't consider the time factor**.**

In this paper static analysis for both rectangular and I cross sections was carried out to determine the maximum total deflection, maximum von misses stress and buckling analysis value by applying the max pay load 52 tons on a gantry crane system.

1. Rectangular section:

a. Total deflection:

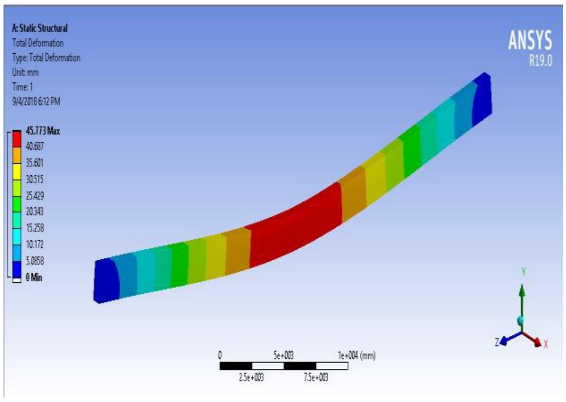

Figure 13. the Max Total deflection for rectangular section is 45.773 mm.

b. Vonmises stress:

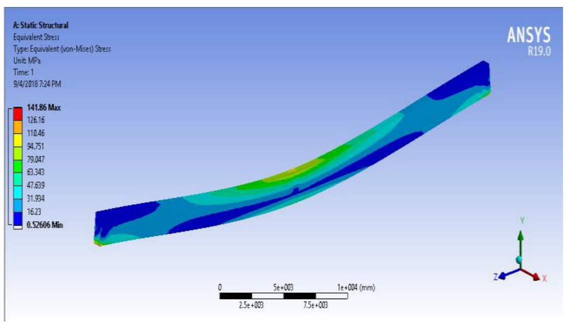

Figure 14: The Max von misses stress value for rectangular section is 141.86 N/mm^2

c. Buckling analysis:

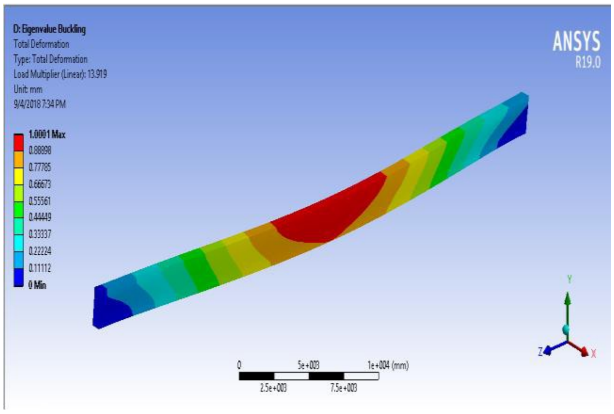

Figure 15. the Max Buckling Analysis Value for Rectangular Section is 1.0001

2. I cross section:

a. Total deflection:

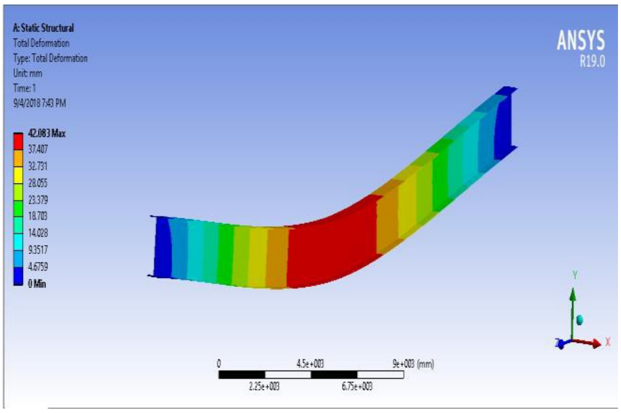

Figure 16. The Max Total Deflection for I Cross Section is 42.083 mm.

b. Von misses stress:

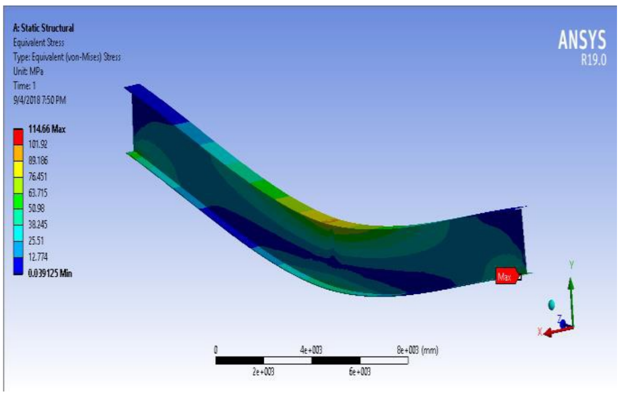

Figure 17: The Max Von Misses Stress Value for I Cross Section is 114.66 N/mm^2

c. Buckling analysis:

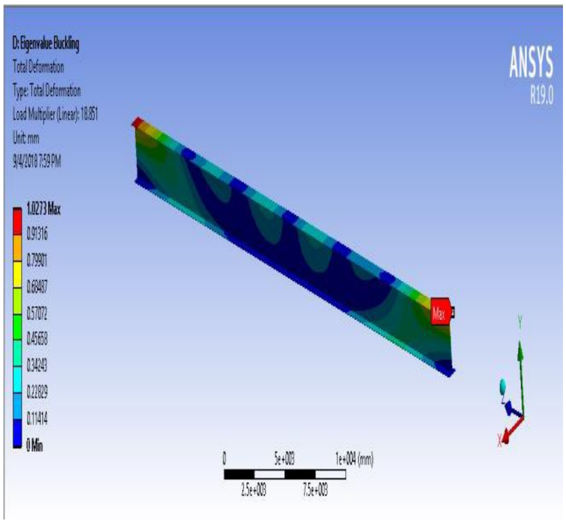

Figure 18: The Max Buckling Analysis Value for I Cross Section is 1.0273

Comparison of Static analysis results for both rectangular and I cross sections:

Table 4: Comparison of Original and Improved Models

S.no	Parameter	Rectangular	I section
1	Deflection	45.772	42.083
2	Stress	141.86	114.66
3	Buckling	1.0001	1.0273

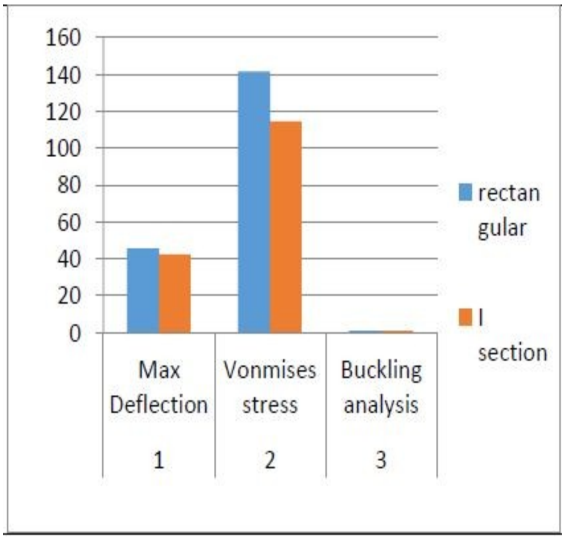

Figure 19: Graphical Representation of Both Models

By comparing the results of static analysis of both rectangular and I cross sections, we concluded that I cross section has less total deflection, vonmises stress values and more buckling analysis value then rectangular cross section.

XI. CONCLUSIONS

Dynamic Analysis:

Under moving load condition the vertical deflections for rectangular section at different speeds 2, 4, 6, 8, 10 m/s are constant, maximum vertical deflection obtained is 4.5×10^{-2} m. For I cross section at different speeds 2, 4, 6, 8, 10 m/s are constant, maximum vertical deflection obtained is 4.1×10^{-2} m. so, finally we concluded that I cross section gives the less vertical deflections than rectangular cross section.

Under moving load condition the horizontal deflections for rectangular section at different speeds 2, 4, 6, 8, 10 m/s are varying, maximum horizontal deflection obtained at speed 10 m/s is 3.2×10^{-2} m. For I cross section at different speeds 2, 4, 6, 8, 10 m/s are varying, maximum horizontal deflection obtained at speed 10 m/s is 2.85×10^{-2}m. so, finally we concluded that I cross section gives the less value and best.

Modal Analysis:

Modal analysis was done for different modes 1, 2, 3, 4, 5 to find natural frequencies. The maximum natural frequency for rectangular section was found at mode 5 and the value is 28.41, for I cross section was found at mode 5 and the value is 29.04. So, finally we concluded that I cross section has more natural frequency than rectangular cross section under same conditions.

Static analysis:

Static analysis was done to determine the maximum total deflection, maximum von misses stress and buckling analysis values for both rectangular & I cross sections.

The Max Total deflection for rectangular section is 45.773 mm, for I cross section is 42.083 mm.

The Max von misses stress value for rectangular section is 141.86 N/mm^2, for I cross section is 114.66 N/mm^2.

The Max buckling analysis value for rectangular section is 1.0001, for I cross section is 1.0273.

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