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Effect of Different Web Openings in Narrow Flange I Section Beam

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Abstract

Weight optimization is great focus of interest in structural application. Many researchers have worked on weight optimization by modifying structural design. Very few researchers have worked on weight optimization by introducing web openings in I section beam. In this paper authors have done comparative analysis of different web openings in I section beam. At the end of the paper most suitable design of web opening have been suggested for strength point of view.

1. Introduction

I section is widely used section among the all other sections in structural application. There are certain advantages such as it other sections in structural application. There are certain advantages such as it offers maximum area moment of inertia. Also its mass is distributed away from the neutral axis.

There are number of application in which I section beam is used. Material cost is major focus of interest for structural engineers. One way to minimize material cost is to minimize its dimensions but that will degrade its functional ability.

One of the way by which one can minimize weight is to introduce different web openings in I section. In the present investigation, all steel beams are hot rolled steel I sections. All web opening are concentric to the mid – height of the sections. Both the stress and the deformation are evaluated.

Shear force and bending moment is obtained by finite element analysis for different depth of opening to depth of beam ratio and three different types of web opening shapes such as hexagonal, rectangular and circular [1]. The presence of large web openings may have a severe penalty on the load carrying capacities of floor beams, depending on the shapes, sizes, and the locations of openings. All the steel beams with web openings of various shapes and sizes behave similarly among each other in terms of deformed shapes under a wide range of applied moments and shear [2]. Finite element modelling can be used to investigate the nonlinear behavior and ultimate capacity of these beams of plate girders containing circular and rectangular web [3]. The frames with reduced web section can provide at least the same level of seismic improvement that the frames with reduced beam section can [4].

2. Analytical calculation

In this paper, narrow flange I beam of carbon steel IPN section number 180 have been taken for the analysis. Dimensions of the I beam is as shown in figure 1 and the beam length is 8000 mm and is fixed as one end. Maximum defection is found out 146.11 mm.

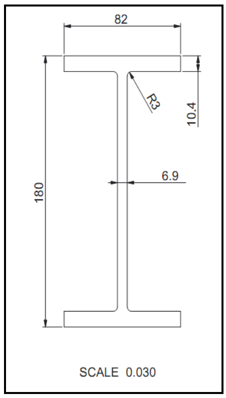

Figure 1. I section beam

3. Finite element analysis

Finite element analysis has been carried out for I section beam without web openings in order to validate analytical results.

3.1 Material properties

Material properties for given base stool cylindrical shell are as shown table 1**.**

Table 1. Material Properties

Sr. No.	Mechanical Properties	Value
1	Density	7850 kg/m^3
2	Young's Modulus	200 GPa
3	Tensile Yield strength	250 MPa
4	Poison's ratio	0.3

3.2 Meshing and boundary conditions

I section beam as mentioned above is meshed using hexahedral element because of its simple geometry. For beam with different web openings tetrahedral elements have been selected to accommodate minor details of the geometry. Total number of nodes and elements are 90442 and 13760 respectively. Mesh model of I beam is shown in the figure 2. Beam is fixed at one end and subjected to 2500 N concentrated load on the other end as shown in figure 3.

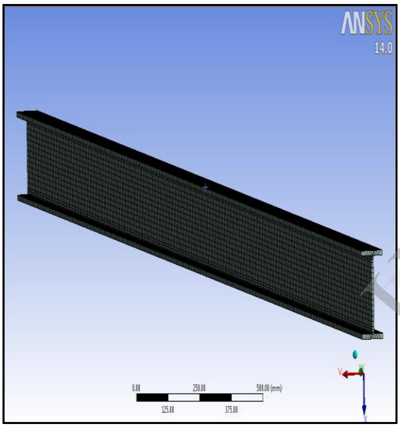

Figure 2. Mesh model

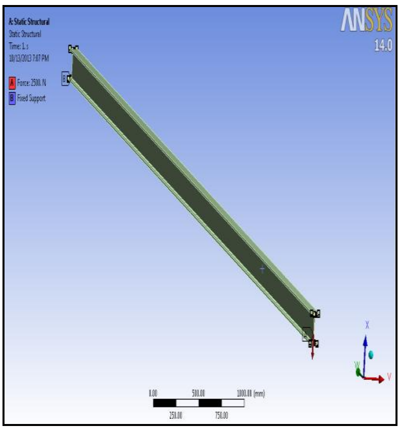

Figure 3. Boundary conditions

4. Results and validation:

Stress and deformation contour of above mentioned design show good conformation between analytical and numerical approach. Figure 4 and figure 5 show stress distribution and deformation contour respectively.

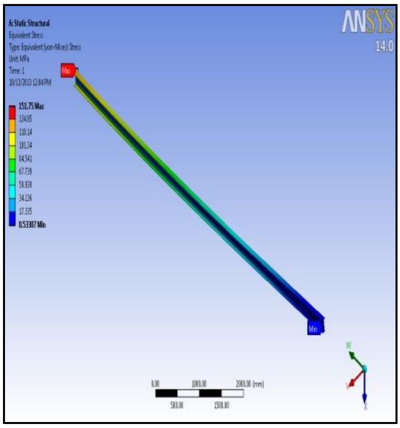

Figure4. Stress contour

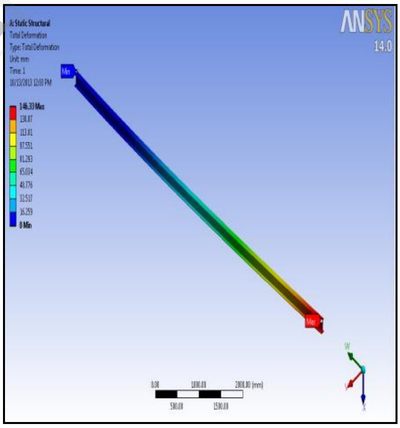

Figure 5. Deformation contour

4.1 Validation of numerical approach

FEA results reveal that there is good conformability between analytical results and FEA results. Table 2 shows 0.15% deviation of deformation.

Table 2. Validation of Numerical Approach

Criteria	Analytical Result	FEA Result	% deviation
Deformation	146.10 mm	146.33 mm	0.15

5. Weight optimization with different web openings

Different web openings have been introduce in I section beam while keeping the boundary conditions same as they were earlier. Also tetrahedral elements have been used for all different web openings. For all different web openings, area of each web opening is selected in such manner that total mass removed by web openings for all different shapes have been kept constant. Total mass of I beam with different web openings is 7960 kg less than that of total mass of I beam without web openings. Different types of web openings, such as circular pocket, rectangular pocket, square pocket, square pocket with 45 degree rotation, elliptical pocket with minor axis along the longitude axis of the beam and elliptical pocket with major axis along the longitude axis of the beam, have been introduce to check out their effect on deformation as well as stress.

All steps, such as model preparation with different web openings, assign material properties, meshing and boundary condition, that have performed earlier on I beam without web openings, are to be done again in order to carry out finite element analysis.

5.1 Results and discussion

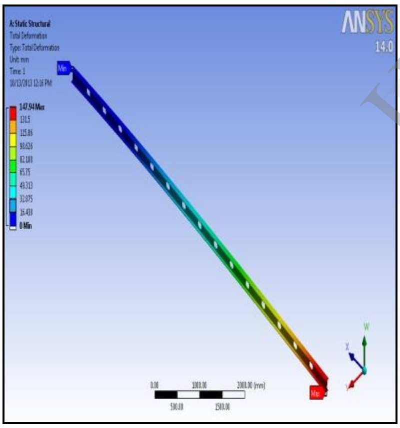

Figure 6. Deformation of beam with circular pockets

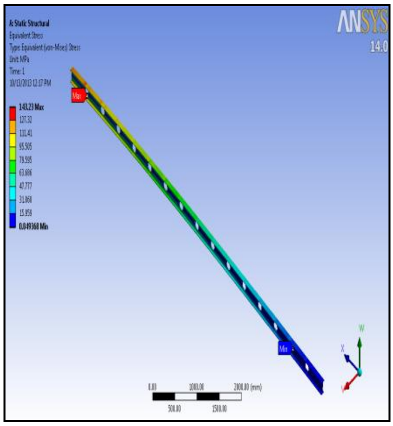

Figure7. Stress of beam with Circular pockets Circular pockets

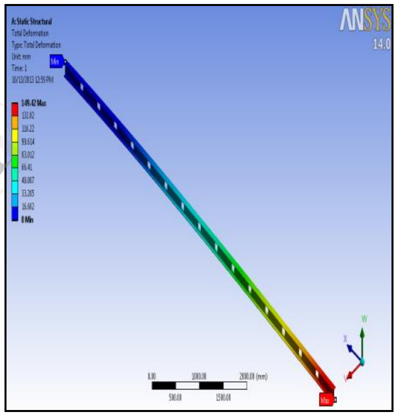

Figure 8. Deformation of beam with Rectangular pockets

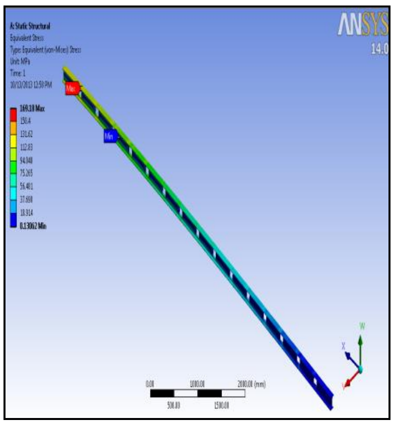

Figure 9. Stress of beam with rectangular pockets

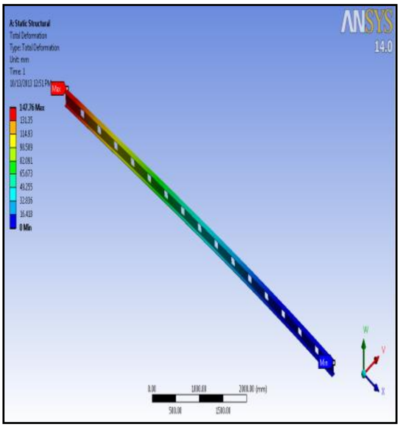

Figure 10. Deformation of beam with Square pockets

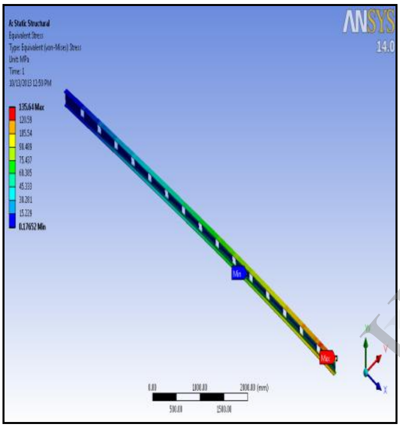

Figure 11. Stress of beam with square pockets

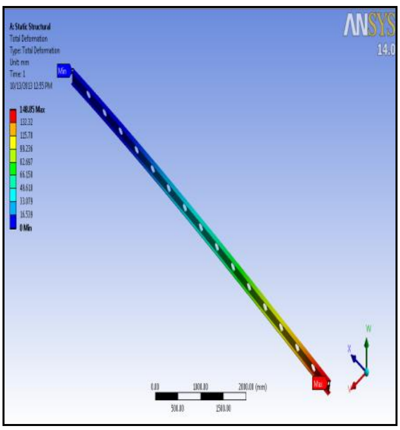

Figure 12. Deformation of beam with Square pocket 45 degree rotation

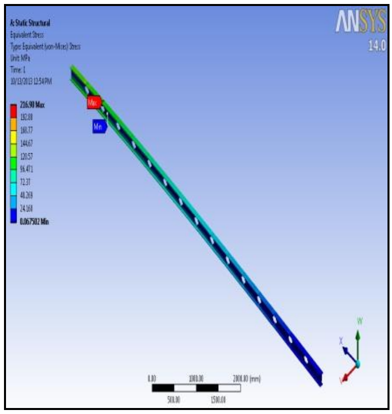

Figure 13. Stress of beam with Square pocket 45 degree rotation

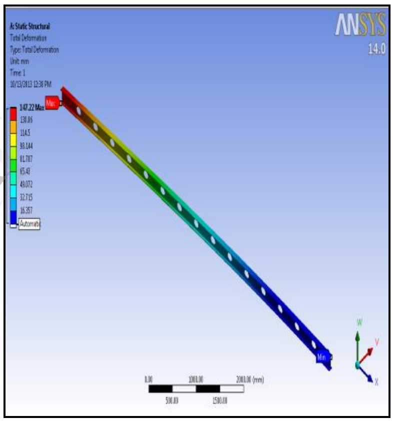

Figure 14. Deformation of beam with Elliptical pocket major axis along the longitudinal axis

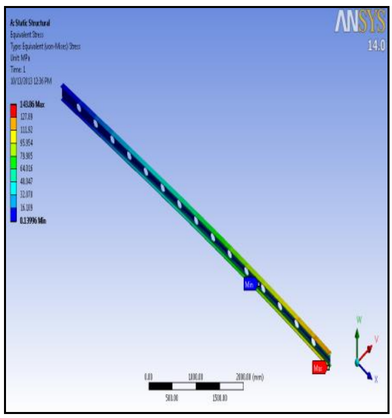

Figure 15. Stress of beam with Elliptical pocket major axis along the longitudinal axis

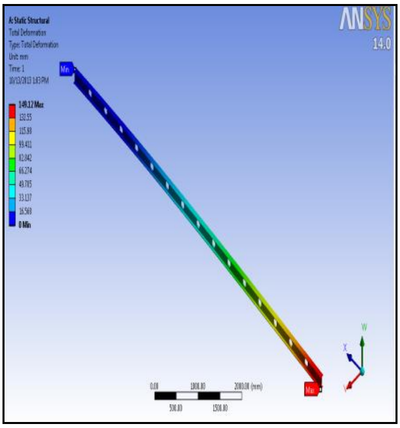

Figure 16. Deformation of beam with Elliptical pocket minor axis the longitudinal axis of beam

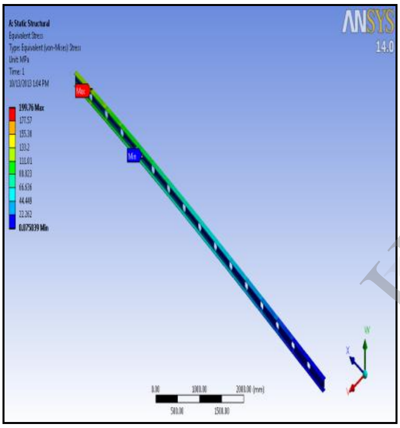

Figure 17. Stress of beam with Elliptical pocket minor axis along the longitudinal axis of beam along

Deformation and stress results are arranged in tabular manner in order to see effects of different web openings with same boundary conditions. Table 3 and table 4 shows deformation and stress results respectively in ascending order.

Table 3. Deformation of I section beam with different web openings

Sr. No.	Pocket profile	Maximum Deformation in mm
1	Elliptical with major axis along the longitudinal axis of beam	147.22
2	Square	147.76
3	Circular	147.94
4	Square with 45 degree rotation	148.85
5	Elliptical with minor axis along the longitudinal axis of beam	149.12
6	Rectangular	149.42

Table 4. Stress of I section beam with different web openings

Sr. No.	Pocket profile	Maximum Stress in MPa
1	Square	135.64
2	Circular	143.23
3	Elliptical with major axis along the longitudinal axis of beam	143.86
4	Rectangular	169.18
5	Elliptical with minor axis along the longitudinal axis of beam	199.7
6	Square with 45 degree rotation	216.98

6. Conclusion

Finite element analysis is very useful tool in order to carry our optimization. From the above results it can be concluded that minimum deformation occurred in each I beam is almost same. There is very less different in deformation due to variation in meshing quality of the beam. It can be also concluded that beam with square web openings with fillet at corners has least minimum stress value among the all other web opening. Deformation and stress value for I beam with square web openings are 147.76 mm and 135.64 MPa respectively.

7. References

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