

Comparative Study of Transverse Stiffeners and Stiffeners along the Opening Edge used for Castellated Beam

Siddheshwari A. Patil¹, Popat D Kumbhar²

PG Scholar, Department of Civil Engineering, RIT Rajaramnagar, Maharashtra, India¹

Associate Professor, Department of Civil Engineering, RIT Rajaramnagar, Maharashtra, India²

ABSTRACT: Castellated beams are fabricated by cutting I section in zigzag way and rejoining it in such a way that the depth of the parent I section is increased. In this paper the analysis of the castellated beam has been studied using the stiffeners. Two different types of stiffener that is stiffeners placed along the transverse direction (transverse stiffeners) and stiffeners placed along the edge of openings are used for the analysis. These two types of stiffeners are chosen in order to increase the strength and to decrease the stress concentration near the web openings. The comparative study of these stiffeners is done by using ABAQUS software. It is observed that the percentage steel used for the transverse stiffeners is very less compared to the stiffeners place along the edge of opening. But in spite of increase in steel percentage for the stiffeners along edge of opening, results are not satisfactory in respect of load carrying capacity. Therefore it is better to provide the transverse stiffener rather than the stiffeners along the edge of opening.

KEYWORDS: Castellated, beam, stiffeners, transverse, opening, analysis.

I. INTRODUCTION

Now-a-days the use of castellated beam is increasing due to its various properties like high-quality strength, economy, lower weight, aesthetic application, etc. Castellated beams are the beams having characteristically hexagonal or the octagonal opening in the web portion of the beam. The other types of the openings are also available, for e.g., circular, sinusoidal, square, diamond openings[1]. These beams are manufactured by making a cut in to the web portion of I section (parent section), and again these two halves are joined such that the depth of the parent I section is increased resulting in to the light weight structure with good structural as well as aesthetic properties [fig 1] [2]. There are also some limitations of castellated beam like reduction of stiffness due to provision of openings, increase in stress concentration near the opening, change in the stress distribution, etc. In order to overcome these disadvantages few researchers have suggested for providing the stiffeners in the web portion.

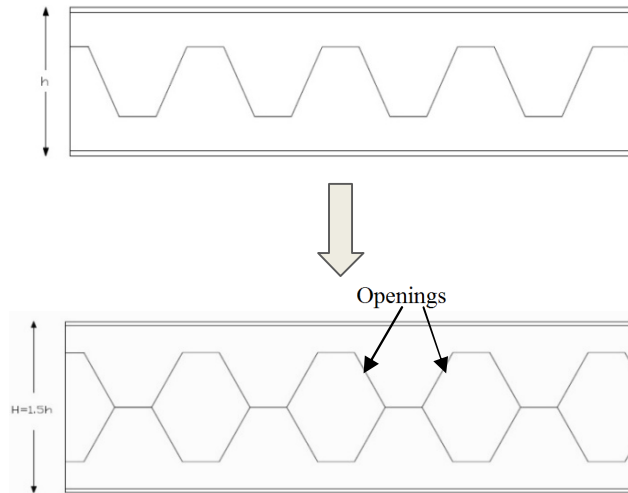


Fig-1: Fabrication of Castellated Beam

Stiffeners are usually provided along the length or normal to the length. There is no regulated knowledge about how stiffeners should be provided for castellated beam. But according to Euro code transverse stiffeners should be provided on both the side of the beam so that it would be symmetric about centreline of the web. Few authors have suggested providing the stiffeners along the edge of opening [3], in order to reduce the stress concentration near the openings. Figure below shows the representation of the castellated beam with transverse stiffeners and the stiffeners along the edge of opening

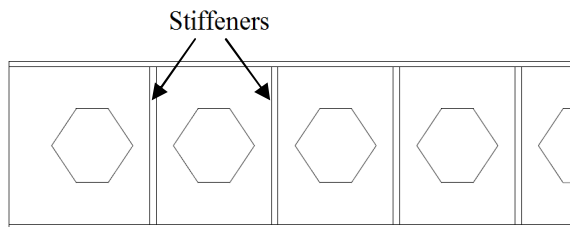


Fig-2: Castellated Beam with stiffeners in transverse direction.

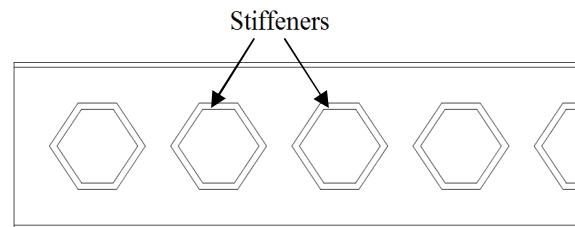


Fig-3: Castellated Beam provided with Stiffeners along edge of openings

The Finite Element Analysis (FEA) of these two types of stiffeners attached to castellated beam is carried out using ABAQUS. The amount of steel required for these both stiffeners are also calculated, in order to get the economy in section.

II. RELATED WORK

Hideo Takabatake, et.al., (1991) [7] the lateral buckling behaviour of the castellated beams provided with stiffeners were studied experimentally for which the beam was controlled against twisting. The batten plates also called as stiffeners were placed at different positions in transverse direction and the analysis was done. During the analysis it was observed that due the stiffeners the buckling of the castellated beam was delayed. Also it was observed that the stiffeners are effective only for particular S/D ratio. Also stiffener along the opening edge was suggested to provide to overcome stress concentration along opening edges of castellated beam.

Ehab Ellobody (2011) [9] the buckling mode analysis was done using ABAQUS software of castellated beam with hexagonal opening. Also the models were tested experimentally tested. The parameters considered were length of beam, cross-section areas and strength of steel total 96 models were tested analytically as well experimentally. It was was

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observed that the steel having good strength carried more load. Whereas for the higher strength of steel distortional buckling was observed and for the steel having normal strength lateral torsional buckling was observed.

Wakchaure M.R. et. al. (2012) [12] investigated the castellated beam with different depth of openings. Also the modes of failures were determined for those various depths of openings. From the result it was observed that the depth of the castellated beam should be restricted nearly up to 0.6 times depth of the opening. It was recommended that for vierendeel failure the stiffeners along the edge of opening should be provided, so that the stress near the corners of the openings will be reduced.

B. Anupriya and Dr. K. Jagadeesan (2013) [3] investigated behaviour of castellated with stiffeners in the openings in vertical, diagonal and the combination of both using ANSYS. This type of stiffeners were chosen in order to reduce the concentration of stress occurred at corners of the openings. It was observed that the stiffener placed in both diagonal and vertical direction gave satisfactory results in terms of load carrying capacity also there was decrease in deflection due to these two stiffeners.

III. FINITE ELEMENT ANALYSIS

Finite Element Analysis is carried out by using Abaqus/CAE 6.13. Whereas the type of part is dependent and the solid type of part is selected for the castellated beam with stiffeners. The comparison of two different types of stiffener is done, placed at different positions. Parameters considered for stiffeners and details are as given below.

A. PARAMETERS OF CASTELLATED BEAM

The analysis of castellated beam has been carried out of size 1000mm x 150mm x 50mm of overall thickness of 4mm, according to the guidelines provided by Euro code. The D/Do of the castellated beam is kept 1.5 whereas S/Do is 1.8. Fig.4. shows the cross section details of the castellated beam which is analysed by inserting the stiffeners.

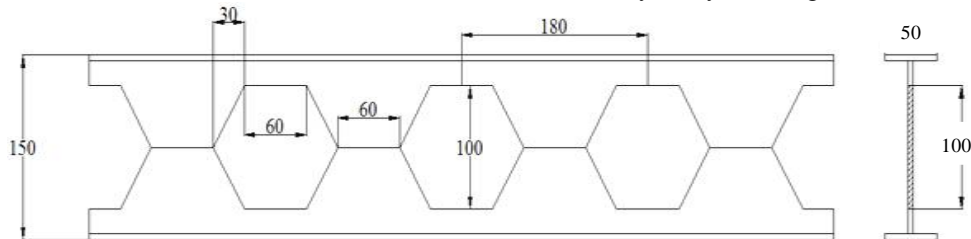


Fig 4: Details of Fabricated castellated beam

B. PARAMETERS OF TRANSVERSE STIFFENERS

Till now there is no proper design for the stiffeners of castellated beam. There are few guidelines provided in Euro Code 3. In which only the rough knowledge of spacing and the minimum area for the stiffener that should be provided is specified. It has also suggested that the stiffeners must be double sided and so placed that it should be symmetric about centreline of the web. The effective cross-section of the stiffener should be at least $30\epsilon t_w$ whereas the spacing between two stiffeners should be $15\epsilon t_w$. If the centre to centre spacing between two openings is more than $15\epsilon t_w$ then the stiffeners should be provided equal to spacing between two adjacent openings.

Where,

ϵ = Strain coefficient

t_w = thickness of web

In this paper total three different thicknesses of transverse stiffeners namely 5mm, 6mm and 8mm are provided. The Table-1 gives the details of sizes of the stiffeners that are provided.

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Representation of the transverse stiffeners is as shown in Fig. No5

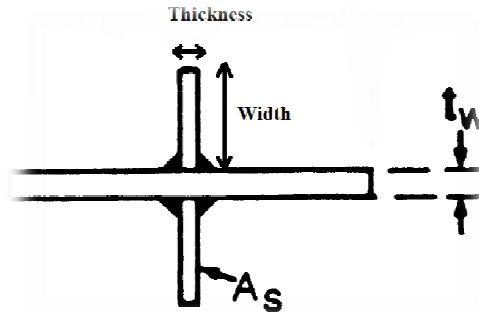


Fig.5: Terminology of transverse stiffener.

Table-1: Details of the transverse stiffeners for castellated beam.

Sr. No	Name	Width (mm)	Thickness (mm)	Volume (mm ⁴)
1	A-1	23	5	16330
2	A-2	23	6	19596
3	A-3	23	8	26128

C. PARAMETERS OF STIFFENERS ALONG THE EDGE OF OPENINGS

Stiffeners provided along the edge of openings are not used in practice till now. According to previous studies it has been told that by using such kind of stiffener the stress concentration produced near the openings will be reduced. Table No. 2 gives the detailing of the stiffeners placed along the edge of opening and the Fig. No. 6 shows the representation of the same stiffener.

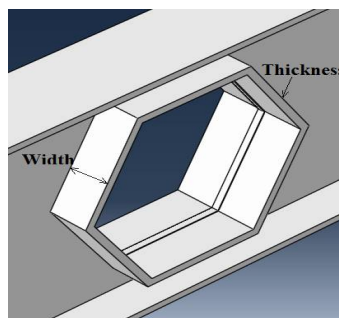


Fig.6: Terminology for stiffener along edge of opening.

Table-2: Details of the stiffeners along opening of the edge.

Sr. No	Name	Width (mm)	Thickness (mm)	Volume (mm ⁴)
1	B-1	23	5	20378
2	B-2	23	6	24748
3	B-3	23	8	33925

D. ANALYSIS USING ABAQUS SOFTWARE

ABAQUS Software was used for carrying out the Finite Element Analysis modelling of castellated beam with transverse stiffeners and the castellated beam provided with the stiffeners along the edge of openings. Fig. 7 and Fig. 8

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show the respective modelling of the software using ABAQUS. The boundary conditions and the loading points are also shown in the same figure.

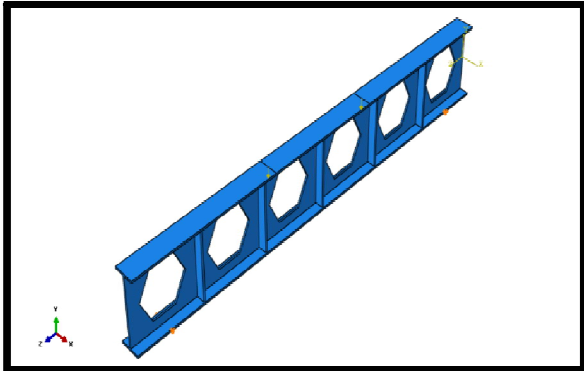


Fig-7: castellated beam with transverse stiffener (A-1).

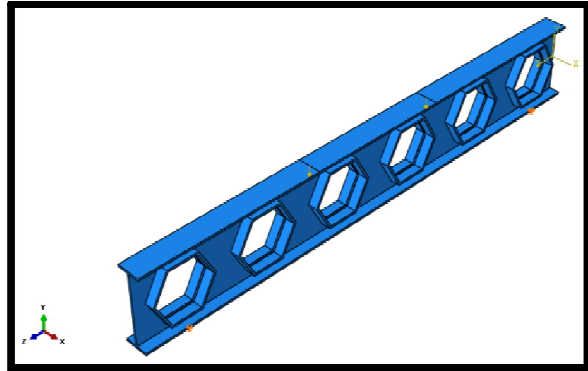


Fig-8: castellated beam with stiffener along opening edge (B-1).

The load carrying capacity of castellated beam using transverse stiffeners and stiffeners provided along edge of opening obtained analytically (using ABAQUS Software) is as shown in Table 2.

Table-3: Load carrying capacities of castellated beam using stiffeners.

Sr. No	Name	Load Carrying Capacity (kN)
1	A-1	55.286
2	A-2	58.091
3	A-3	62.803
4	B-1	51.88
5	B-2	57.135
6	B-3	66.928

E. VALIDATION OF ABAQUS SOFTWARE

In this paper, validation of the software is done by analysing the castellated beam with circular openings (Cellular beam) in ABAQUS Software and comparing those results with the previous results of author Jamadar A. M., Kumbhar P. D[6]. The parameters considered for the cellular beam are same the parameters considered by previous author. The shell type of the part is selected by prior author, while in this paper solid type of part is selected. Table No 3 shows parameters considered of castellated beam :

Table-4: Details of the beam considered for validation.

Description	Do (mm)	D (mm)	D/Do	S/Do
Value	110	150	1.36	1.4

The author had also performed the experimental test for the same parameters of cellular beam. Table no 4 shows the ABAQUS as well as the experimental results in the previous paper and the ABAQUS result during this work paper. Very small difference was observed in these three results.

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Table-5: Load carrying capacities of the beam.

Description	Experimental[6] Results	ABAQUS[6] Results	ABAQUS Results
Load at Yield (kN)	33	32.5	31.6

IV. RESULT AND DISCUSSIONS

Following Table No. 6 shows the percentage of load carrying capacity of castellated beam with stiffener to the volume of the respective one stiffener used. This will give the maximum load carrying capacity using the minimum amount of steel.

Table-6: Load/volume of castellated beam using stiffeners.

Sr. No	Name	Load Carrying Capacity (kN)	Volume (mm ⁴)	Load Carrying Capacity (kN) / Volume(mm ³)
1	A-1	55.286	16330	3.385548
2	A-2	58.091	19596	2.964432
3	A-3	62.803	26128	2.403667
4	B-1	51.88	20378	2.545883
5	B-2	57.135	24748	2.308671
6	B-3	66.928	33925	1.972822

In above table no. 6 the results show that the performance of the beam with the stiffener in the transverse direction is better than the beam with the stiffener along the edge. In case of stiffener along the edge of opening the volume of the steel consumed is more but the load carrying capacity is not considerably increased. Using transverse stiffener the load carrying capacity is increased proportional to the thickness of the stiffener.

V. CONCLUSION

The volume consumed by transverse stiffener is less than the stiffener along the edge of opening. Also, the load carrying capacity of transverse stiffener is considerably more than the stiffener along the opening edge. In case of transverse stiffener, each stiffener acts as a single short column and hence integrates the load carrying capacity. It also helps in compensating faults of welded joints.

In case of stiffener placed along edge of opening stress concentration along the opening edge is reduced this will ultimately reduce the failure in torsional effect but will not effectively help in increasing load carrying capacity.

Thus, the load carrying capacity is not increased in case of the stiffener along the edge as it fails to act as a proper link for the load transfer to the bottom flange and acts as an overhang which ultimately behaves as a cantilever part.

Hence, the transverse stiffener is more preferable than the stiffener along the edge.

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