Deflection Comparison of Different Web Opening Castellated Beams by Using Finite Element Analysis

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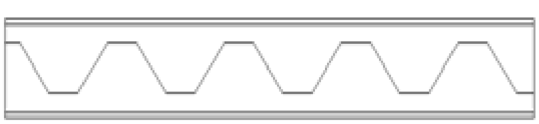
Abstract- *Castellated beams are those beams which have openings in their web portion. Castellated beams are fabricated by cutting the web of hot rolled steel (HRS) I section into zigzag pattern and thereafter rejoining it over one another. Use of castellated beams is become very popular now a day due to its advantageous structural applications. This is due to increased depth of section without any additional weight, high strength to weight ratio, their lower maintenance and painting cost. The principle advantage of castellated beam is increase in vertical bending stiffness, ease of service provision and attractive appearance. However one consequence of presence of web opening is the development of various local effects. The openings made in the webs are of generally hexagonal, diamond, rectangular or square in shape. By studying the different research paper it found that castellated beams with hexagonal, rectangular or square opening mostly fail due to shear stress concentration at the corner of opening, so our objective of this paper is to provide new web opening shape that is sinusoidal opening to avoid failure of castellated beam due to shear stress concentration at the corner of opening. From the finite element analysis using ansys, it is concluded that, castellated beams with sinusoidal web opening shows less deflection as compare to castellated beams with hexagonal web opening.*

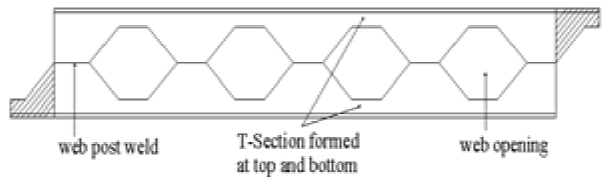
Keywords- Castellated beam, Circular web opening, Hexagonal web opening, Sinusoidal web opening, finite element analysis etc.

I. INTRODUCTION

Castellation is a process of fabricating a section with improved section properties from virgin rolled section that is improving moment of inertia, improving depth. There by increase in moment of resistance and controlled on deflection.



(a)web cut



(b)completed beam

Fig 1: Fabrication Process

This process increases the depth of the beam by approximately 50%, therefore increasing the strength and stiffness by about 20 to 30% without increasing the weight of the beam. Also the holes in the web allow ductwork to run through beams instead of underneath ultimately reducing the depth of the floor system. Although there are many advantages to using castellated beam, the one disadvantage is fabrication cost. The extra cost of cutting and welding the web is usually the deciding factor for their feasibility. Castellated beams are more popular in areas where the cost of steel is high and labour costs are low. The use of castellated beams in Europe has existed ever since the adoption of the fabrication process developed by Litzka Stahlbau of Bavaria, Germany (Boyer 1964). The design concept for castellated beams is based on typical beam limit states, but the presence of web openings and welds can cause other modes of failure. The potential modes of failure associated with castellated beams are:

1. Flexural Failure Mechanism
2. Lateral-Torsional Buckling
3. Vierendeel Bending Mechanism
4. Weld Rupture at Web Post
5. Shear Buckling of Web Post
6. Compression Web Post Buckling

1.1 Research Objectives:

The objective of this research is to examine the deflections of different web opening castellated simply supported beams.

II. ANALYSIS BY ANSYS

The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. ANSYS is a general purpose finite element modeling package for numerically solving a wide variety of problems which include static/dynamic structural analysis (both linear and nonlinear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems. The castellated beams with different web opening shape have been analysed using a finite element (FE) model in ANSYS.

2.1 ANSYS analysis procedure

SHELL181 is suitable for analyzing thin to moderately-thick shell structures. It is a four node element with six degrees of freedom at each node: translations in the x, y, and z directions, and rotations about the x, y, and z-axes. (If the membrane option is used, the element has translational degrees of freedom only). The degenerate triangular option should only be used as filler elements in mesh generation. SHELL181 is well-suited for linear, large rotation, and/or large strain nonlinear applications. Change in shell thickness is accounted for in nonlinear analyses. In the element domain, both full and reduced integration schemes are supported. SHELL181 accounts for follower (load stiffness) effects of distributed pressures.

Table -1: Detailing of various beams

Sr. No	Name	Specification	Length L (mm)	Depth D (mm)	Width of flange b_f (mm)	Thickness of flange t_f (mm)	Thickness of web t_w (mm)
1	I_P	Parent section without castellation	1700	150	8	8	5
2	I_H	Section with hexagonal web opening	1700	225	8	8	5
3	I_{S1}	Section with sinusoidal web opening with fillet radius equal to 1/4th of opening	1700	225	8	8	5
4	I_{S2}	Section with sinusoidal web opening with fillet radius equal to 1/6th of opening	1700	225	8	8	5
5	I_{S3}	Section with sinusoidal web opening with fillet radius equal to 1/8th of opening	1700	225	8	8	5

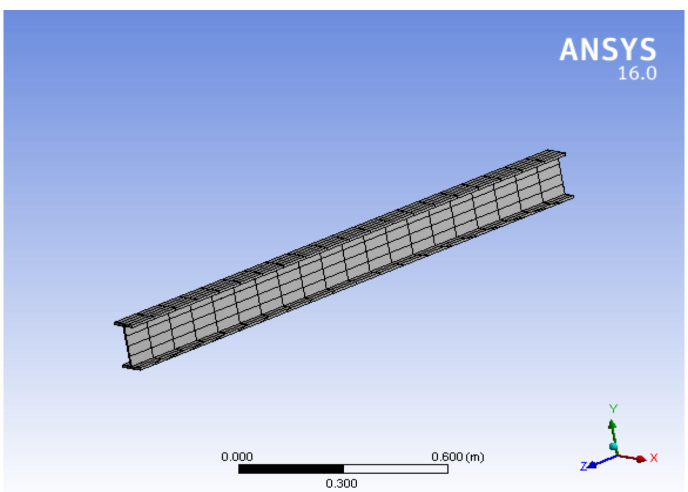


Fig -2: Typical Finite Element Mesh for I_P

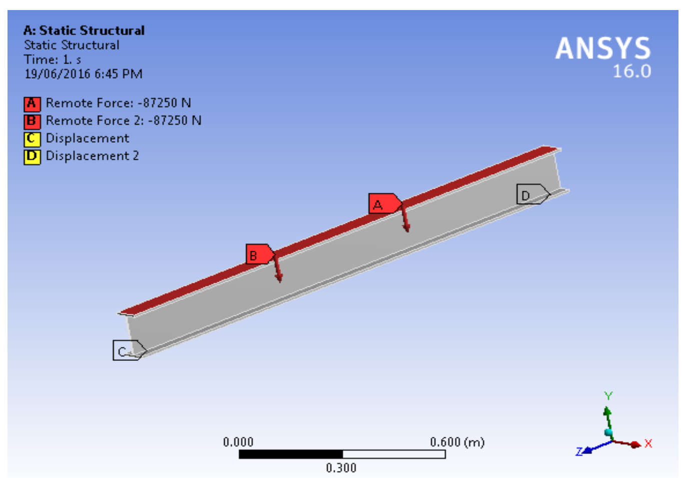


Fig -3: Position of Supports and Loads for I_P

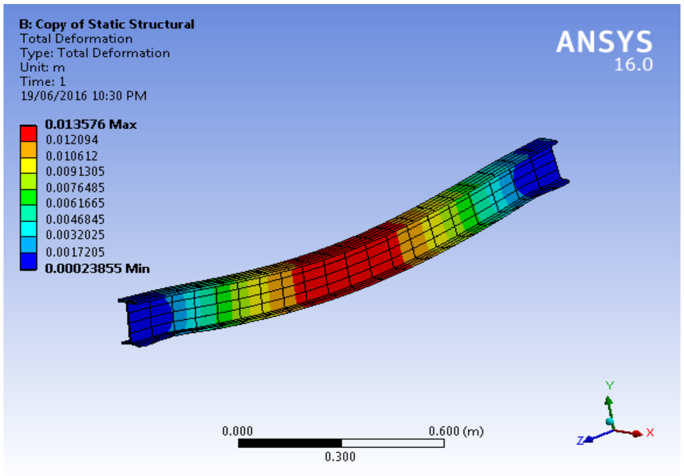


Fig -4: Total Deflection of I_P

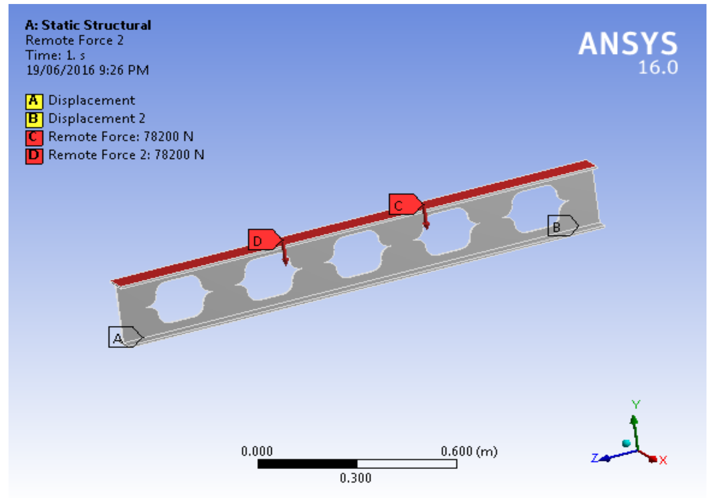


Fig -7: Position of Supports and Loads for I_{S1}

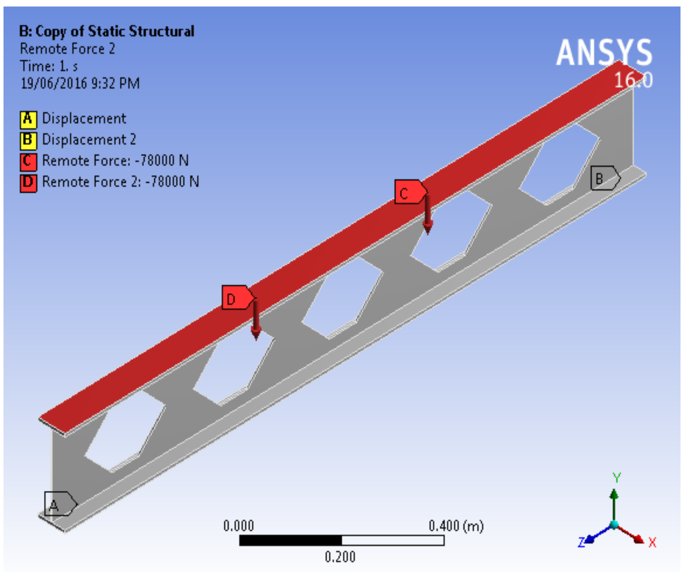


Fig -5: Position of Supports and Loads for I_H

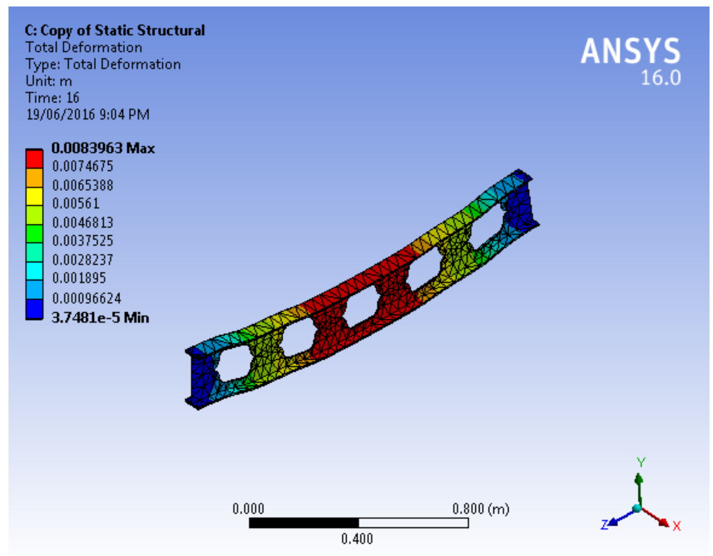


Fig -7: Total Deflection of I_{S1}

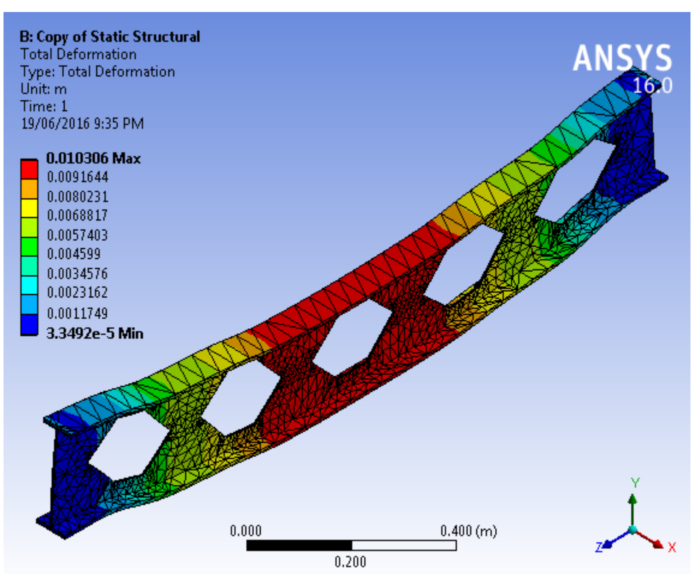


Fig -6: Total Deflection of I_H

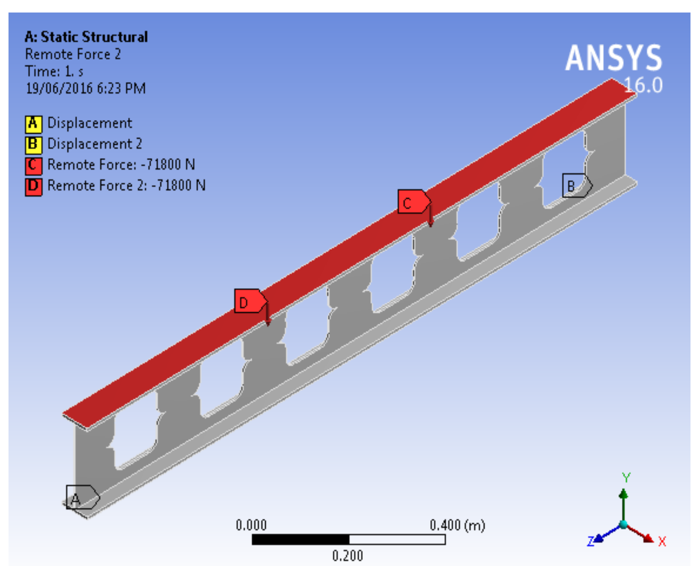


Fig -9: Position of Supports and Loads for I_{S2}

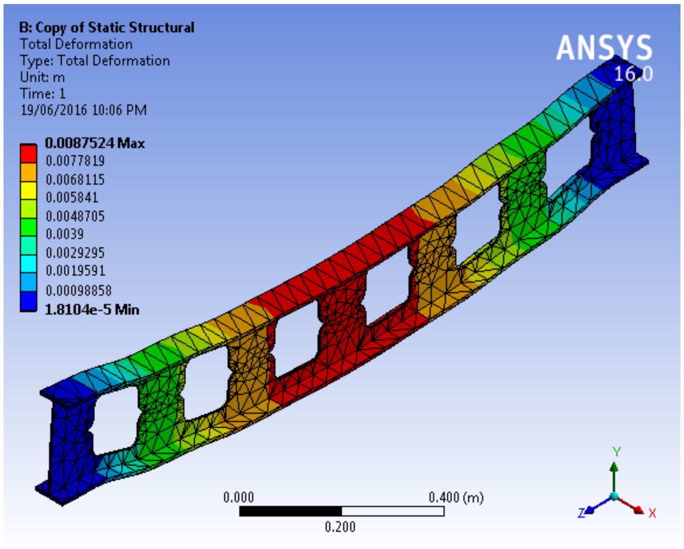


Fig -10: Total Deflection of I_{S2}

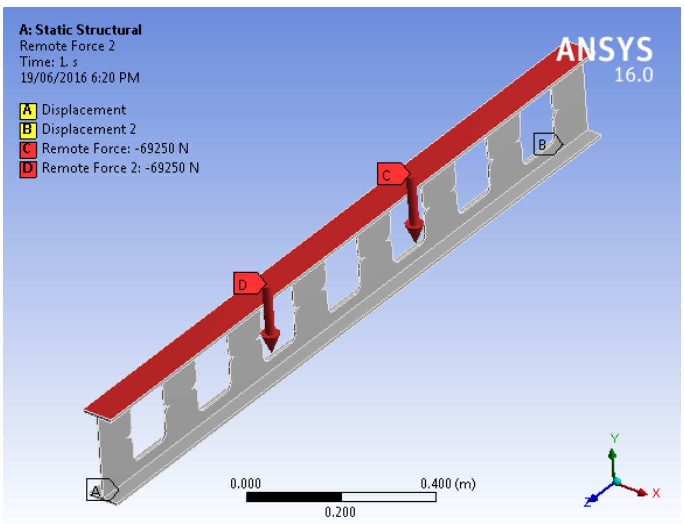


Fig -11: Position of Supports and Loads for I_{S3}

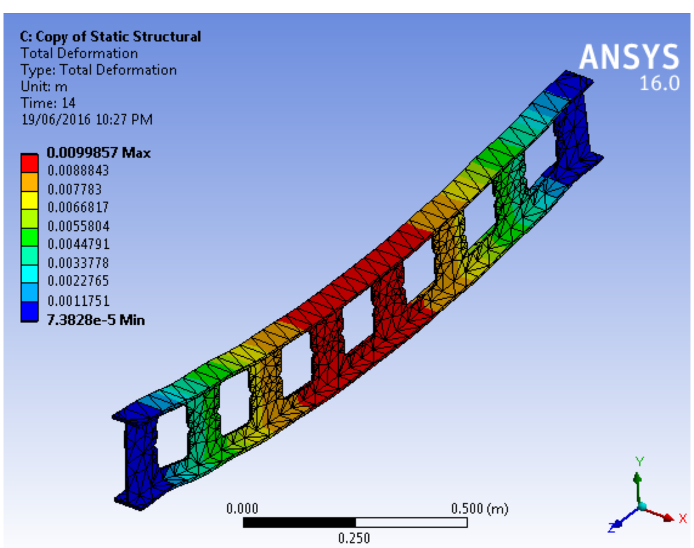


Fig -12: Total Deflection of I_{S3}

III. RESULTS

With reference to ansys analysis results are on the basis of load carrying capacity and corresponding deflections of castellated beams

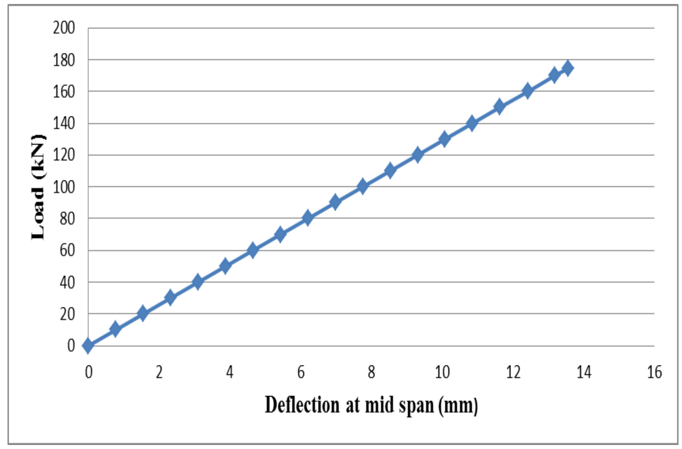


Chart -1: Load V/s Deflection for I_P by Ansys

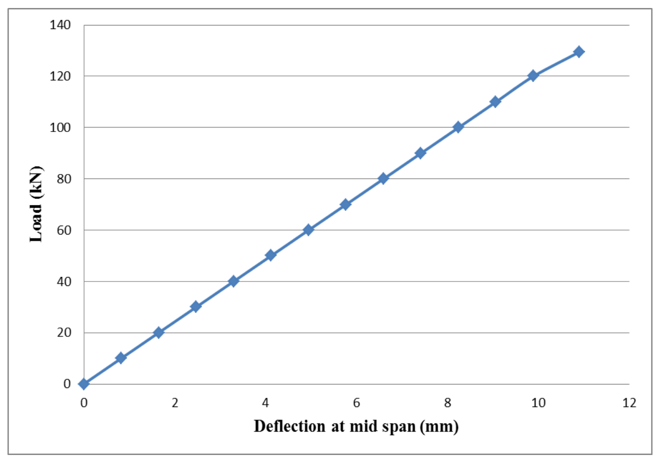


Chart -2: Load V/s Deflection for I_H by Ansys

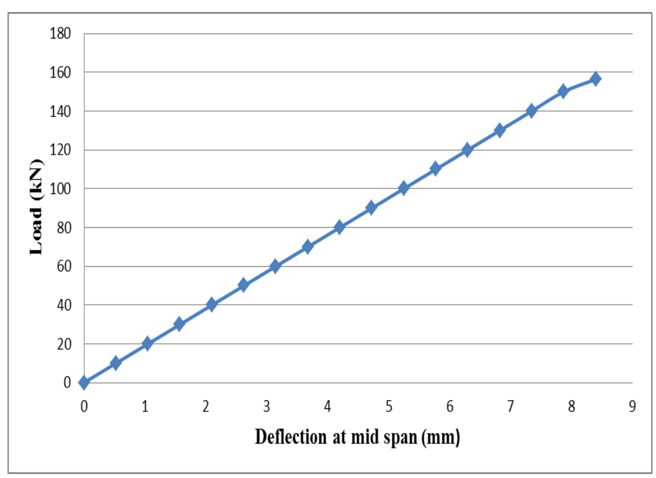


Chart -3: Load V/s Deflection for I_{S1} by Ansys

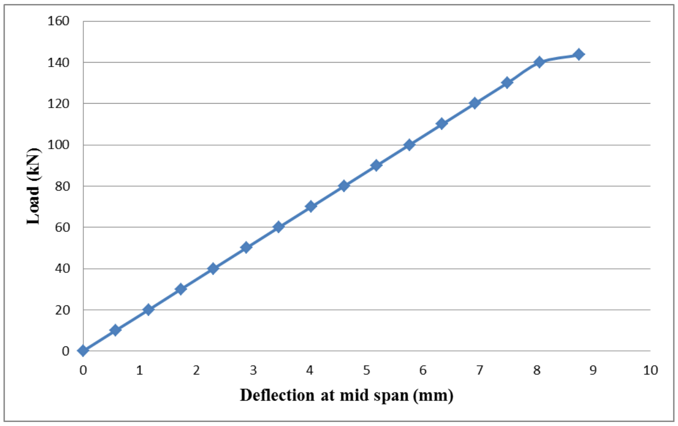


Chart -4: Load V/s Deflection for I_{S2} by Ansys

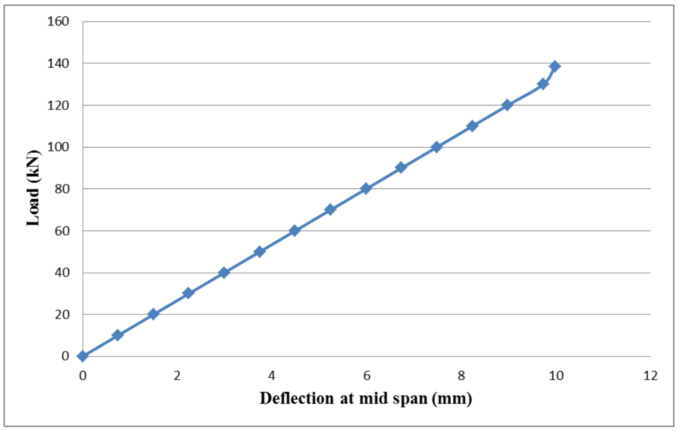


Chart -5: Load V/s Deflection for I_{S3} by Ansys

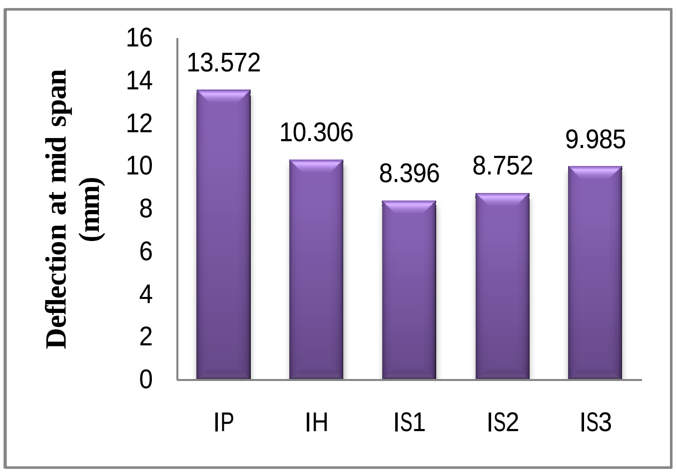


Chart -6: Comparison of Deflection of tested beam specimens by Ansys

IV. CONCLUSIONS

From the above discussed results it can be concluded that:

1) Load carrying capacity of castellated beam with sinusoidal web opening is more as compare to castellated beam with hexagonal opening.
2) The Castellated beam with sinusoidal web opening has as good structural performances as compare to hexagonal openings in the form of the stresses distribution, shear capacity and failure mode etc.
3) Also the Castellated beams with Sinusoidal web opening have higher shear capacity than that with hexagonal web opening.
4) Sinusoidal web opening castellated beams shows less deflection as compare hexagonal web opening castellated beam.
5) Deflection of I_{S1} compare to I_H is 11.51 % less, that of I_{S2} compare to I_H is 6.87% less and of I_{S3} compare to I_H is 3.57% less.
6) Finite element analysis shows that shear stress get easily redistributed at the fillet corner of Sinusoidal Web Opening Castellated Beams.
7) Comparing the results of all Sinusoidal Web Opening Castellated Beams it is found that a castellated beam with Sinusoidal Web Opening with fillet radius equal to $1/4^{th}$ of opening shows better performance compare to castellated beam with Sinusoidal Web Opening with fillet radius equal to $1/6^{th}$ and $1/8^{th}$ of opening in both load carrying and deflection point of view.

REFERENCES

[1] Amayrey, M. P. Saka "Failure load prediction of castellated beamsusing artificial neural networks asian journal of civil engineering (building and housing) vol. 6, (2005), 35-54.

[2] Tadeh Zirakian, Hossein Showkati "Distortional buckling of castellated beams" Journal of Constructional Steel Research 62 (2006), 863–871.

[3] Ehab Ellobody "Interaction of buckling modes in castellated steel beams" Journal of Constructional Steel Research 67 (2011), 814–825.

[4] Amir Hossein Gandomia, Seyed Morteza Tabatabaei, Mohammad Hossein Moradian, Ata Radfar, Amir Hossein Alavi "A new prediction model for the load capacity of castellated steel beams" Journal of Constructional Steel Research 67 (2011), 1096–1105.

[5] Hossein Showkati, Tohid Ghanbari Ghazijahani, Amir Noori, Tadeh Zirakian "Experiments on elastically braced castellated beams" Journal of Constructional Steel Research 77 (2012), 163–172.

[6] 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, August 2012.

[7] M.R.Wakchaure, A.V. Sagade “Finite Element Analysis of Castellated Steel Beam” International Journal of Engineering and Innovative Technology (IJEIT) Vol 2, Issue 1, July 2012.

[8] A.R. Zainal Abidin , B.A. Izzuddin , “Meshless local buckling analysis of steel beams with irregular web openings” Engineering Structures 50 (2013), 197–206.

[9] Peijun Wang, Qijie Ma, Xudong Wang “Investigation on Vierendeel mechanism failure of castellated steel beams with fillet corner web openings”, Engineering Structures 74 (2014), 44–51.

[10] Peijun Wang , Xudong Wang, Ning Ma “Vertical shear buckling capacity of web-posts in castellated steel beams with fillet corner hexagonal web openings” Engineering Structures 75 (2014), 315–326.

[11] Delphine Sonck, Jan Belis “Lateral–torsional buckling resistance of cellular beams” Journal of Constructional Steel Research 105 (2015), 119–128