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Optimization of Various Parameters of Castellated Beam Containing Sinusoidal Openings

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***Abstract*: This paper discusses optimization of the size of opening i.e. depth and width of opening of castellated steel beam containing sinusoidal openings. Optimization of opening of sinusoidal shape was performed using finite element method (FEM). The results of FEM analysis are verified by implementing laboratory testing of 150 mm height castellated beam specimen. All the castellated beam specimens were modified from 100 mm I beam. Optimum results from FEM analysis was a castellated beam with sinusoidal openings having opening size 0.62 times its overall depth with S/D_0 ratio 1.4 and D/D_0 1.61 From laboratory testing results and FEM analysis it is observed that, the deflection obtained from FEM result is 1.170 mm. While deflection from experiment results is 1.172 mm. Percentage variation in above case is almost negligible, that is 0.18 percent.**

***Keywords:* Castellated beam, sinusoidal openings, finite element analysis, steel beam**

I. INTRODUCTION

Castellated name come from the Latin word whose meaning is to structurally fortify. Before castellated beams, I-beams were used in construction because they are strong and solid way of supporting houses and other industrial structures. Castellated beams were developed as structural channels to increase the beam's depth of parent I-beam and strength without adding additional material causing no change in weight. Since 1950, because of shortage of steel and increase in cost of steel, castellated beams gets started to be used in the construction. Castellated beams were advanced in Europe to overcome the steel shortages and high cost of steel.

Castellated beams are the beams having different geometrical shape perforations in the web of beam. The different shapes such as hexagonal, circular, rectangular, diamond, sinusoidal etc. are used in castellated steel beams. These shapes are constructed with the help of computer controlled cutting torch to cut the section according to given geometry.

Castellated beams are produced in two steps. In first step the beam is cut in required pattern. In second step both top and bottom parts are welded together to create deeper section. Construction of castellated beam is very efficient process as most of the work is done by automated plasma torch cutting. In order to reduce the man power time and cost on the site, the beams can be constructed with connection points already manufactured into the beam.

The principle advantage of castellated beam is we can increase the depth of beam to increase its strength without Adding its weight. Hence castellated beams are high efficient when it come to load carrying capacity. Many investigators related with behavior of castellated I beam was carried out by [7]-[8] Few researcher [4]-[5] were also carried out research related with behavior of cellular beam with sinusoidal openings. So far there was less research related with optimized depth and length of opening.

This paper explains the results of research for obtaining the optimum size of sinusoidal opening within castellated beam. The aim of this research are (1) examining the result obtained from FEM analysis by conducting laboratory test of castellated steel beam;(2) identifying the maximum stress, of castellated beam containing sinusoidal opening by conducting finite element method; and (3) finding the optimum size of opening of sinusoidal opening within castellated beam .

II. RESEARCH METHOD

A. *General*

The procedure used in the project was divided into three steps. First step is related with software analysis in computer. Method used for analysis of castellated beam with sinusoidal opening was finite element method. Deflection was computed from software analysis which is then verified by performing the second step which is laboratory tested of castellated beam. In third step after comparing the result parametric study was conducted for optimization of depth of opening and width of opening. For laboratory testing two point loading test is preferred, whose schematic representation is shown below.

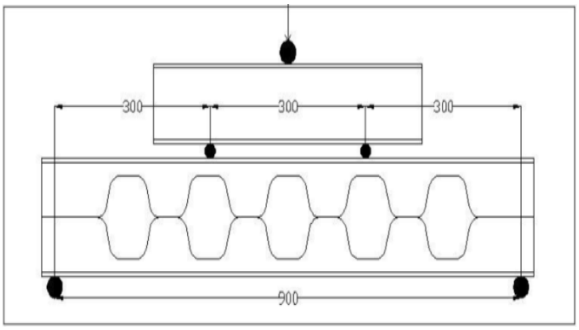

Fig1. Two point loading system in castellated steel beam model

B. *Guidelines for perforation in web*

The openings made in the web of beam greatly affect the

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structural performance of the beam. And hence it is essential to make some logical and practical considerations while providing openings in the web of beam. Following are the general guidelines which given by the euro code and some of them are assumed on field considerations.

These guidelines for opening in the web of beam can be changed or altered without affecting the structural performance of beam [11]. These guidelines are as below

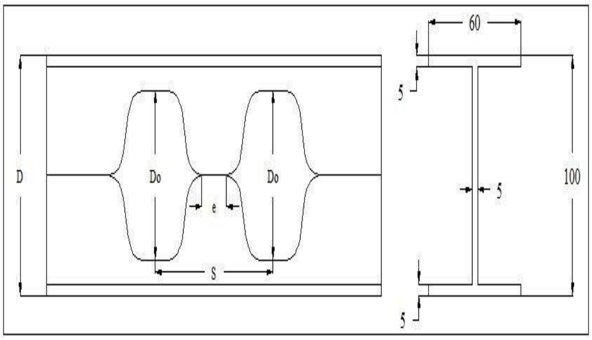

Fig 2. Typical Castellated Beam with its Cross Section

1. 1.08 < S/Do< 1.5
2. 1.25 < D/Do< 1.75
3. Do< 0.8 D
4. e >0.4 Do
5. Width of end post > 0.5Do

Where,
D_0 = Depth of opening
D = Overall depth of opening
S = Centre to Centre spacing between the two opening
e = Clear distance between two opening

C. *Criteria for Failure*

In order to identify the failure of beam in Abaqus, a von mises failure criterion is used to determine the failure condition of ductile material [10]. Von mises stress is defined as uniaxial tensile stress that creates the same distortional energy as any actual combination of applied stress. Failure occurs when the von mises stress value increases beyond the yield stress value of material. In this project work material used for analysis of beam is steel whose yield stress is 250 MPa. The load that produces stress below 250 MPa is taken as permissible load.

D. *Laboratory Testing Setup*

Laboratory test was carried out using simple support system beam and subjected with two point loading system. Effective length of beam was 900 mm, depth of opening 110 mm, total depth of beam 150 mm and thickness of beam 3.5mm.

Fig3. Laboratory testing setup

E. *Selection of parameters for parametric study on beam with sinusoidal shaped openings*

Considering the limitations of perforation in the web of beam given by euro code different dimensions of web perforations are selected. The criterion such as S/D_0 and D/D_o ratio of the opening are considered for the study. These different parameters and their respective cross sectional dimensions are given in table No 1. For beam with sinusoidal openings. All the castellated beams have been derived from 100 mm depth I beam. All the beams were analyzed by using finite element software and optimize section for depth of opening and width of opening has been found. For castellated beam,
First S/D_0 ratio (i.e. 1.4) is kept constant while D/D_0 ratios have been varied from 1.25 to 1.75. After this same process we have repeated for other S/D_0 ratios. i.e. (1.3 and 1.2).

III. RESULTS AND DISCUSSION

A. *Comparative analysis results between software results with laboratory results*

The finite element analysis results are verified by using laboratory tests. Purpose of this laboratory test is to check the correlation between software model and real model. Verification was conducted based on the maximum load given by software to the corresponding deflection of castellated beam having sinusoidal opening. Model used for laboratory test was having depth of 150 mm and of opening depth of 110 mm.

Table I. Parameters considered for sinusoidal opening

Sr. No.	D_0	D	D/D_0	S/D_0	S	e
1	130	165	1.26	1.4	182	52
2	120	160	1.33	1.4	168	48
3	110	155	1.40	1.4	154	44
4	100	150	1.50	1.4	140	40
5	90	145	1.61	1.4	126	36
6	80	140	1.75	1.4	112	32
7	130	165	1.26	1.3	169	52
8	120	160	1.33	1.3	156	48
9	110	155	1.40	1.3	143	44
10	100	150	1.50	1.3	130	40
11	90	145	1.61	1.3	117	36
12	80	140	1.75	1.3	104	32
13	130	165	1.26	1.2	156	52
14	120	160	1.33	1.2	144	48
15	110	155	1.40	1.2	132	44
16	100	150	1.50	1.2	120	40
17	90	145	1.61	1.2	108	36
18	80	140	1.75	1.2	96	32

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Table II. Comparison between FEM analysis results and laboratory testing results

Sr.No.	Load (kN)	Deflection by software in mm	Deflection by experiment in mm
1	5	0.29	0.15
2	10	0.58	0.52
3	15	0.87	0.85
4	20	1.17	1.17
5	25	1.46	1.53
6	30	1.75	1.72
7	35	2.05	2.24
8	40	2.34	2.68
9	45	2.69	3.36
10	50	2.93	3.84
11	55	3.22	4.18

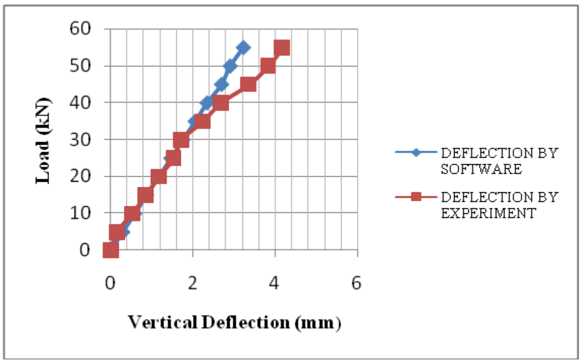

Fig 4. Comparison between FEM analysis results and laboratory testing results

B. *Finite element analysis of castellated beam to optimize depth of opening and width of opening*

After verifying the finite element model with software model, parametric studies were conducted on the castellated beams. The aim of parametric study is to examine the depth and width of opening which carries the maximum load without failure. The parameters, which are selected for this study, include depth of opening and width of opening. All other dimensions such as depth of parent I beam, thickness of web and flange were kept constant. Finite element analysis was performed for eighteen castellated beams for optimizing depth of opening. Then from that, optimized depth width of opening was optimized. Each study was carried out by varying one parameter while keeping other parameter constant. It should be noted that while doing analysis, the loading condition and support condition were kept same as those adopted for experimentally tested castellated beam

Table III. Results of FEM analysis of castellated beam to optimize depth of opening

Sr No	D_0	D	D/D_0	S/D_0	Length of opening	Load at yield	Stress (N/mm^2)
1	130	165	1.26	1.4	130	25	240
2	120	160	1.33	1.4	120	26	245
3	110	155	1.40	1.4	110	27	258
4	100	150	1.50	1.4	100	30	259
5	90	145	1.61	1.4	90	38	244
6	80	140	1.75	1.4	80	36	246
7	130	165	1.26	1.3	117	22	257
8	120	160	1.33	1.3	108	23	251
9	110	155	1.40	1.3	99	25	259
10	100	150	1.50	1.3	90	32	246
11	90	145	1.61	1.3	81	34	250
12	80	140	1.75	1.3	72	32	247
13	130	165	1.26	1.2	104	22	249
14	120	160	1.33	1.2	96	24	246
15	110	155	1.40	1.2	88	34	247
16	100	150	1.50	1.2	80	29	247
17	90	145	1.61	1.2	72	29	245
18	80	140	1.75	1.2	64	32	245

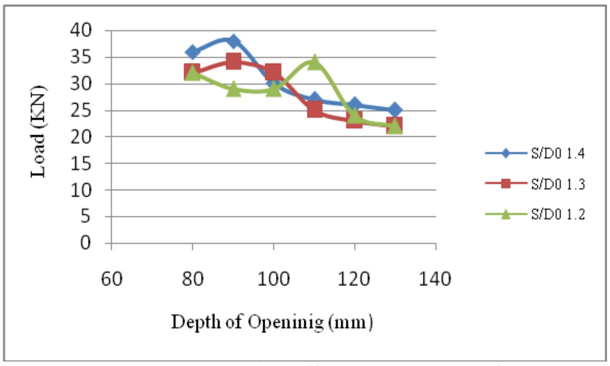

Fig5. Variation in yield load for different S/D_0 and D/D_0 for castellated beam

Beam with D/D_0 ratio equal to 1.611 and S/D_0 ratio equal to 1.4 takes the maximum load of 38 kN After optimization of depth of opening, Width of opening has been optimized. To optimize whole opening of sinusoidal shape, optimized depth has been taken and width of opening has been varied

Table IV. Results of FEM analysis of castellated beam to optimize width of opening

Sr No	D_0	D	D/D_0	S/D_0	Length of opening	Load at yield	Stress (N/mm^2)
1	90	145	1.61	1.4	90	38	244
2	90	145	1.61	1.3	81	34	244.2
3	90	145	1.61	1.2	72	29	244.6

After analysis it is observed that, D/D_0 ratio equal to 1.61 and S/D_0 ratio equal to 1.4 takes the maximum load of 38 kN. i.e. beam with depth of opening 90mm , overall depth 145mm, length of opening 90 and center to center spacing 126mm takes the maximum load .

IV. CONCLUSION

Based on analysis of castellated beam with Finite element method and laboratory test, it can be concluded that

- From laboratory testing results and FEM analysis it is observed that, the deflection obtained from FEM result is 1.170 mm. While deflection from experiment results is 1.172 mm Percentage variation in above case is almost negligible, that is 0.18 percent. The method used for analysis of castellated beam was valid.
- The optimum condition is obtained at castellated beam with sinusoidal openings with opening size 0.62 times its overall depth with S/D_0 ratio 1.4 and D/D_0 1.61.

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REFERENCES

[1] British Standard Institution (1992). Design of steel structures. Part 1.1: General rules and rules for building. Eurocode 3, ENV 1993-1-1, 1992.

[2] Delphin sonck and jan belis (2014). Lateral–torsional buckling resistance of cellular beams. *Journal of Constructional Steel Research,* 105, 119–128.

[3] Durif S. and Bouchair A. (2012). Behavior of cellular beams with sinusoidal openings. *Steel Structures and Bridges,* 40, 108–113.

[4] Durif S., Bouchair A. and Vassart O. (2014). Experimental and web post specimen from cellular beams with sinusoidal openings. *Engineering Structure,* 59,587-598.

[5] Durif S. and Bouchair A. (2016). Analytical model to predict the resistance of cellular beams with sinusoidal openings. *Journal of Constructional Steel Research,* 121, 80–96.

[6] Ehab Ellobody (2011). Interaction of buckling modes in castellated steel beams. *Journal of Constructional Steel Research,* 67, 814–825.

[7] Jamadar A. M. and Kumbhar P. D. (2015). Parametric study of castellated beam with circular and diamond shaped openings. *International research journal of engineering and technology,* 2, 081-084.

[8] Jichkar R. R., Arukia N. S. and Pachpor P. D. (2014). Analysis of Steel Beam with Web Openings Subjected to Buckling Load. *Journal of engineering research and application,* 4, 185-188.

[9] Konstantinos Daniel Tsadaridis and Cedric D'Mello (2011). Web buckling study of the behavior and strength of perforated steel beams with different novel web opening shapes. *Journal of Constructional Steel Research,* 67, 1605–1620.

[10] Listiyono Budi, Sukamta and Windu Partono (2016), Optimization analysis of size and distance of hexagonal hole in castellated steel beams. *Procedia Engineering,* 171, 1092-1099.

[11] Lawson R. M. and Hicks S. J. (2011). Design of Composite beams with large web openings: in accordance with Eurocodes and the UK national Annexes. Steel Construction Institute, Berkshire, UK.

[12] Rohit Kurlapkar and D.B.Kulkarni(2019). Behavior of castellated beam with sinusoidal opening. *International research journal of engineering and technology,* 6, 2478-2480.

[13] Soltani M. R., Bouchaïr A. and Mimoune M. (2012). Non-linear analysis of ultimate behaviour of castellated beams. *Journal of Constructional Steel Research,* 70, 101– 114.