Finite Element Analysis to Compare the Deflection of Steel Beam with and without Web Openings

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Abstract: *In order to decrease the cost of steel members and to increase its stiffness, several new methods have been adopted and castellated beams are one such method. In castellated beams, first the web portion of the beam is cut in a zigzag pattern, according to the shape of the castellation to be made and then the two halves are joined together by welding. During the process of welding, the two halves are moved in such a way that the desired hole shape is formed. These openings help to provide the passage of services through the beams. This helps to reduce the overall floor height. Aesthetic appearance may also be considered as an advantage. These castellated beams have same strength as that of a solid beam. In this paper, finite element analysis was performed to compare the deflection of steel beam with and without web openings of ISMB 150 section. ANSYS 14.5 was used for the analysis. Results showed that the castellated beam with hexagonal opening showed more load carrying capacity and lesser deflection compared to solid beam and steel beam with circular opening (cellular beam).*

***Keywords –*** *Castellated Beam, Cellular Beam, Deflection, Finite Element Analysis, Web Openings*

I. Introduction

Many structures are using steel as there constructional element. Castellated beam reduces the cost of structural steel and also increase the stiffness of steel members. Castellated beams are beams having holes or castellations on its web portion. It is made by cutting the web portion of the solid beam in a zigzag pattern and then arranging the two halves in such a way that castellations are made in the web portion. It is the then welded together to form a castellated beam. In castellated beams, one can increase the depth of the beam without any additional steel.

Wakchaure et. al (2012) investigated the effect of web openings on various structural aspects of castellated beam, various modes of failures and the effect on deflection with increase in the depth of web openings. Depth of beam increased in processes of castellation by 40, 50 and 60 %, with the hexagonal shape openings of angle 60^0 width, since the castellated beams are relatively slender and have web openings, which have an influence on their resistance. They concluded that castellated steel beam behaves satisfactory for serviceability upto a maximum depth of opening 0.6 D. Sagade et. al (2012) investigated the effect of web openings by analyzing the behavior of castellated steel beams having I- shaped cross- section and concluded that the castellated steel beam behaves satisfactorily with regards to serviceability requirements upto a maximum web opening depth of 0.6 H.

Anupriya et. al (2013) investigated the behavior of shear strength of castellated beams through an extensive finite element study. from the results obtained from ANSYS, it was concluded that deflection reduces when stiffeners are provided vertically along with diagonal stiffeners. Anupriya et. al (2014) investigated the behavior of shear strength of castellated beam with and without stiffeners and concluded that the shear strength of castellated steel beams can be improved by providing diagonal stiffeners along the web opening. Also it was concluded that the stiffeners provided on the web opening is more effective than stiffeners provided on the solid portion of the web.

In this work, we are considering a solid steel beam and castellated beams having hexagonal and circular openings. Castellated beams having circular openings are sometimes called as cellular beams. Ansys 14.5 is used for finite element analysis. Length of the beam is 975 mm and effective length is taken as 880 mm. Below figures show the schematic diagrams of parent section, castellated steel beam with hexagonal openings and castellated steel beam with circular openings.
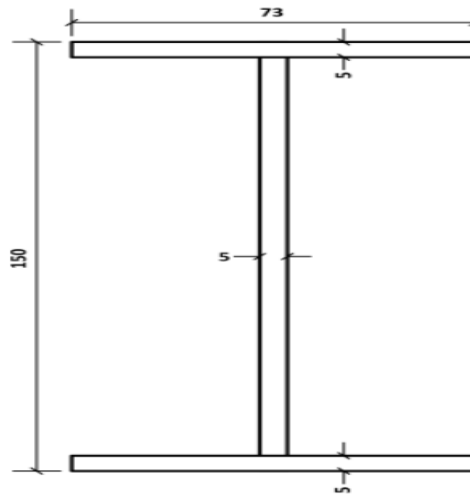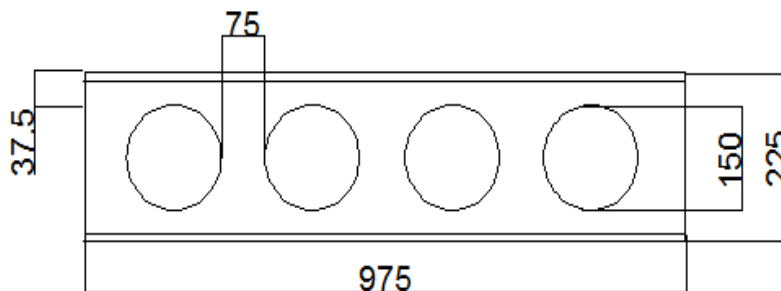
All dimensions are in mm

Fig. 1. Schematic diagram of parent section
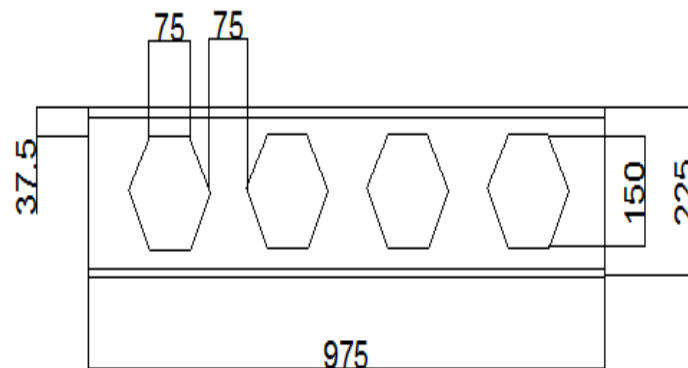
All dimensions are in mm

Fig. 2. Schematic diagram of castellated beam with hexagonal opening

All dimensions are in mm

Fig. 3. Schematic diagram of castellated beam with circular opening

II. Finite Element Analysis

2.1 Ansys 14.5

ANSYS (acronym for Analysis System) is a general purpose Finite Element Analysis (FEA) program that solves a vast area of solid and structural mechanics problems in geometrically complicated regions. ANSYS provides

solutions for many type of analysis ANSYS is a widely used commercial general-purpose finite element analysis program.

2.2 Analysis Procedure

A three dimensional finite element model is developed to study the behavior of castellated beam. Beams are of I shaped cross section. Modeling and analysis was done using ANSYS 14.5. Element type used is SOLID 185. SOLID185 Structural Solid is suitable for modelling general 3-D solid structures. It allows for prism, tetrahedral, and pyramid degenerations when used in irregular regions. Various element technologies such as B-bar, uniformly reduced integration, and enhanced strains are supported.
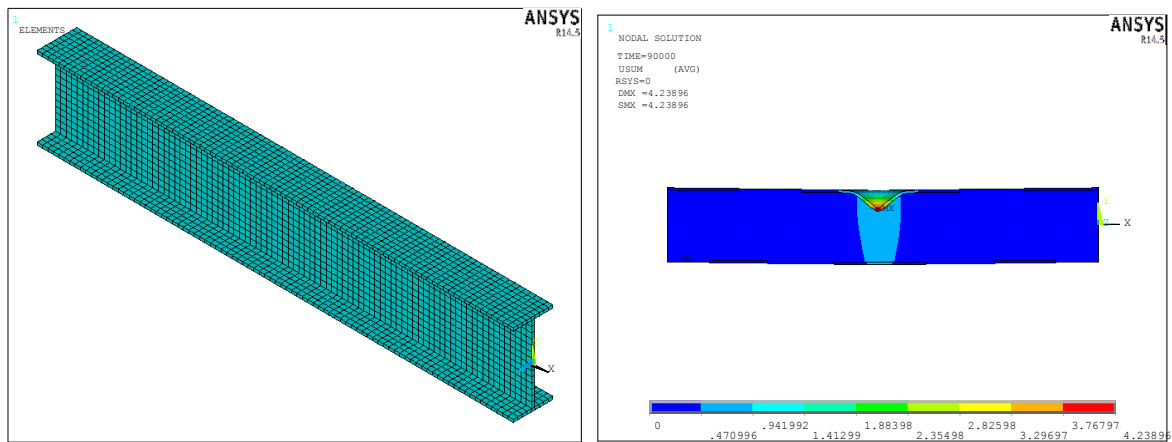
Properties:

Young's modulus, $E = 2 \times 10^{11}$ N/m^2, Poisson's ratio = 0.3, Yield strength = 2.5×10^8 N/m^2, Density of steel = 7850 kg/m^3.
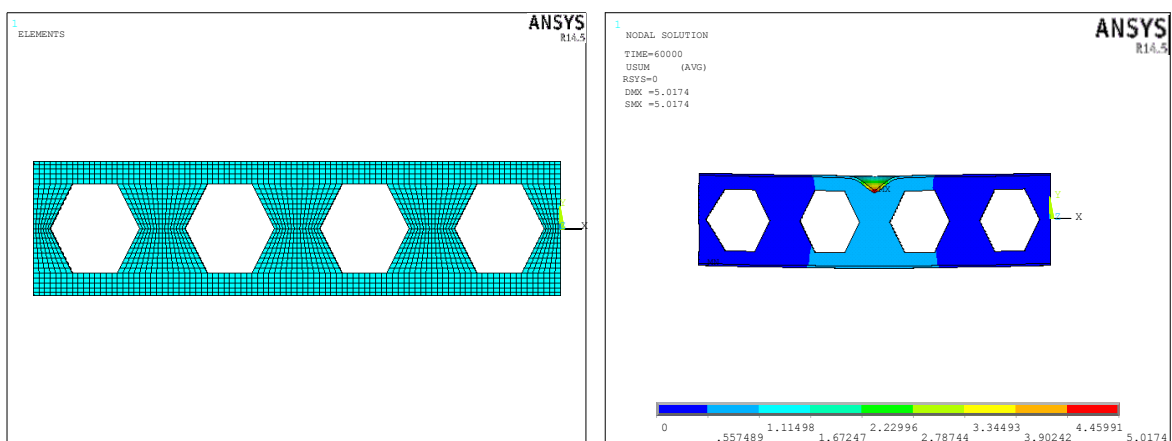
Static analysis was performed to determine the deflection of the solid beam and castellated steel beams having hexagonal and circular openings.

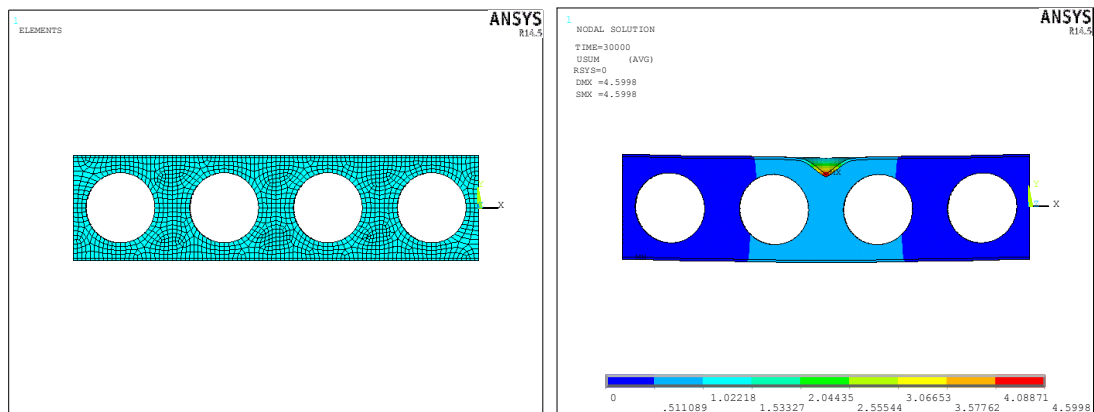Effective length of the beam is taken as 880 mm.

2.3 Test Results

Fig. 4. Solid Beam (a) Meshed Model (b) Deflected Model

Fig. 5. Beam with Hexagonal Opening (a) Meshed Model (b) Deflected Model

Fig. 6. Steel Beam with Circular Openings (a) Meshed Model (b) Deflected Model

Table 1 shows the comparison of deflection of solid beam, castellated beam with hexagonal and circular openings.
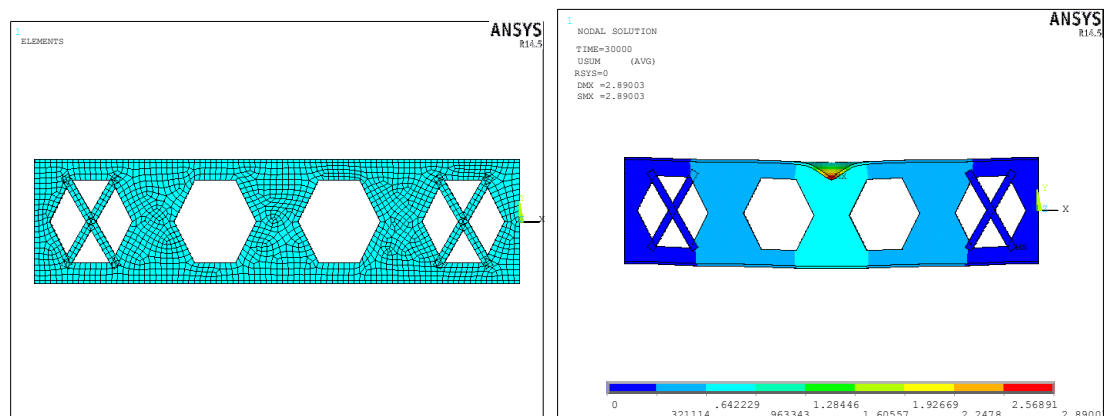
Table 1. Comparison of deflection values

Sl.No	Load (kN)	Deflection (mm)		
		Solid beam	Beam with Hexagonal Opening	Beam with Circular Opening
1	30	2.48	3.084	4.599
2	60	4.031	5.017	6.0017
3	90	4.238	6.856	9.847
4	120	5.308	8.153	-
5	140	13.988	9.198	-

From the above software analysis we can find that castellated steel beams with hexagonal openings show better load carrying capacity and deflection is small as compared with solid beam. So it will be better if castellated steel beams with hexagonal openings are used instead of other shapes.

2.4 Diagonal stiffeners in the shear zone of web opeings

From the experimental and numerical analysis it was clear that steel beam with hexagonal openings show more load carrying capacity and lesser deflection as compared to solid beam and steel beam with circular opening. Von mises stresses were developed for steel beam with hexagonal opening and it was observed that the stress concentration is more near the opening leading to shear failure. Hence the webs are stiffened by providing diagonal stiffeners along the shear zone to reduce the stress concentration. Length of stiffeners is 190 mm, width of stiffeners is 15 mm and the thickness is 5 mm.

Fig. 7. Castellated beam with Diagonal Stiffeners (a) Meshed Model (b) Deflected Model

Table 2. Comparison of deflection of castellated beam with and without stiffeners

Sl.No	Load (kN)	Deflection (mm)	
		Without diagonal stiffeners	With diagonal stiffeners
1	30	3.084	2.890
2	60	5.017	3.052
3	90	6.856	4.392
4	120	8.153	5.898
5	140	9.198	6.099

III.   Conclusions

- From the numerical analysis, it was observed that, as compared to solid beam and steel beam with circular opening, steel beam with hexagonal opening showed more load carrying capacity.
- If diagonal stiffeners are provided along the shear zone of web openings, deflection can further be reduced.

Acknowledgements

References

[1]. B.Anupriya, Dr.K. Jagadheesan," Strength study on castellated beam", International Journal of Engineering Research and technology,(2013)
[2]. Wakchaure M.R, Sagade A.V, Auti V.A," Parametric study of castellated beam with varying depth of web opening", International journal of scientific and Research publications, vol.2, Issue 8(2012)
[3]. A.V Sagade ," Finite element analysis of castellated steel beam", International journal of engineering and innovative technology, vol 2, issue 1 (2014)
[4]. A.M Jamadar, P.D Kumbhar," Finite element analysis of castellated beam: a review", International journal of innovative research in advanced engineering, vol 1, issue 9, (2014)
[5]. Prof. R.R Jichkar, Prof N.S. Arukia, " Analysis of steel beam with web openings subjected to buckling load", International journal of Engineering and applications,(2014)
[6]. B.Anupriya, Dr.K Jagadhesan, "Shear strength of castellated beam with and without stiffeners using FEA", International journal of Engineering and technology, vol 6.(2014)
[7]. Amin Mohebkhah, Hossein Showkati, "Bracing requirements for inelastic castellated beams", Journal of constructional steel research, (2005)
[8]. L. Amayreh ,M. P. Saka, " Failure load prediction of castellated steel beams using artificial neural networks", Asian Journal Of Civil Engineering (Building And Housing) Vol. 6, Nos. 1-2 (2005), 35-54, (2005)
[9]. Mohsen Gerami, Hamid Saberi, " Effect of beam length and braced length on moment rotation behaviour of castellated beams", Open journal of safety science and technology,(2013)