Experimental Study on Castellated Beam to Enhance the Shear Strength

Raj Kumar T N[1]
M.E. Structural: Department of Civil Engineering
SONA College of technology,
Salem- 636 005, India.

Dr. K. Jagadeesan[2]
Dean PG: Department of Civil Engineering
SONA College of technology,
Salem- 636 005, India.

***Abstract*-The principle advantage of the castellated beam is that you can increase the depth of a beam to increase its strength, without increasing its weight. So when it comes to maximizing load bearing capacity, the castellated beam is highly steel efficient. In this paper a steel section is selected, castellated beams are fabricated with increase in depth of web openings. Testing is carried out on beam with two point load and simply supported condition. The deflection at center of beam and various failure patterns are studied. Shear carrying capacity is reduced in the castellated beam due to perforations at center. The shear carrying capacity can be increased by stiffening the web. Hence to increase the shear strength of the castellated beam and also to reduce the deflection, shear stiffeners are introduced along the web opening.**

Keywords— Key words: Castellated beam,load bearing capcity, shear strength, stiffeners.

1 INTRODUCTION

The primary advantage of castellated beams is the improved strength due to the increased depth of the section without any additional weight. Beam length is a core advantage of the castellated beam. Through castellation, you can increase the length of the beam to create wide-span and wide-open bay designs. The castellated beam is an elegantly simple approach, from design to erection. The design uses steel efficiently to achieve long spans. You can specify either hexagonal or cellular openings with built-in connections for faster and easier erection. In addition, mechanical, electrical and plumbing runs are easily integrated, which is not feasible using a solid wide flange beam. Erection time is often faster.
The primary advantage of this new section is the increased depth of the beam without increasing its weight. In some instances, the depth is increased as much as 50%. By increasing the depth of the beam, strong axis bending strength and stiffness are improved as the strong axis moment of inertia and section modulus are increased.
The Castellated beams are prepared from rolled steel I sections. The web of I beam is cut in zigzag pattern along the Centerline in desired opening shape by flame cutting, then re-joining the two halves on one another by means of welding. The process of Castellation is illustrated in Figure 1.

The castellated beam has different type of modes of failure due to geometry, web slenderness, hole opening, type of loading and provision of lateral supports.

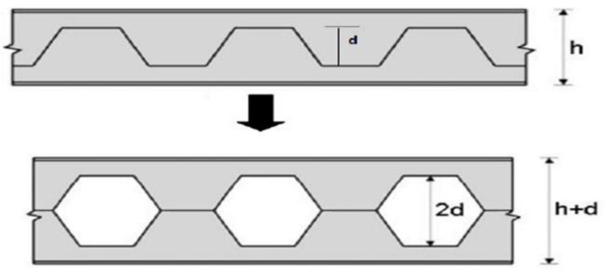


Figure 1 castellation of steel beam

2 DESIGN OF CASTELLATION

Castellated beam is designed for a span length of 1.61 meter simply supported at both the ends with a two point load. ISMB 200 is selected and depth of the beam is increased 1.5 times the original depth as IC 300 with an angle cut of 56^0.

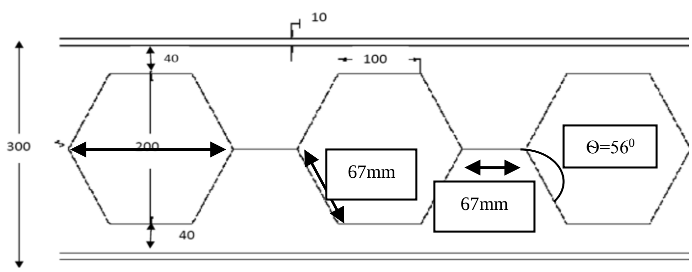


Figure 2 specifications of castellated beam

Castellated beam is designed and the beam is checked for shear, buckling, flexure, vierendeel analysis and the design methods are consistent with BS 5950-1 2000 Steel Work part 1 and 3.

3 FABRICATION OF CASTELLATED BEAM

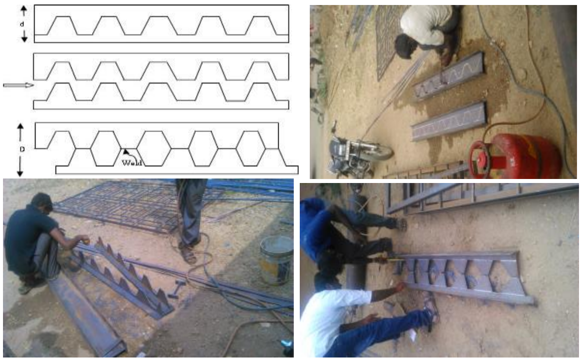
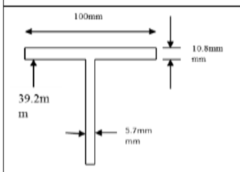
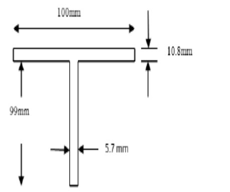
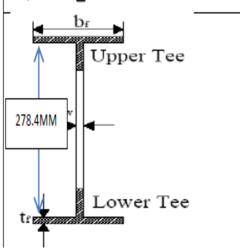


Figure 3 shows the flame cutting, two half pieces, arrangement of zigzag pattern.

Figure 4 shows the fabricated castellated beam IC 300 from the ISMB 200 hot rolled steel.

4 THEORETICAL ANALYSIS

The theoretical calculation involves the determination of moment of inertia, shear and permissible deflection of IC300 (figure 4).

SECTION	AREA	$\bar{y}$	I_x
	Area of flange = 100X 10.8 =1080 mm² Area of web = 39.2 X 5.7 =223.44mm² Total AREA =1303.44 mm²	$\bar{y}$ = 40.21mm	I_x=30.936*10⁴mm⁴
	Area of flange = 100*10.8=1080mm² Area of web = 99.4*5.7=566.58mm² Total AREA =1646.58mm²	$\bar{y}$ = 85.84mm	I_x=320.93*10⁴mm⁴
	Tee section areas = upper tee + lower tee = 1080+1080 = 2160mm² Web area = 278.4*5.7=1586.8mm²	$\bar{y}$ = 150mm	I_x= 5543*10⁴mm⁴

Average moment of inertia = $1964*10^4 mm^4$
From bending theory M/I =F/y
M= 22kN.m (where F=165N/mm² y = 150mm)

Permissible load

Let W be the load that can be applied over the section.
W=3M/L (2pt load)
= $(3*22*10^6)/1610$
= 40.99 kN
So total load is 82kN (taken as 80kN)

Check for Shear,

Maximum end shear = P = 80 kN
Average Shear Stress

$$\tau_{va} = \frac{P}{d^I t} = \frac{80X\,10^3}{78.4\,X\,10.8}$$

=94.48N/mm²
94.48< 0.40 f_y (100 N/mm²)

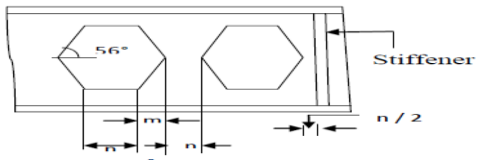
Check for Deflection,

$$\delta_1 = \frac{23\,PL^3}{648\,EI} = \frac{23\,X\,(80)X\,10^3\,X\,(1.61\,X\,10^3)^3}{648\,X\,2\,X\,10^5\,X\,19.64 * 10^6}$$

$$\delta_1 = 3.02\ mm$$

Shear at ends =80 kN,
Shear at Centre = 0,
Average Shear = (80+0)/2=40kN
From figure 4 the dimensions will be *p*= 3, *m*=75mm, *n*= 75 mm, $I_{t=}$ $30.936*10^4 mm^4$(only t section 1)
Where,

P = Number of perforation panels in half span
m, n = Distance as shown in fig 2.3
I_T = Moment of Inertia of T - Section



$$\delta_2 = v_{avg}\,X\,p(m+n)^3/24E\,I_T$$

$$\delta_2 = 0.1\ mm$$

$$\delta_1 + \delta_2 = 3.12mm$$

$$\delta_{all} = l/325$$

= 1610 / 325 = 4.95 mm > 3.12mm
Deflections are within the permissible limits.
Moment resistance of Tee section

$M_R = \sigma_{st}\,A\,L$

= 150*(1080*223.44)*(300-(2*9.79))
= 54.826kN.m

5 NUMERICAL STUDIES

Finite element analysis is used to determine the failure modes of castellated beam. The castellated beams (IC 300) are analyzed with different loadings and with and without diagonal and vertical stiffeners.

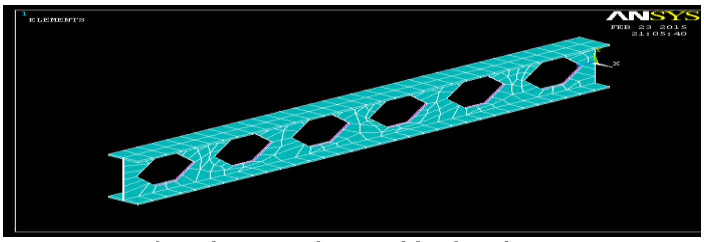


Figure 5 shows the IC WOS beam model with meshing size 50

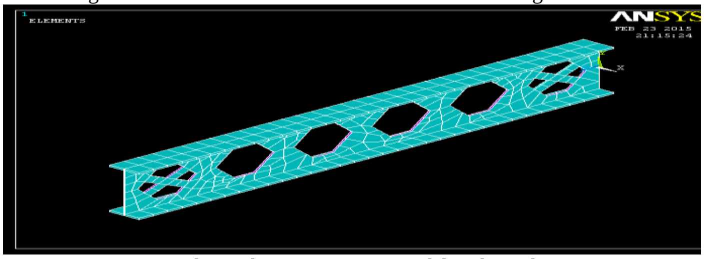


Figure 6 shows the IC 300-WDS model with meshing

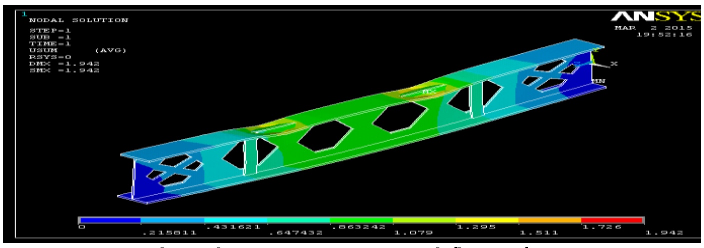


Figure 7 shows the IC 300-WDS& WVS deflection for 40KN

The following table shows the castellated beam deflection for different loading:

BEAM	LOAD(KN)	DEFLECTION(mm)
IC 300-WOS	40	2.354
	70	4.487
IC 300-WDS	40	2.136
	70	3.698
IC 300-WDS&WVS	40	1.942
	70	2.542

6 EXPERIMENTAL STUDIES

Experimental investigation is carried out in the castellated beam without stiffeners (IC300WOS), castellated beam with diagonal stiffeners and vertical stiffeners (IC300WDS&WVST). The test is carried out by applying two point loads and deflection of beam is studied and different failure modes are analysed.

Figure 8 shows the loading arrangement of IC300 WOS

FIGURE 9 shows the web buckling of IC300 WOS

Figure 10 shows the loading arrangement of IC WDS&WVS

FIGURE 11 shows the web buckling of IC300 WDS&WVS

The following table shows the deflection of IC WOS:

S.NO	LOAD(KN)	DEFLECTION(mm)
1	5	0.42
2	10	0.70
3	15	0.95
4	20	1.20
5	25	1.47
6	30	1.65
7	35	1.90
8	40	2.10
9	45	2.50
10	50	3.10
11	60	3.60
12	70	4.20

Shear stress of IC WOS

$$\tau_{va} = \frac{P}{d^I t}$$

= $(70*10^3)$/ 78.4*10.8
= 82.67N/mm^2

Where,
P= end reaction in N, d'= depth of the stem of T – section,
t = thickness of the stem.

The following table shows the deflection of IC WDS &WVS

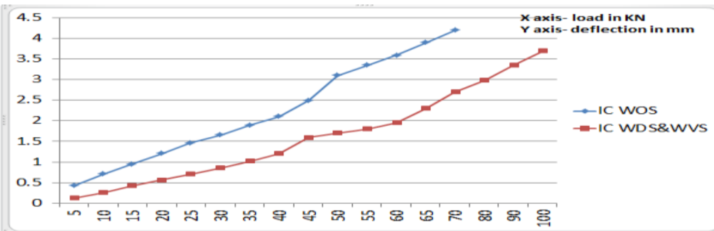
S.NO	LOAD(KN)	DEFLECTION(mm)
1	5	0.12
2	10	0.26
3	15	0.42
4	20	0.56
5	25	0.7
6	30	0.85
7	35	1.02
8	40	1.2
9	45	1.6
10	50	1.7
11	55	1.8
12	60	1.95
13	65	2.3
14	70	2.7
15	80	2.9
16	90	3.6
17	100	4.1

Shear stress of IC WDS&WVS

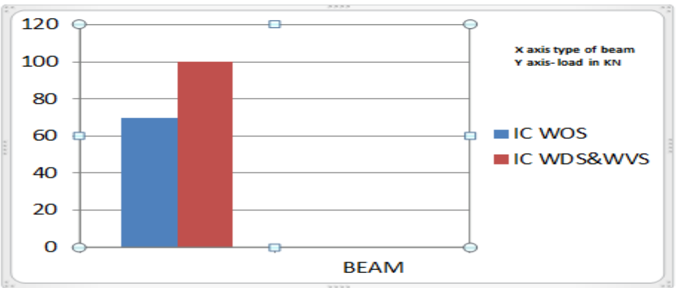
$$\tau_{va} = \frac{P}{d^I t}$$

= $(100*10^3)/ 78.4*10.8$
= $118.7 N/mm^2$

Where,
P= end reaction in N, d'= depth of the stem of T – section,
t = thickness of the stem.



Graph 1 shows graph for the load vs deflection of IC 300 of Castellated beam with and without stiffeners.



Graph 2 shows the comparison of load bearing capcity of beams.

From the above graphs the ultimate load bearing capacity is increased and deflection is reduced for IC WDS&WVS when compared to IC WOS.

7 CONCLUSIONS

1. The depth of the ISMB 200 is increased to IC 300 without adding the additional steel.
2. The shear strength is improved from 82.67 to $118.7 N/mm^2$ by providing the stiffeners along the hole.
3. It was observed that IC without stiffeners the deflection is more, when stiffeners are provided diagonally and vertically on the web opening along the shear zone deflection is reduced.
4. It was observed that IC without stiffeners the load is 70KN, when stiffeners are provided diagonally and vertically on the web opening along the shear zone load is increased to 100KN.
5. It is concluded that shear failure is more near the holes than the solid web, hence shear stiffeners provided on the opening of the web.
6. Castellated beams are well accepted for industrial buildings, power plant and multistory structures were generally loads are less and spans are more with its economy and satisfying serviceability criteria.
7. Castellated section with stiffeners hold good for aesthetic purpose, long span construction and cost effective purpose.

7 REFERENCES

[1] B.Anupriya & Dr.K.Jagadeesan, Strength Study on Castellated Beam. Vol. 2, Issue 12, Dec 2013, International Journal of Engineering Research & Technology ISSN: 2278- 0181
[2] Wakchaure M.R, Sagade A.V, Auti V.A, Parametric Study of Castellated Beam With Varying Depth of Web Opening. Vol. 2, Issue 8, August 2012, International Journal of Scientific & Research Publications ISSN 2250-3153
[3] Komal S. Bedi, Mr. P.D. Pachpor, Moment and Shear Analysis of Beam with Different Web Openings, 2012, Vol.1 Issue 4, pp. 1917 to 1921. International Journal of Engineering Research & Applications , ISSN: 2248-9622
[4] M.R.Wakchaure, A.V. Sagade Finite Element Analysis of Castellated Steel Beam Vol 2 Issue 1 / July 2012, International Journal of Engineering & Innovative Technology, ISSN: 2277-3754.
[5] N.K.Chhapkhane, Shashikant, R. Kamble, Analysis of Stress Distribution in Castellated Beam using Finite Element Method and Experimental Techniques, Vol.3 Issue 03, Aug-Sep 2012 International Journal of Mechanical Engineering Applications Research - ISSN: 2249- 6564.
[6] P.D. Pachpor, Sharda P. Siddh, Finite Element Analysis of Steel Beam with Web Opening of Different Shapes, Vol.1 Issue 5, July 2011 International Journal of Science and Advanced Technology, ISSN: 2221- 8386.
[7] Sabarish.J and Biju.V. 2011, Web Buckling of Castellated Beams Presented in National Conference.
[8] Sharada P. Siddh, prof.P.D.Pachpor, " Finite Element Analysis of Steel Beam With Web Opening of Different Shapes" Volume 1, No 5 July 2011, International Journal of Science and Advanced Technology ISSN 2221-8386.
[9] H.Showkati, "Lateral – Torsional Buckling of Castellated Beams", Vol.32, No.B2, PP153-156, Iranian Journal of Science & Technology, Transaction B, Engineering. 2008.
[10] J.P.Boyer, "Castellated Beams – New Developments" presented at the AISC National Engineering Conference, Omaha, nebr, in May, 1964.
[11] Codes Referred: IS 800 – 2007 and Hand Book for the Design of Castellated Beams - Oxford Publications.