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COMPARATIVE STUDY OF PARENT BEAM AND CASTELLATED BEAM WITH VARYING SIZE OF OPENING

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ABSTRACT

The use of castellated beams or perforated web beams has become very popular these days due to its advantageous structural applications. Castellated beams are those beams which have perforations or openings in its web. Generally castellated beams are provided with hexagonal, circular and square shaped openings. However, in view of structural applications, the appropriate size and shape of openings provided in the web are always a major issue of concern. A lot of research work has been carried out in optimizing sizes of castellated beams and hence there is need to optimize the beams with varying depth of hexagonal opening. Therefore, in this paper, parametric study of castellated beam with varying depth of openings has been carried out to optimize its size. The Finite Element Analysis (FEA) of the beam using Abaqus/CAE 6.13 software and by following the provisions of Eurocode 3 has been carried out for different sizes of openings. Failure load is found out by considering von-misses failure criteria and the results obtained for optimized beam is validated by experimentation. Results indicate that, the beam gives better strength results for 90mm web openings for a opening size of 0.66 times the overall depth of the beam. Study shows that, local modes of failure are the most dominant factors and need to be considered in the analysis and design of castellated beam.

Keywords: Castellated beam, Perforated web beam, Cellular beam, Finite element analysis, Abaqus, Web openings, Optimization of web openings.

I.INTRODUCTION

Use of steel as structural member in structure is rapidly gaining interest now a days. In steel structures the concept of pre-engineered building (PEB) is most popular because of ease and simplicity in construction. Such pre-engineered buildings have very large spans but comparatively less loading. Therefore, steel sections are generally safe in strength requirement but the difficulty is that the section have to satisfy serviceability requirement i.e. deflection criteria in safety check. Hence, it is essential to use beams with more depth in order to satisfy this requirement. Using perforated web or open web beams is the best solution in order to overcome

this difficulty. Perforated web beam is the beam which has perforation or openings in its web portion. One more advantage of using beams with perforated web is that a reduction in total weight of the structure is possible and hence lesser quantity of steel is required (Wakchaure M. R. et.al. 2012).

Perforated web beams may also be called as castellated beams when perforations are made of hexagonal or square shape. There is one more type of perforated web beam called as cellular beam which has circular perforations (Pachpor P. D. et.al. 2013). Perforations can be made of square or diamond shaped openings. Use of castellated beam with hexagonal opening is very common in recent years because of the simplicity in fabrication.Castellated beams are those beams, which are made by cutting flange of a hot rolled steel I beam along its centerline and then welding the two halves so that the overall beam depth will be increased for more efficient structural performance against bending (Soltani M. R. et.al. 2012)

II. CASTELLATED BEAM

2.1.1Process of castellation

The Castellated beams are prepared from hot rolled steel I sections. The web of I beam is cut in zigzag pattern along the centreline in desired opening shape, then re-joining the two halves on one another by means of welding (Erdal F. and Saka M. P. 2013) The process of castellation is illustrated in Fig.1.5

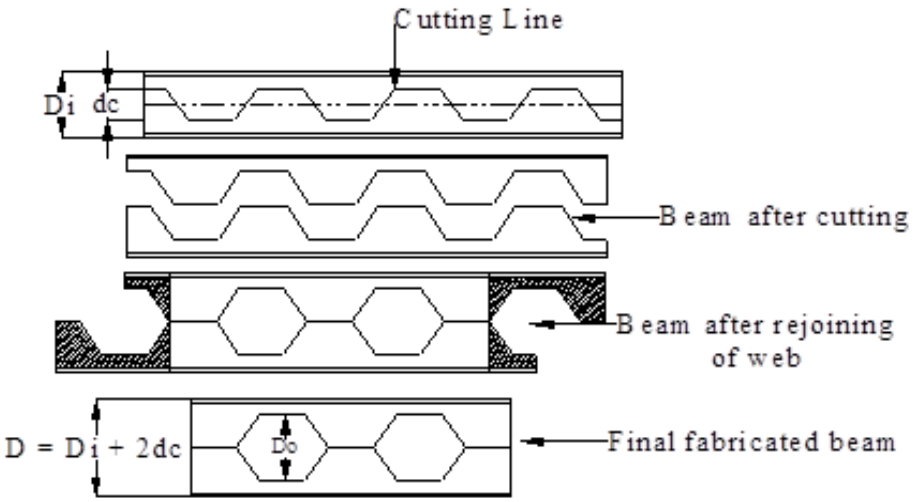

Fig. No. 1 Castellation Process of Castellated Beams

2.1.2 Terminology in castellated beam

The various basic terms involved in the analysis and design of castellated beams are illustrated in Fig. No. 3.1 below;

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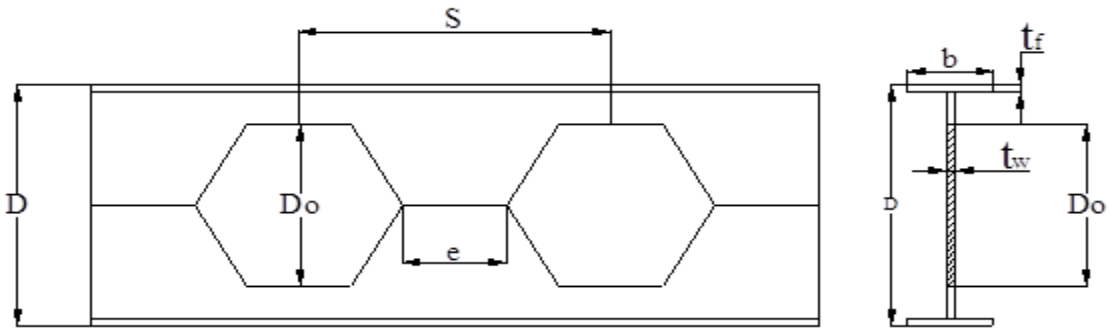

Fig. No. 3.1 Typical cross section of the beam

Where,

Do = Depth of opening provided
D = Overall depth of the opening
S = Centre to Centre spacing between the two opening
e = Clear distance between two opening
b = Width of flange of I beam
t_f = Thickness of flange of I beam
t_w = Thickness of web of I beam

2.1.3 Types of castellated beam

Castellated beams are generally classified on the basis of type or shape of perforation made in the web of the beam (Boyer J. P. 1964) these classifications are as follows

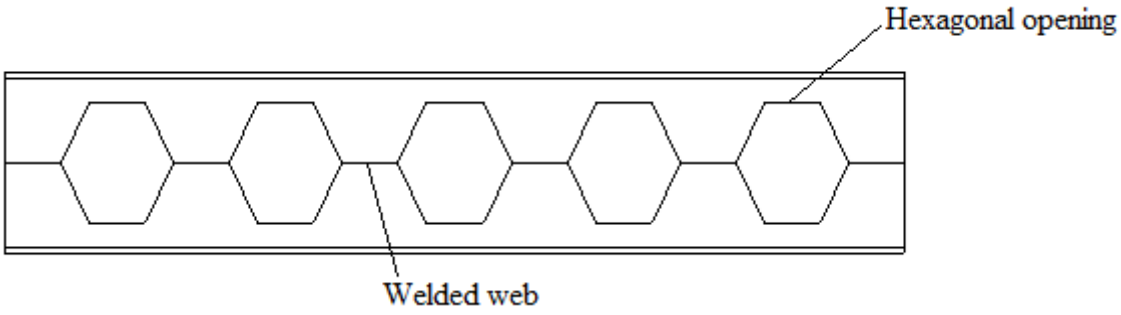

Fig. No. 2 Castellated beam with hexagonal opening

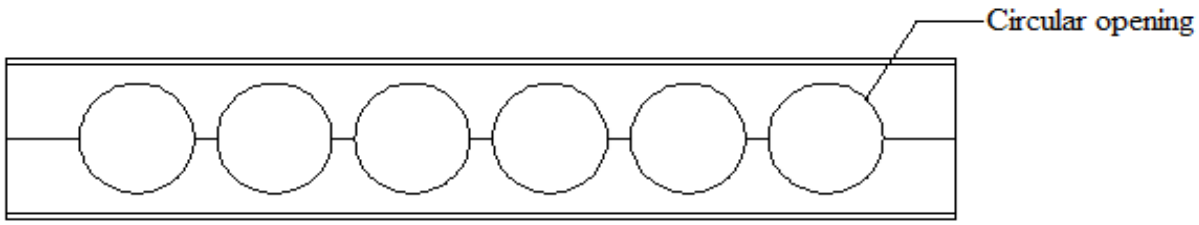

Fig. No. 3 Castellated beam with circular opening (Cellular beam)

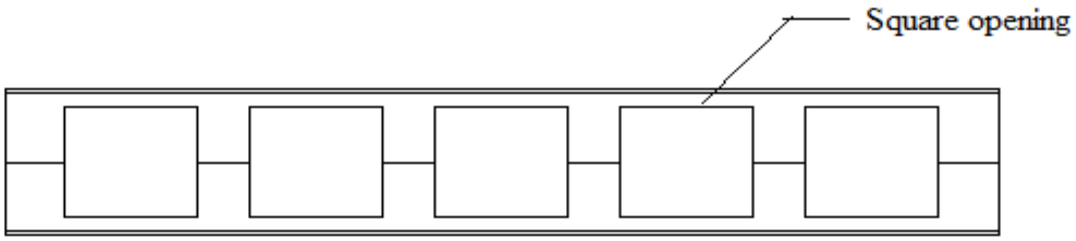

Fig. No. 4 Castellated beam with square opening

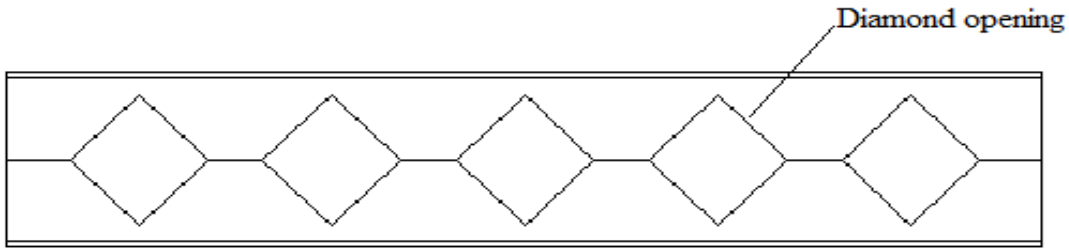

Fig. No. 5 Castellated beam with diamond opening

III. METHODOLOGY USED

The analysis and design methods of castellated beam as per the standards given by Euro code 3are illustrated. Also, methodology adopted in this dissertation to achieve the objectives is explained.

3.1.1Design of castellated beam

Design of the castellated beam includes checking of following;

1.Moment (flexural) capacity castellated beam.

2.Shear capacity of the beam.

3.Flexural and buckling strength of web post.

4.Vierendeel bending of upper and lower tee.

5.Strength of welded joint between two openings

3.1.2 Methodology adopted in parametric study of opening

After understanding the design standards as per the Eurocode the approach is decided to achieve objectives of the project, this approach is discussed in upcoming points. It is decided to analyze the beam for different dimension of the opening for different shape, and whichever section gives most satisfactory results would be tested experimentally for the purpose of validation of the research.

1. **Selection of method of analysis**

In order to optimize the dimension of the openings of the castellated beam, it is very important to decide proper analytical method. Due to complex geometry of castellated beam the finite element analysis (FEA) is the best available to analyze the beam. FEA is done by the simulation software “Abaqus/CAE 6.13”.

2. **Selection of section for parent hot rolled steel I beam and span of the beam**

Span of the parent I beam is selected in view of practical difficulties in testing as well as economic considerations and market availability of section. As the span of the beam to be tested in universal testing machine (UTM) is limited to 900mm in length and maximum loading capacity of the UTM.

3. Selection of parameters for parametric study on beam with hexagonal shaped opening

Depending upon the limitations of opening specified by the codes different dimension of the web openings are selected. The parameters which are selected to study are S/Do and D/Do ratio of the opening. The castellated beam are derived from the 90 mm depth ISLB I section.

Sr. No.	Do (mm)	D (mm)	D/Do	S/Do	S (mm)	e (mm)
1	115	147	1.28	1.4	161	46
2	110	145	1.32	1.4	154	44
3	100	140	1.4	1.4	140	40
4	90	135	1.5	1.4	126	36

Table No. 1 Parameters considered for hexagonal shaped opening

4. Selection of type of loading

As reviewed in the literature it is clear that, the castellated beams tend to fail in local failure modes. Hence, type of loading which has to be applied on beam plays a vital role in causing the failure of beam. Two point loading is the most preferred loading method used for the beams which are susceptible to local failure modes. So, in this project work all the beams are analyzed and tested under two point loading.

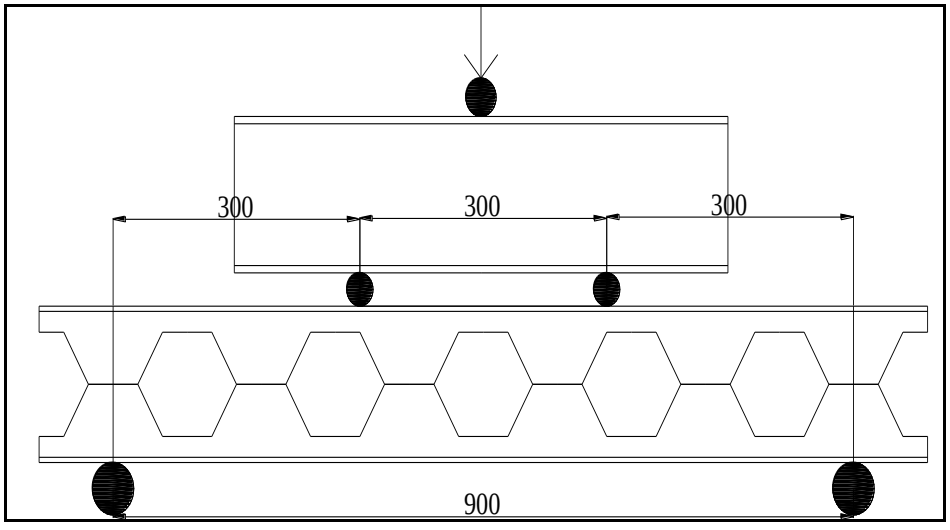

Fig. No. 7 Schematic representation of two point loading test

IV. FINITE ELEMENT MODELLING

Abaqus is the simulation software used for finite element analysis of different structural members, it also used for finite element analysis of many mechanical parts. Following are some important point to be consider while FEM of castellated beam.

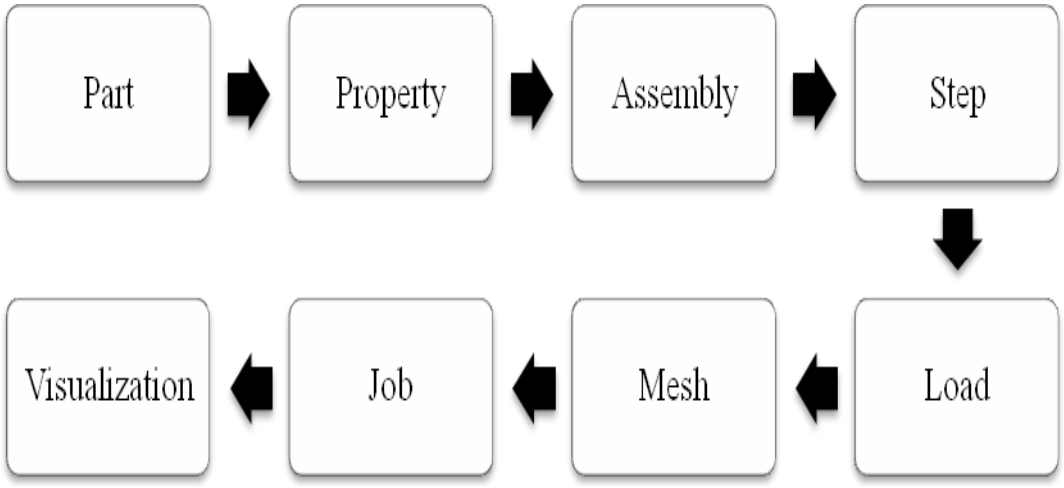

Fig. No.8 Flow chart of FEM in Abaqus

V.RESULTS

The FEA of parent ISLB I beam and castellated beam with hexagonal openings are carried out and results are compared with the experimental values. For all of the analysis failure load is taken as load causing the von-misses stresses to reach yield stress of steel (250 N/mm^2) as explain in failure criteria.

Table no. 2 Comparative behavior of parent I and optimized castellated beam

Sr. No.	Type of beam	Load at yield (kN)	Deflection by FEA (mm)(Software)	Deflection by Experiment (mm)	Percentage error (%)
1	Parent ISLB I beam	41.5	2.35	2.60	9.61
2	Castellated Beam	41.5	1.236	1.35	8.44

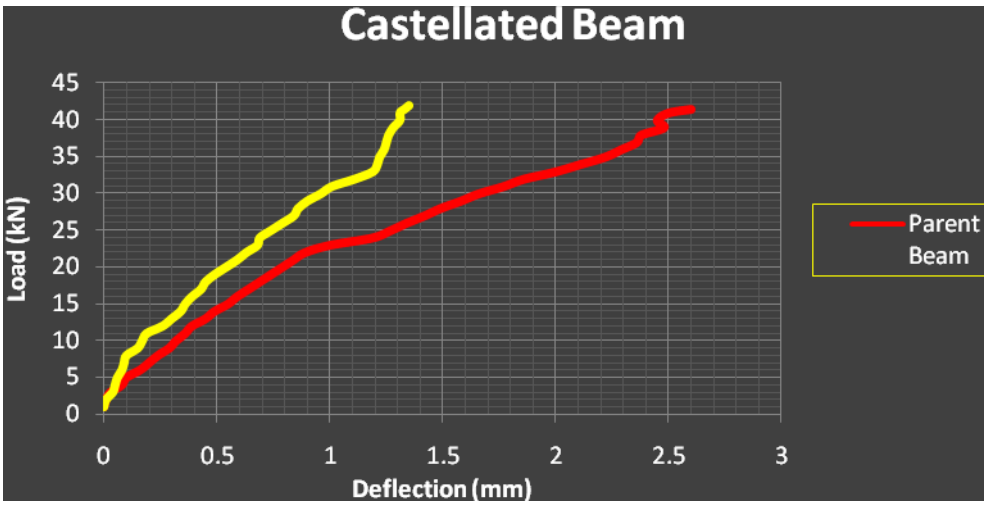

Fig no 9 Load vs. Deflection curve for parent I andoptimized castellated beam

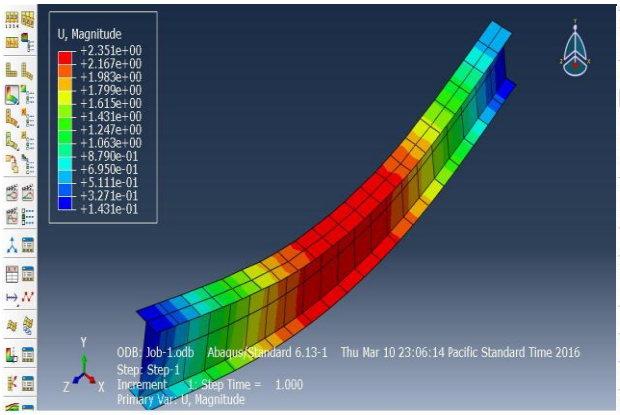

Fig. No. 10 Deflection of Parent Beam

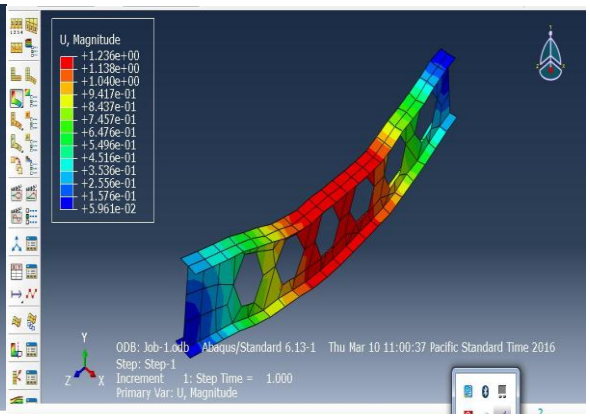

Fig. No.11 Deflection of castellated beam

VI. CONCLUSION

Following concluding remarks can be drawn from the study carried out in this project,

1. Castellated beam behaves satisfactorily as compared to its parent I beam in respect of deflection and strength requirement.
2. The possible optimization for castellated beams with different sizes of openings is as follows;

a. Castellated beam with optimum hexagonal openings is proved to be better than other opening in respect of load carrying capacity.

b. Hexagonal beam with opening size of 0.66 times of its overall depth for S/Do ratio of 1.4 and D/Do ratio of 1.5 has shown minimum deflection for load 41.5 KN.

3. Results of Abaqus software (FEA) are in good agreement with the results of experimentation.
4. Castellated beam is more effective for larger spans and lesser loading (e.g. roof of indoor sport complex etc.)

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