Design Evaluation of Castellated Beam for Various Parameters-Review

Amarjeet Kumar[1] Jayanta Chakraborty[2]
[1]PG Student [2]M.Tech
[1,2]Department of Structure Engineering
[1]RKDF Institute of Science & Technology, Bhopal, Sarvepalli Radhakrishnan University, India
[2]RKDFIST, SRKU, AGM-Construction, TCL, India

Abstract— Castellated Beams made from steel I Sections are being broadly used in structural applications because it has high moment of inertia and high strength to weight ratio. This paper is reviewing related with the evaluation of castellated beam with solid beam, also carried out for same loading and geometric condition. Parametric study is done by shifting various parameters of castellated beam like shape of opening, welded length, ratio of depth of opening to total depth and angle of cut. This paper is intended to provide comparing castellated beam with solid beam.

Keywords: Castellated beam, Flexure mechanism, Lateral torsional buckling, Vierendeel mechanism, Stiffener

I. INTRODUCTION

Since Second World War structural designer have discovered numerous ways of reducing the cost of steel structures. But have frequently been prohibited from utilizing the high strength property of structural steel by building code requirements on maximum allowable deflection to get best advantage. As a result numerous new methods have been developed to increase stiffness of steel member, without any increase in weight of steel required. Castellated beam is one of the best elucidations.

Castellated beams are I-beams or girders with notches cut from the center member. The notches whether they are square as in a castle, rectangular, circular, hexagonal or octagonal or any other shape reduce the weight of the beam without greatly reducing its strength. The result is a beam with a higher strength-to-weight ratio.

Figure 1: Castellated beam

II. METHOD OF ANALYSIS

Few different methods presently used are stated below:

A. *Elementary Bending Theory*

n this method, reduced web section is considered in calculating stress and deflection in beams. Results calculated by this method deviate appreciably from the actual value because of neglecting local bending in the T-section.

B. *VIERENDEEL ANALYSIS*

In this method, apart from considering longitudinal stresses due to bending, stresses' arising in the T-section due to local bending from shear force is also considered.

C. *Frame Analysis*

In this method, beam is treated as rigid frame with members of variable moment of inertia between joints. Flexibility approach by this method was carried out by Sherbourne. A stiffness approach was carried out by Srimani and Das where the deflection results were quite encouraging.

D. *Finite Difference Method*

This method is used for finding elasticity solution. For bending and shear loading where there was a good agreement between the theoretical and experimental results.

E. *Finite Element Technique*

In this method, treating castellated beam as a plane stress problem was analyzed by Srimani and Das, where a combination of rectangular and triangular elements covering the web and axially loaded bar elements replacing the flanges were considered.

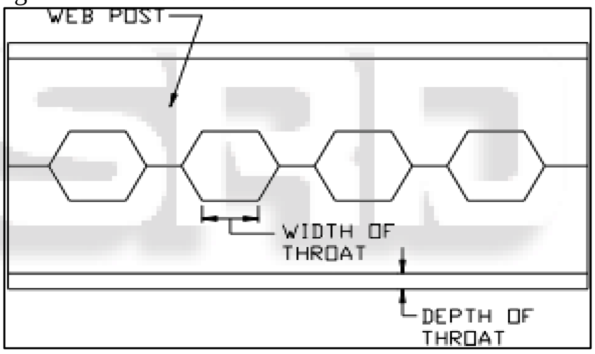
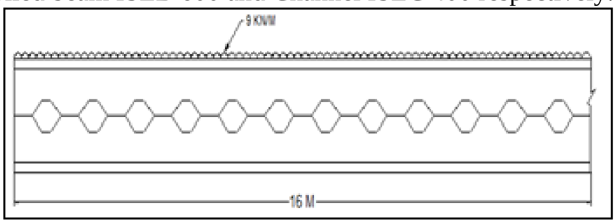


Fig. 2:

III. METHODOLOGY

A typical castellated beam along with its two sections in solid and open panel is shown in figure 3. The figure also describes the different parameters of the section. Castellated beams made from 48 Indian Standard rolled beams and 27 Indian Standard Channel Section have been considered for properties calculations. These sections are designated, for example, like CLB 600 and CLC 400 corresponding to rolled beam ISLB 600 and Channel ISLC 400 respectively.



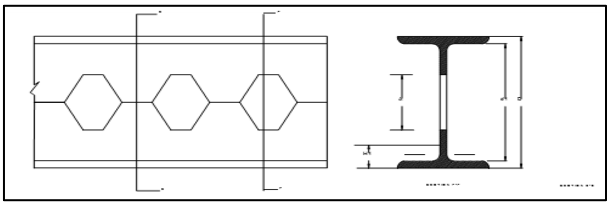


Fig. 3: Sectional properties

W=Unit weight of beam section.
H1=CG distance of T-section from extreme fiber of flange.
Ig=Gross moment of inertia of a castellated beam.
IN =Net moment of inertia of a castellated beam.
IT=Moment of inertia of T-section.
ZXX=Net section modulus of castellated beam.
A=Depth of hole of castellated beam.

IV. COMPARISON OF CASTELLED BEAM

Design a laterally restrained castellated beam for a span of 16 m to support a uniformly distributed load 9 KN/M Assume angle of cut 60 degree. In this comparison, castellated beam and Solid steel beam having same span and load is designed as per IS-800- 2007 and Minimum Requirement of Section is found out for different loading conditions.

No	Loading condition	Minimum Requirement of Section	
		Castellated Beam	Solid Beam
1	UDL	CMB-450	ISWB-550
2	UDL with one point load	CMB-450	ISLB-600
3	UDL with two point load	CMB-450	ISMB-600
4	UDL with three point load	CWB-450	ISMB-600

Table 1: Distinguish between castellated beam & solid beam for minimum requirement of section

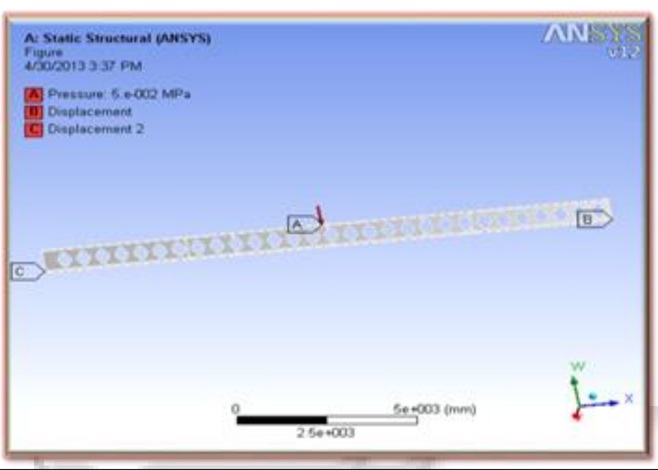


Fig. 4: Hexagonal Opening

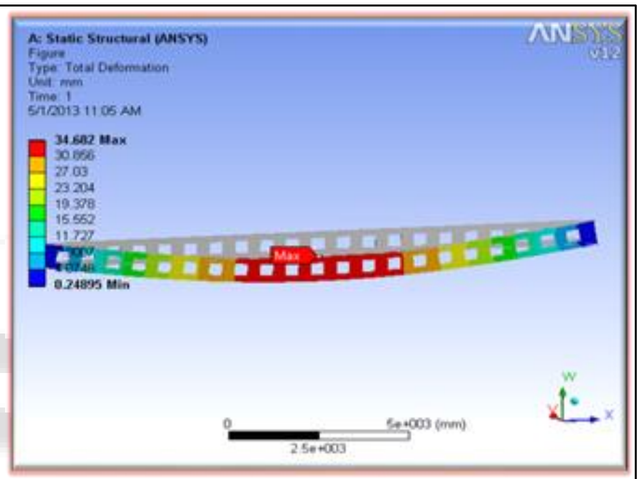


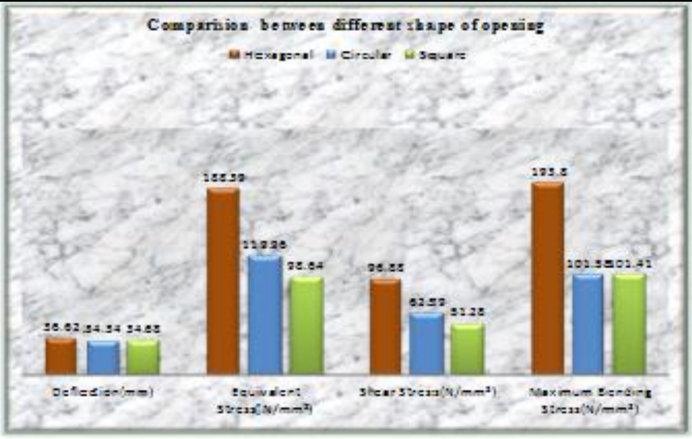
Fig. 5: Square Opening

A. *Different shapes openings:*

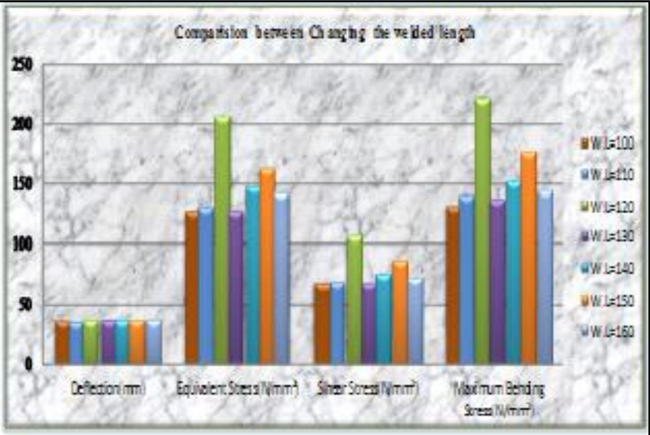
In this evaluation is carried out between deflection, Equivalent Stress, Maximum Shear Stress and Maximum Bending Stress for different shapes openings. Refer table 3 and graph1.

Sr. No.	Description	Hexagonal	Circular	Square
1	Deflection	36.62mm	34.34 mm	34.68mm
2	Equivalent Stress	188.39 MPA	119.96 MPA	98.64MPA
3	Maximum Shear Stress	96.88 MPA	62.39 MPA	51.28 MPA
4	Maximum Bending stress	193.8 MPA	101.58MPA	108.41MPA

Table: 3



Graph 1: Comparison between different shapes of opening (square, circular & hexagonal)



Graph 2: Comparison between different shapes of opening welded length.

B. *Different Welded length*

In this comparison is carried out between deflection, Equivalent Stress, Maximum Shear Stress and Maximum Bending Stress for different Welded length. Refer table 4 and graph2.

Description	W.L = 100	W.L = 110	W.L = 120	W.L = 130	W.L = 140	W.L = 150	W.L= 160
Deflection, mm	36.62	36.45	36.54	36.57	36.42	36.45	36.38
Equivalent Stress, N/mm²	127.45	130.91	206.85	127.44	147.58	163.31	142.19
Maximum Shear Stress, N/mm²	67.38	68.93	106.56	66.99	74.08	85.80	71.45
Maximum Bending Stress, N/mm²	132.77	141.07	221.36	137.3	151.85	177.57	144.39

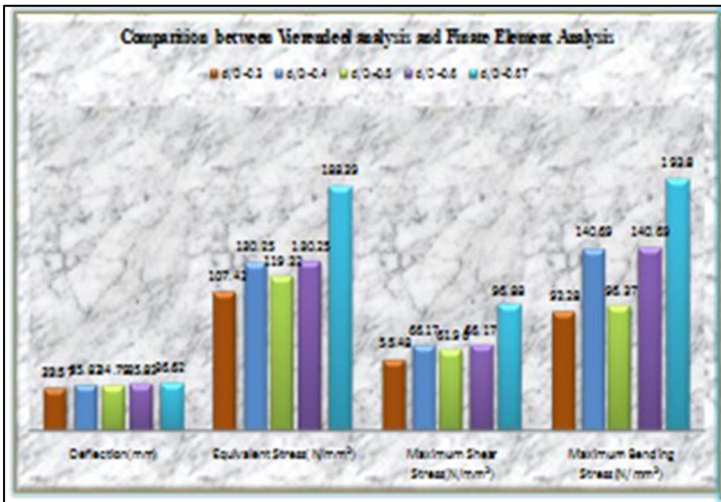
Table 4: comparison between different Welded lengths

C.

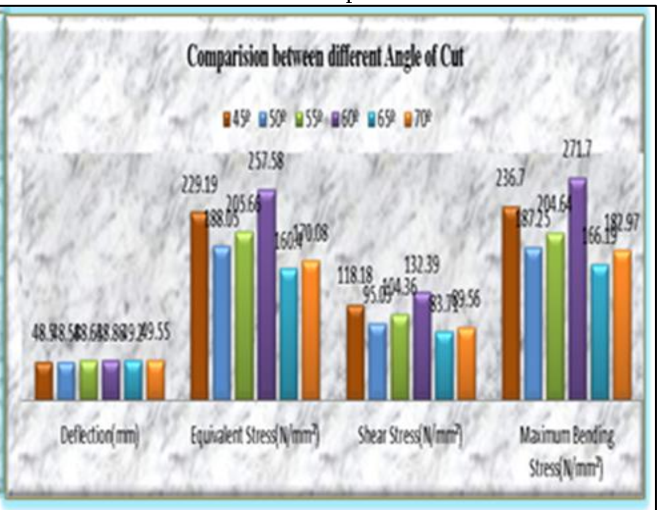
In this comparison is carried out between deflection, Equivalent Stress, Maximum Shear Stress and Maximum Bending Stress for different Ratio of depth of opening to total depth. Refer table 5 and graph3.

Sr. No	Description	d/D=0.3	d/D=0.4	d/D=0.5	d/D=0.6	d/D=0.67
1	Deflection, mm	33.57	35.82	34.79	35.82	36.62
2	Equivalent Stress, N/mm²	107.42	130.25	119.22	130.25	188.39
3	Maximum Shear Stress, N/mm²	55.48	66.17	61.96	66.17	96.88
4	Maximum Bending Stress, N/mm²	92.28	140.69	96.37	140.69	193.80

Table 5: comparison for different Ratio of depth of opening to total depth



Graph 3: Comparison for different Ratio of depth of opening to total depth



Graph 4: Comparison for different angle & Cut by Changing Angle of Cut:

D.

In this evolution is carried out between deflection, Equivalent Stress, Maximum Shear Stress and Maximum Bending Stress by Changing Angle of Cut. Refer table 6 and graph4.

Sr. No	Description	45º	50º	55º	60º	65º	70º
1	Deflection, mm	48.50	48.58	48.63	48.86	49.20	49.55
2	Equivalent Stress, N/mm²	229.19	188.05	205.66	257.58	160.40	170.08
3	Maximum Shear Stress, N/mm²	118.18	95.03	104.36	132.39	83.71	89.56
4	Maximum Bending Stress, N/mm²	236.7	187.25	204.64	271.70	166.19	182.97

Table 6: comparison between different Angle of Cut

V. Result & Discussion

In this paper, analysis of castellated beam is done by changing various parameters like welded length, ratio of depth of opening to the depth of beam, angle of cut etc. By changing welded length it is seen that maximum stresses occur at a length of 0.25 times the depth of hole and stresses are less at a length of 0.33 times the depth of hole.

By changing ratio of depth of opening to the depth of beam, it is seen that as ratio increases stresses are also increases. In most of castellated beam 45 or 60 degree angle of cut is provided. By changing different angle of cut it is seen that maximum stresses occur at 60 degree angle of cut and minimum stresses occur at 65 degree angle of cut.

It is seen that value of deflection is not depend on different parameters of hole. Different parameters of hole are affecting to stresses only.

VI. Conclusion

By reviewing the above papers, it can be concluded that castellated beam with solid beam it is concluded that solid beam required higher section than castellated beam for same loading and geometric condition. It is also found that higher section required in solid beam is due to the deflection only, because solid beam is safe in all checks like shear, bending, web buckling and web crippling but it is not safe in deflection. To minimize the deflection in solid beam higher section is required.

By changing shape of opening in castellated beam (i.e. Hexagonal, Square, Circular), it is concluded that there is no effect of shape of opening on deflection but shape of opening effect on stress concentration. Maximum stress concentration occur in Hexagonal shape of opening.

By changing welded length of castellated beam, it is concluded that there is no effect of welded length on deflection. Welded length depends upon depth of hole of castellated beam. Generally it is 0.25 times the depth of hole or 0.33 times the depth of hole is provided. It is also concluded that maximum stresses occur at a length of 0.25 times the depth of hole and stresses are less at a length of 0.33 times the depth of hole.

By changing ratio of depth of opening to total depth, it is concluded that as ratio increases stresses are also increases. Maximum stresses occur at ratio 0.67 and minimum at 0.3.

By changing angle of cut in castellated beam, it is concluded that there is no effect of angle of cut in castellated beam but it effects on stresses. Generally 45 degree is minimum angle of cut and 70 degree is maximum angle of cut can be provided. In most of castellated beam 45 or 60 degree angle of cut is provided. By changing different angle of cut it is concluded that maximum stresses occur at 60 degree angle of cut and minimum stresses occur at 65 degree angle of cut.

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