Castellated Beam with Diagonal Stiffeners Along Hexagonal Cuts

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Abstract - *The high strength properties of structural steel cannot always be utilized to best, due to the limitations on maximum allowable deflections. Castellated beams with web openings are aimed at increasing the stiffness or load carrying capacity of steel members without any increase in weight of the steel required. Hexagonal openings in web which is the more common castellation shape because of the simplicity in its fabrication. Very little work has been done to avoid failure of castellated beams, it has been suggested to provide stiffener with proper dimensions and locations. I beam with diagonal stiffeners along hexagonal castellation is considered in this study. In this paper a comparative study of deflection, shear stress, flexure and von-mises stress is done.*

***Key Words*: *Castellated beams, Stiffness, Stiffener, Deflection, Flexure, Von-mises stress* mises stress**

1. INTRODUCTION

Steel structure building are becoming more and more popular due to their various advantages such as the better satisfaction with the flexible architectural, durability, strength to weight ratio, design, low inclusive cost. Due to the limitations on maximum allowable deflections, the high strength properties of structural steel cannot always be utilized to its maximum advantage. As a result, several new methods have been aimed at increasing the stiffness or load carrying capacity of steel members without any increase in weight of the steel required. Castellated beams with web openings were one of these solutions. Castellated Beam is a type of expanded beam which is made by separating a standard rolled shape into two halves by cutting the web in a regular alternating pattern. The halves are re-joined by welding after offsetting one portion so that the high points of the web pattern come into contact, finally we obtain a beam of higher depth known as castellated beam with openings at web compared to the normal beam.

A number of common and practical web openings are possible in castellated beam, such as circular, square, rectangular, hexagonal. Use of castellated beam with hexagonal openings is more common in recent years because of the simplicity in its fabrication. As height of castellated beam will get increase it gives high bending and shear strength as section modulus of castellated beam will get increase. To fully utilize the engineering advantage of castellated beams, erection stability must be considered. The increase in depth of castellated beam leads to many modes of failure when subjected to loading such as formation of flexure mechanism, lateral torsional buckling, formation of Vierendeel mechanism, rupture of the welded joint in a web post and shear buckling of a web post which needs to be taken care of. Use of stiffeners in the web portion of beam helps in minimizing these failures by an increasing the ultimate load and the initial stiffness. Therefore, a detailed study in respect of number of stiffeners, size of stiffener and their locations in the web portion of castellated is carried out using I-beam(ISMB150) with diagonal stiffeners along hexagonal opening. In this paper a comparative study of deflection, shear stress, flexure and von-mises stress is done.

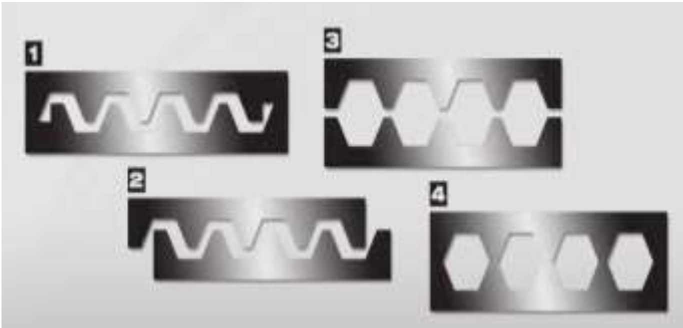


Fig -1: **Fortification of hexagonal castellated beam**

2. MODELLING OF CASTELLATED BEAM WITH DIAGONAL STIFFENERS

In the paper, "Shear strength of castellated beam with and without stiffeners using FEA (ANSYS 14)" by B. Anupriya and Dr.K.Jagadeesan, effect of diagonal stiffeners was numerically studied. A three dimensional (3D) finite element model with diagonal stiffener (WDS) is developed using ANYSIS-14 of castellated beam (IC 225) from parent I-beam(ISMB150) [4]. The dimensions of specimen are taken as specified in table 1.

T able -1: Details of Specimen WDS 225

Specimen detail	WDS 225
Length (m)	3.2
Thickness of flange t_f (mm)	7.5
Thickness of the web t_w (mm)	5
Breadth of the web b_w (mm)	80
Height of the web opening(mm)	150
Length of stiffener (mm)	190
Width of stiffener (mm)	15
Thickness of Stiffener (mm)	5

The load vs deflection is obtained as in table 2. The ultimate load within elastic range is 80KN. As the maximum allowable Deflection = L/325 = 3200/325 = 9.84mm

Table -2: Comparison of Load Vs Deflection of WDS 225

Sl. No	LOAD (KN)	DEFLECTION (mm)
1	10	0.96
2	20	1.93
3	30	2.89
4	40	3.85
5	50	4.82
6	60	5.78
7	70	6.74
8	80	7.70
9	90	8.67
10	100	9.63

Various finite element models are developed and obtained values of deflection, flexure, shear stress and von mises stress. Stress concentration of the beam is studied.

The steel is modelled as linear elastic and isotropic material with the Young's modulus, E = 2e+11 Pa, the Poisson's ratio υ = 0.3, Density of Steel = 7830 kg/m^3 and the shear modulus G = 7.6923e +10 Pa.

Castellated beam (IC 225) obtained from standard I-Section beam(ISMB150). The beam span is 3.2m. Provided with seven number of hexagonal castellation along its web. The clearances of end castellations are 587.5mm one either side longitudinally. And the spacing between the castellations are 75mm each. The angle of hexagonal cuts are 45 degrees with the horizontal. Two concentrated loads are applied vertical at a distance of 1000mm apart. The castellated beam is simply supported and two-point loading is applied through bearing plates. The simple supports are given as one end fixed and other end displacement support.

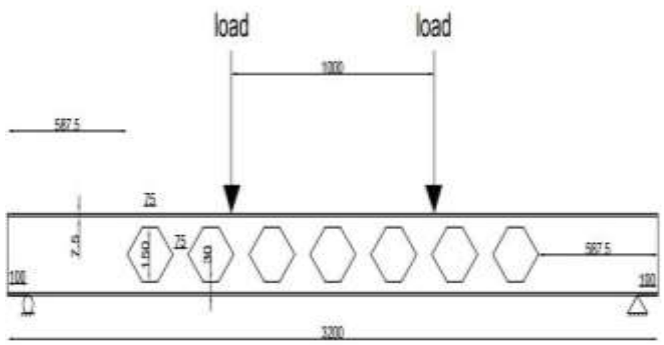
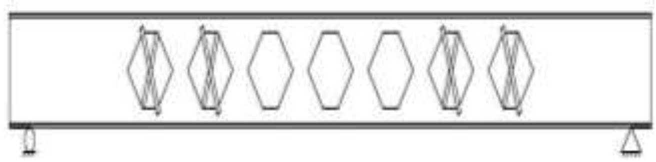


Fig -2: Dimensions of castellated beam(IC225)

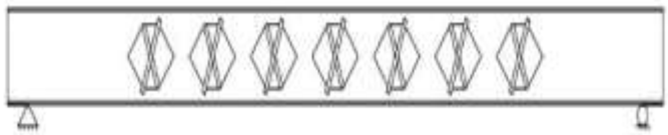
Taken two cases for study

Case 1: with diagonal stiffeners along shear zone only

Case 2: with diagonal stiffeners throughout castellation



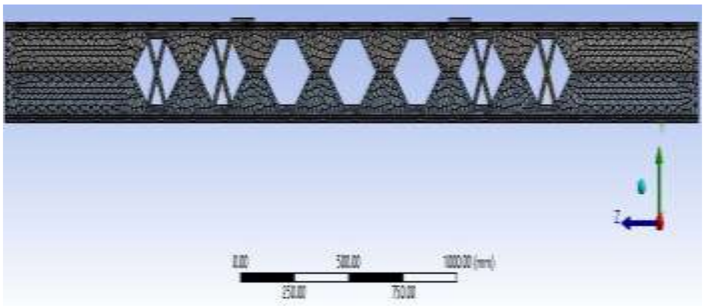
(a)



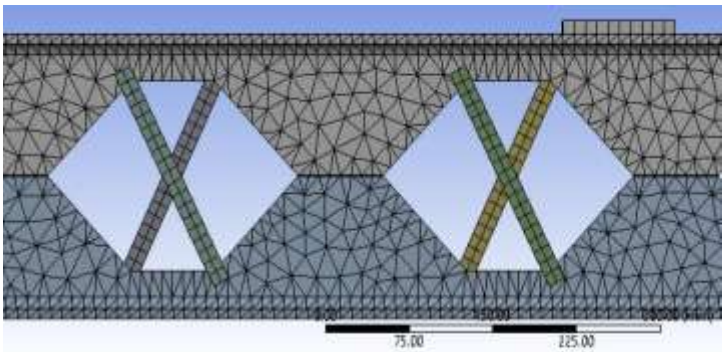
(b)

Fig -3: Two cases studied (a) Case 1: IC225 with diagonal stiffeners along shear zone only (b)Case 2: IC225 with diagonal stiffeners throughout castellation

Length of stiffener (mm), width of stiffener (mm) and thickness of Stiffener (mm) are 190mm,15mm and 5mm respectively.



(a)



(b)

Fig -4: Model of castellated beam developed in ANSYS and the meshing applied (a) on entire beam (b)zoomed view

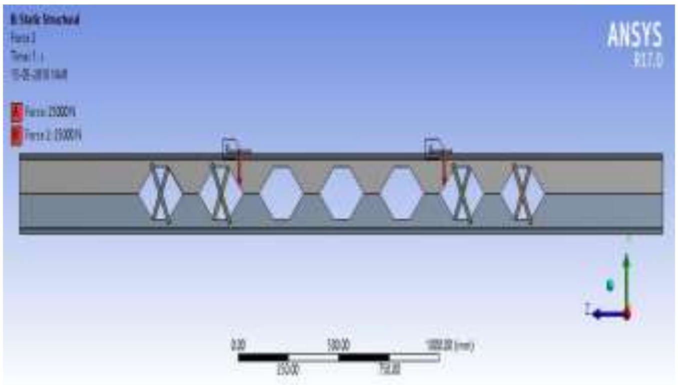


Fig -5: Application of two-point loading

3. RESULTS AND DISCUSSION

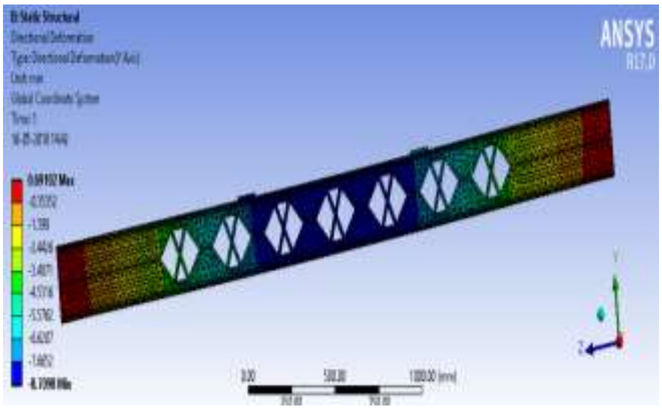


Fig -6: Deflection of castellated beam with stiffeners throughout castellation.

Table -3: Values of deflection, flexure, shear stress and von mises stress for IC225 with stiffeners along shear zone only.

LOAD (KN)	DEFORMATION (mm)	SHEAR STRESS (N/mm^2)	EQUIVALENT STRESS (N/mm^2)	MAXI. PRINCIPAL STRESS(N/mm^2)
10	0.94	13.424	19.146	19.274
20	1.881	31.244	39.105	39.203
30	2.821	45.31	58.709	58.57
40	3.762	60.989	78.138	77.895
50	4.902	76.515	97.529	97.754
60	5.664	94.852	117.23	116.921
70	6.583	110.82	136.12	136.85
80	7.524	125.92	156.41	156.9
90	8.464	143.08	174.65	176.23
100	9.404	157.23	195.41	195.95

T able -4: Values of deflection, flexure, shear stress and von mises stress for IC225 with stiffeners throughout castellations.

LOAD (KN)	DEFORMATION (mm)	SHEAR STRESS (N/mm^2)	EQUIVALENT STRESS (N/mm^2)	MAXI. PRINCIPAL STRESS(N/mm^2)
10	0.871	15.929	19.659	19.798
20	1.742	33.864	39.289	39.569
30	2.6129	47.797	59.028	59.276
40	3.4839	63.17	78.644	79.286
50	4.611	78.9	98.361	98.889
60	5.446	95.627	118.15	118.56
70	6.381	111.49	138.01	138.42
80	6.9678	127.46	158.19	158.77
90	7.8388	145.42	177.2	178.89
100	8.7098	159.23	197.45	197.98

The charts comparing the values of deflection, flexure, shear stress and von mises stress for IC225 with stiffeners along shear zone and throughout castellations are represented in charts 1,2,3 and 4.

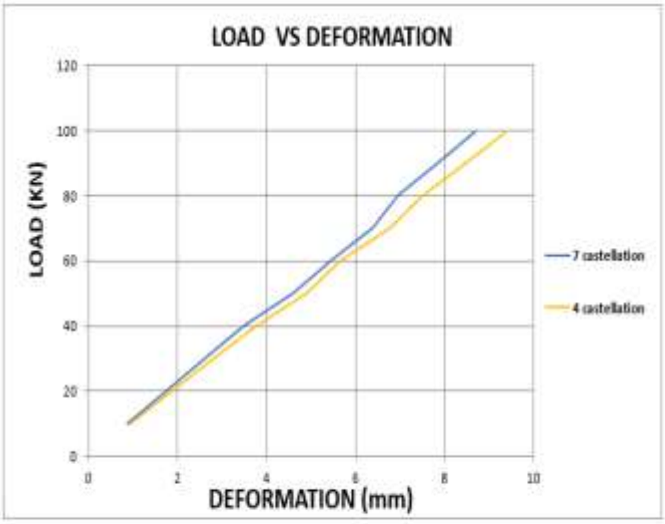


Chart -1: Load vs deflection

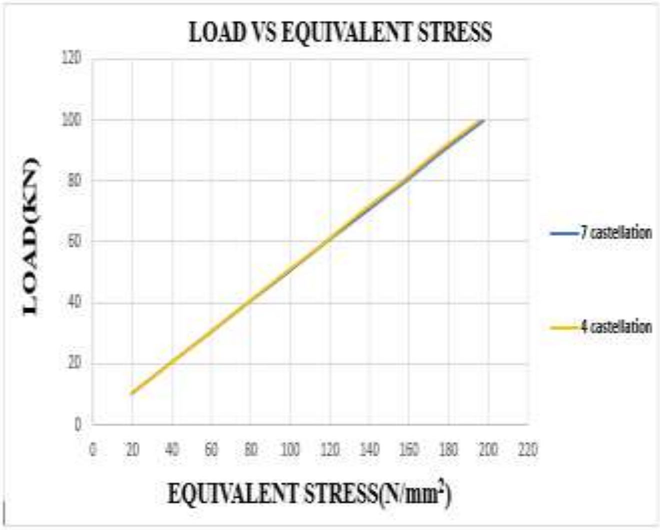


Chart -2: Load vs equivalent stress

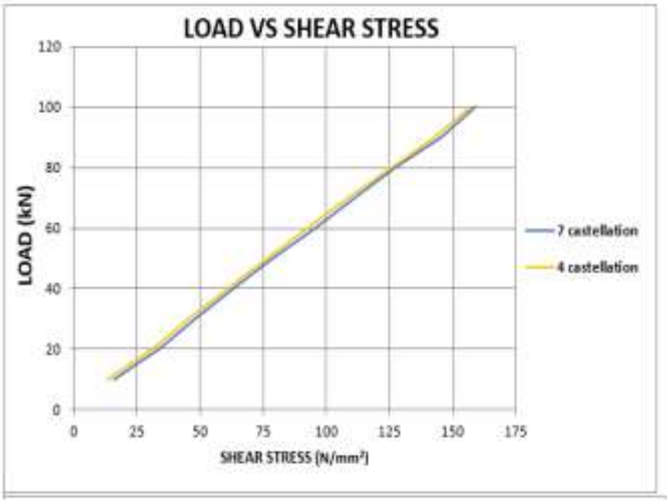


Chart -3: Load vs shear stress

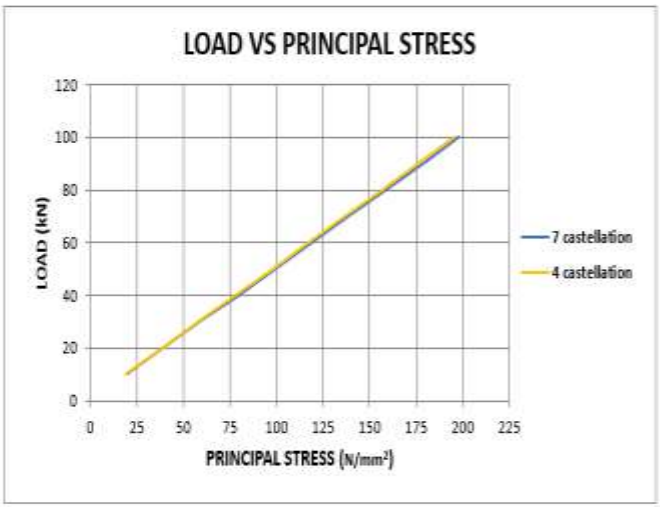


Chart -4: Load vs principal stress

The load vs deflection values obtained for stiffeners throughout castellation are is less compared to stiffeners provided along shear zone alone.

The load vs shear stress values obtained for throughout castellation are is more compared to stiffeners provided along shear zone alone.

The load vs equivalent stress and load vs maxi. principal stress values obtained for stiffeners along shear zone and stiffeners throughout castellation are almost similar, this implies that providing diagonal stiffeners along flexure zone don't have a notable impact on flexural strength properties of the beam.

4. FUTURE SCOPES

Some area for future study includes following points:

1. Finite element modelling of castellated beam can be done for studying the optimum size of the stiffener which can be provided along the castellation to reduce shear and flexure of the beam.

2. Parametric studies like stiffeners provided along the flexure zone alone can be studied.

5. CONCLUSIONS

Castellated beams are good structural members for construction provided their failures are taken care of. By providing stiffeners with optimum number and dimension, and at correct positions, the castellated beam can replace solid beams of same specifications. The load vs deflection values obtained for stiffeners throughout castellation are is less compared to stiffeners provided along shear zone alone.

The load vs shear stress values obtained for throughout castellation are is more compared to stiffeners provided along shear zone alone. The load vs equivalent stress and load vs maxi. principal stress values obtained for stiffeners along shear zone and stiffeners throughout castellation are almost similar, this implies that providing diagonal stiffeners along flexure zone don't have a notable impact on flexural strength properties of the beam.

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