ISSN 2395-1621

A numerical study of Structural Behavior of Castellated Beam with & without Stiffeners

[#1]Pooja P. Rugge, [#2]Pallavi K. Pasnur

[#1]M.E student, Department of Civil Engineering,
Pune University, ICOER, Wagholi, Pune, Maharashtra, India.

[#2]Assistant Professor, Department of Civil Engineering,
Pune University, ICOER, Wagholi, Pune, Maharashtra, India.

ABSTRACT

Use of castellated beam is become very popular now a day due to its advantageous structural applications. Castellated beams are those beams which are fabricated by cutting in its web of hot rolled steel (HRS) I section into zigzag pattern & thereafter re-joining it over another. The openings made in the webs are of generally hexagonal, circular, diamond or square in shape. Therefore considering structural performance of the beam, the size & shape of openings provided in the web are always an important issue of concern. In this due to increase in depth of the beam the load carrying capacity of the parent I section is increased with same quantity of material. The increase in depth of castellated beam leads to web post buckling & lateral torsional buckling when these beams are subjected to loading. There are many other modes of failure like formation mechanism, lateral torsional buckling, & formation of vierendeel mechanism, rupture of the welded joint in a web post & shear buckling of web post which needs to take care of. Study shows that use of stiffeners in web portion of beams helps in minimizing these failures. This paper present an experimental & analytical study on behavior of the castellated beam with cellular & hexagonal shaped openings has been studied using the stiffeners. Two different types of stiffeners are provided that is stiffeners placed along the transvers direction & stiffeners placed along the edge of the openings. These two types of stiffeners are chosen in order to increase the strength & decrease the stress concentration near the web openings. In this paper we place stiffeners along the transvers direction of the opening. After performing experimental study, the beam is analyzed by the finite element method by using general finite element analysis software ANSYS & the results were compared with those obtained experimentally.

Keywords: Castellated beam, Hexagonal web opening, Circular web opening, finite element method, Stiffeners.

ARTICLE INFO

Article History

Received: 25th March 2017

Received in revised form :

25th March 2017

Accepted: 25th March 2017

Published online :

4th May 2017

I. INTRODUCTION

Castellated Beam is also known as perforated web. To increase the depth of sectionis main objective of perforated web so that the parametermoment of inertia will be increase. The use of Castellated beam has been founded in many years. In 1950s, Europe was the first country to use castellated beam due cheap labour cost. Castellated beam is a name commonly used for type of expanded beam. The main advantage of castellated beam is toenhance the strength due to enlarged depth of the section beyond any additional weight. This unique type of beam produced a mechanical behavior similarly as of isolated rectangular openings primlyrelated to the Vierendeel bending. In castellated beam to avoid local failure of beam provision of plate below concentrated load.In certain occasions the choice for castellated beams may not be so prominent. For example, when a beam is withstanding substantial concentrated loads or when the castellated beam is used as a continuous beam across different supports. In portals with solid knee junctions, load concentrations appear which are respectively undesirable for castellated beams. In these case castellated beams have to reinforced at the places where these load concentrations are present. For example, by implanting plates into one or more than one of the web openings. The extra fitting and welding work engaged in this is relatively valuable. After all, each plate desires six to eight welds; which on a beam with a length of, say, 12 teeth make the welding costs one and half times one two-thirds as high. The finest technical solution in that cases is to border the openings in question with welded-on raised edges. Horribly this is also the costliestsolution. One more minus point when very moderatedemands are set for fire hindrance, castellated beams could be less attractive since the fire resistant coating has to be around 20% thicker than for rolled sections in order to gain the same fire resistance.

Different types of castellated beams:

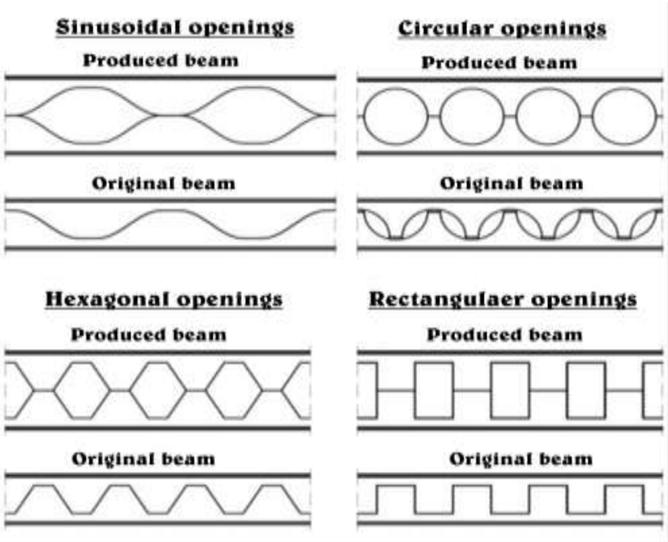

Figure 1: Different Types of castellated beam

Stiffeners

Stiffeners are those structural components which are used to strengthen shear & moment resistance of steel plates along the longitudinal & transvers or/and along the edge of opening, but if castellated beams are subjected to concentric loading in such beam prove to be inappropriate. In such cases castellated beams must reinforced at the places where these load concentrations occur.

The various types of stiffeners are used for I beam or Castellated beam are as listed below.

1. Intermediate transvers web stiffeners: Intermediate transvers stiffeners may be placed either at one side of web portion. The buckling strength of web can be increased due to these stiffeners.
2. Load carrying stiffeners: load carrying stiffeners are allowed when the load applied to the section is greater than that of the buckling of web can be avoided, which is caused because of intense loading.
3. Bearing stiffeners: bearing stiffeners are placed where the capacity of the web is less than that of the load applied on the flange portion. These stiffeners helps to minimize the local crushing which is caused because of the loads applied to the specimen.
4. Torsion stiffeners: Torsion stiffeners is provided in such manner that the tensile force can be simply transmitted through the web portion.
5. Diagonal stiffeners: diagonal stiffeners are provided in order to bear the shear applied which more than that of the web of the beam. The stiffeners provided have different strength that of the web of the beam.

II. METHODOLOGY

Following the design standards, the approach is decided to achieve objectives of the research. The analysis of the beam with circular and hexagonal shaped openings is carried out for different sizes and the optimized section is tested experimentally for the purpose of validation of the research.

Selection of Method of Analysis

In order to improve the dimension of the openings of the castellated beam, it is crucial to determine proper diagnostic method. Due to complicatedtrigonometry of castellated beam the finite element analysis (FEA) is the finest available method to analyze the beams. The FEA of the castellated beam under application is done by the simulation software namely ANSYS

Selection of Hot Rolled Section

Steel (HRS) I Beam and Span of the Beam Span of the parent HRS I beam was decided taking into account. the testing facilities available with the Universal Testing Machine (UTM) in the laboratory and also on the basis of section availability of the market. The parent HRS I beam section of 250mm depth was chosen due to the limitations on span (1800mm) and maximum loading capacity (1000kN) Loading Frame.

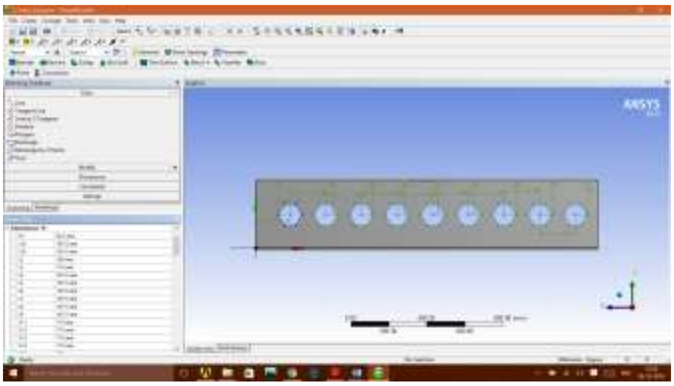

Figure 2: Model of Hexagonal Castellated Beam

Problem statement

Design a suitable 'I' beam for a simply supported span of 1.8 m and carrying a dead or permanent load of 20 kN/m and anconcentrated load of 40 kN/m. Assume full lateral restraint and stiff support bearing of 100 mm.

III. DESIGN LOAD CALCULATION

The following load factors are chosenin this example.

LDγ and LLγ are taken as 1.50 and 1.50 respectively.

γLD – partial safety factor for dead or permanent loads

γLL – partial safety factor for live or imposed loads
Total factored load = 1.50× 20 + 1.50 × 40.0 = 90 kN / m

Factored bending moment = 90 × 1.82 /8 = 36.45 kN – m
Z—value required for fy=250 MPa ;γm =1.10
Z_{reqd} = 168.39 cm 3
Try ISMB 250

D = 250 mm
B = 125 mm
t = 6.9 mm
T = 12.5 mm
I_{zz} = 5131.6 cm4
I_{yy}= 334.5 cm4

Section classification:
Flange criterion = B/2T = 5.0
Web criterion = (D – 2T)/t = 32.61
Since B/2T <9.4 ε & (D-2T)/t < 83.9 ε

The section is classified as ‘ PLASTIC
Moment of resistance of the cross section:
Since the section considered is ‘PLASTIC’
Md = mypfZγ×

Where Z_p is the plastic modulus
‘Z_p’ for ISMB 250 = 459.76 cm3
M_d = 459.76 × 1000 × 250 /1.10
= 104.49 kN-m > 36.45 kN-m

Hence ISMB-250 is fit in flexure.
Shear resistance of the cross section:
This check must be considered more basically in beams where the maximum bending moment and maximum shear force may produce at the same section simultaneously, such as the supports of continuous beams. For the present example this checking is not required. However for completeness this check is presented.
Shear capacity

A_v =250 × 6.9 = 1725 mm2
V_c = 0.6 × 250 × 1725 /1.10 =235.3kN
V = factored max shear = 36.45 × 3 / 2 =54.69 kN
V /V_c =54.69/235.3 = 0.24 < 0.6
Hence the effect of shear need not be considered in the moment capacity calculation.

Check for Web Buckling:
The slenderness ratio of the web = L_{eff}/r_y = 2.5 d/t =2.5 × 194.1/6.9
=70.33
The corresponding design compressive stress fc is found to be
f_c = 203 MPa (Design stress for web as fixed ended column)

Stiff bearing length = 100 mm
450 dispersion length n1 =187.5 mm

P_w = (100 + 187.5) × 6.9 × 203.0
= 315.16 kN
402.70 > 126 Hence web is safe against shear buckling
Check for web crippling at support
Root radius of ISMB 250 = 13 mm
Thickness of flange + root radius = 25.5 mm
Dispersion length (1:2.5) n2 = 2 x12.5 x 2.5 = 62.5 mm
P_{crip} = (100+62.5) × 6.9 × 250 / 1.15
= 245.63 kN> 126kN
Hence ISMB 250 has adequate web crippling resistance
Check for serviceability – Deflection:
=5 mm < L/200

Hence O.K

Finite element analysis of castellated beam

Finite element analysis of castellated beams is worked out in Ansys software to determine the maximum stress concentration near openings & structural behavior of beam under loading. FE models of hexagonal & circular beams are shown in figures.

Figure No 3: FE model of castellated bean in Ansys

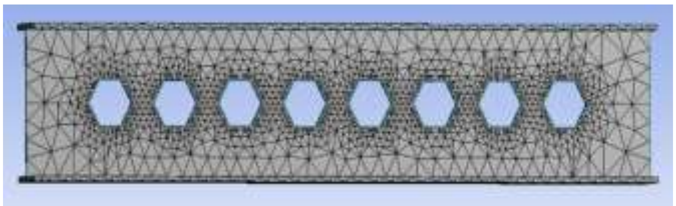

Figure No 4: Meshing of castellated beam

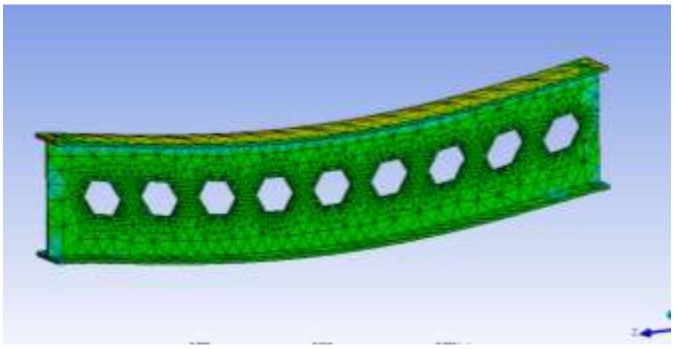

Figure No5: Variation in stresses of hexagonal beam

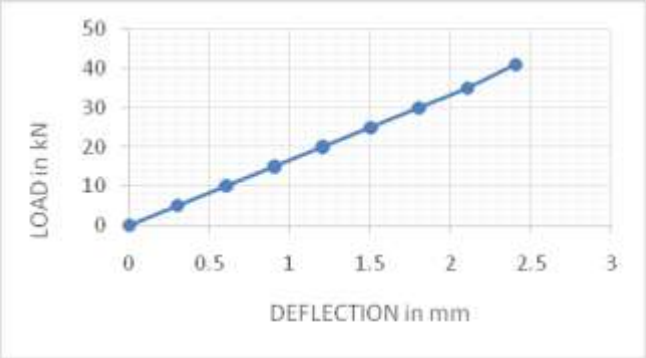

Chart-1: Load vs. Deflection curve for cellular shape openings.

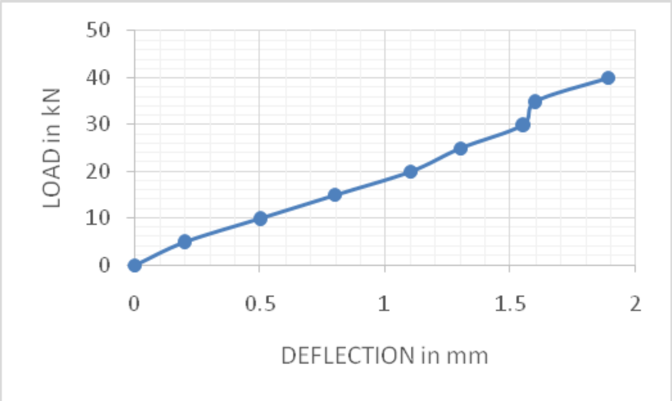

Chart-2: Load vs. Deflection curve for Hexagonal shape openings.

From above graphs, it is observed that beams with hexagonal opening takes the load of 40 KN causing the deflection of 1.6 mm&beam with circular shaped opening takes the load of 31 KN causing deflection of 2.5 mm. Therefore, from the analysis it is calculated that castellated beam with circular shaped opening is satisfy the strength requirement.

Comparative Results of Castellated Beam with hexagonal & circular shaped opening

Comparative results of castellated beam with hexagonal &circular shaped openings are given in Table-1 below.

Table-1: Failure load & deflection of Castellated beam along with their shape openings by Finite element analysis.

Sr.No	Type of castellated beam	Failure load in (KN)	Deflection (mm)
1	Hexagonal opening	40	1.6
2	Circular opening	42	2.5

From above table -1 it is concluded that castellated beam with circular shaped opening is more suitable with respect to hexagonal shaped openings.

IV. CONCLUSION

1 Castellated beam with circular shaped opening takes 42 KN load as the deflection is 2.5mm

2 Castellated beam with hexagonal shaped opening takes 40 KN load as the deflection is 1.6mm

3 Also as compare to circular beam the stress concentration in hexagonal beam near opening is more, so we have to prefer circular shape opening.

REFERENCES

[1] Peijun Wang, kangruiGuo, Mei Liu, Lulu Zhang “Shear buckling strengths of web-posts in a castellated steel beam with hexagonal web openings” - Journal of Constructional Steel Research 121 (2016)

[2] Delphine Sonck, Jan Belis “Weak-axis flexural buckling of cellular and castellated columns” Journal of Constructional Steel Research 124 (2016)

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

[4] Peijun Wang, Ning Ma, Xudong Wang “Numerical Studies on large deflection behaviors of restrained castellated steel beams in a fire”- Journal of Construction Steel Research 100 (2014)

[5] PeijunWang,Qijie Ma, Xudong Wang “Investigation on Vierendeel mechanism failure of castellated steel beams with fillet corner web openings”- Engineering Structures 74 (2014)

[6] S.Durif, A. Bouchair, O. Vassart“Experimental tests & numerical modelling of cellular beams with sinusoidal openings” Journal of Constructional Steel Research 82 (2013)

[7] FerhatErdal, Mehmet Polat Saka “Ultimate load carrying capacity of optimally designed steel cellular beams” – Journal of Constructional Steel Research 80 (2013)

[8] Hossein Showkati , TohidGhanbariGhazijahani , Amir Noori , TadehZirakian “Experiments on elastically braced castellated beams” - Journal of Constructional Steel Research 77 (2012) 163–172

[9] Ram Chandra, Design of Steel Structure, Volume II, Standard book house, Delhi.

[10] S.K. Duggal, Limit State Design of Steel Structure, Tata MeGraw Hill Education.

