Finite Element Analysis of Castellated Beam

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Abstract - *Necessity is the mother of invention. Now days, Engineers are constantly trying to improve the materials and properties of design and construction. Use of castellated beam is become very popular due to its advantageous structural applications. These uses take advantage of the increased strength and the economy of castellated beams. An available literature does not deal with the behaviour of double web castellated beam with increase in depth of opening. Castellated beam and effects of deflection with increase in the depth of web openings are analysed with the help of Finite Element Analysis software ANSYS 16.0 However, one consequence of presence of web opening is the development of various local effects. In this paper a steel section is selected, castellated beams are fabricated with increase in depth of web openings. Experimental testing will be carried out on beam of span 1.5m and loading will be taken up to serviceability limit. The deflection at center of beam and various failure patterns will be studied. The beams with increase in depth are then compared with each other and with parent section for various parameters and for serviceability criteria.*

In this paper, Finite Element Analysis software ANSYS 16.0 was performed to compare the deflection and stress of steel beam with single web and double web castellated beam. The numerical calculations have been done for single web and double web castellated beams with different spans have been analysed, in which uniformly distributed load for 12 KN/m or more. The beams are considered as simply supported conditions. The spans are 1.5m, 3m, 5m and 7m. With different parent sections for ISMB 150, ISMB 200, ISMB 250 and ISMB 300 for single castellated beam and IC 225, IC 300, IC 375 and IC 450 for double web castellated beam. This Analysis showed the results for double web castellated beam with staggered hexagonal opening having more load carrying capacity and lesser deflections as compared to single web castellated beam with hexagonal opening. This paper investigates the effect of web openings on various structural aspects of double web castellated beam.

*Key Words***:** *Castellated beam, Deflection, Stress, Finite Element Analysis, single-double web openings.*

1. INTRODUCTION

Use of steel for structural purpose in structure is rapidly gaining interest these days. One such improvement occurred in built-up structural members in the mid-1930, an engineer working in Argentina, Geoffrey Murray Boyd, is castellated beam. Castellated beams are such structural members, which are made by flame cutting a rolled beam along its center line and then re-joining the two halves by welding so that the overall beam depth is increased by 50% for improved structural performance against bending.

Castellated beam reduces the cost of structural steel. Castellated beams having holes or castellation on its web portion. It is made by cutting the web portion of the solid beam in zigzag pattern and then arranging the two halves in such a way that castellations are made in the web portion. It is the then welded together to form a castellated beam. In castellated beams, one can increase the depth of the beam without any additional steel.

2. FINITE ELEMENT ANALYSIS

In this paper, a three dimensional (3D) finite element model is developed to stimulate the behaviour of double web castellated beam having an I-shaped cross section. Various finite element models for determining the Y-directional deformations and von-mises stresses of I-beam with various cross-section and lengths are developed and useful results have been obtained. Fixed supported I-beam models have been analyzed and the corresponding deflections and stresses are obtained for a variety of cross-sectional geometries, and lengths where d is depth of web opening, D is depth of beam. Modelling is conducted using the general-purpose finite element software package ANSYS 16.0.

In this paper, firstly solved some numerically problems for single web castellated beam and double web castellated beam with UDL 12 KN/m for different span of 1.5m, 3m, 5m and 7m. From that results analysis have been done in Ansys 16.0. ANSYS provides solutions for many type of analysis ANSYS is a widely used commercial general-purpose finite element analysis program.

2.1 ANSYS Analysis Procedure Results of ANSYS analysis

A three-dimensional finite element model is developed to study the behaviour of single and double web castellated beam. Beams are of I shaped cross section. Modelling and analysis were done using ANSYS 16.0.

Properties: - Young's modulus, E= 2 x 10^5Mpa2, Poisson's ratio = 0.3, Density of steel = 7850 kg/m3.

Static analysis was performed to determine the deflection of the single and double web castellated beam and having hexagonal openings. Each I-shaped beam is characterized by its span L, flange width bf, flange thickness tf, depth of parent h, depth of castellated beam hc and web thickness tw. Web perforations were hexagonal in shape, with side (s) spacing between two holes and are uniformly spaced at distance S along the span of the beam. The size of the elements along the span of the beam is restricted not to exceed twice the size of the element across   the flange. Several mesh configurations are attempted until the above-provided limitations are set after providing convergence of the predicted buckling load within reasonable execution time. Detailing of various beams as below:

For IC 225:

Span L=1500mm, h=225mm, hc=150mm, bf=80mm, tf=7.6mm, tw=4.8mm, S=75mm

For IC 300:

Span L=3000mm, h=300mm, hc=200mm, bf=100mm, tf=10.8mm, tw=5.7mm, S=100mm

For IC 375:

Span L=5000mm, h=375mm, hc=250mm, bf=125mm, tf=12.5mm, tw=6.9mm, S=125mm

For IC 450:

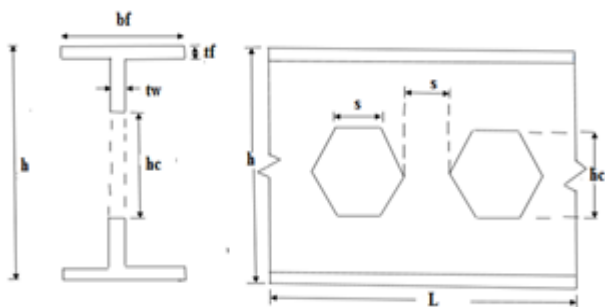Span L=7000mm, h=450mm, hc=300mm, bf=140mm, tf=12.4mm, tw=7.5mm, S=150mm

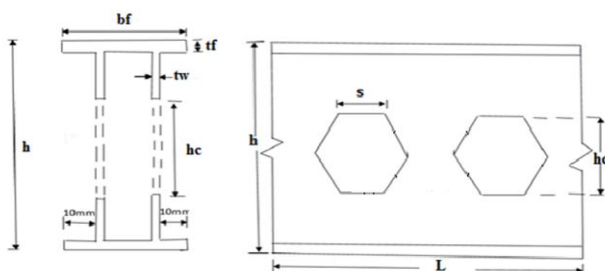**Fig -1**: Cross section of Single web Castellated Beam

Fig -2: Cross section of Double web Castellated Beam

The above problem statements are same for single web and double web castellated beam except the web thickness for double web castellated beam is 6 mm in each case.
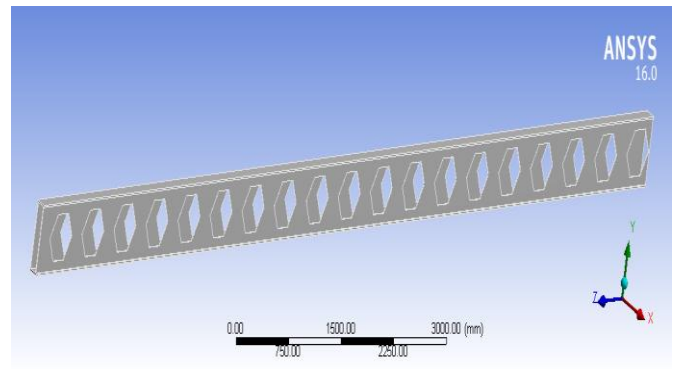
2.2 Results of ANSYS analysis

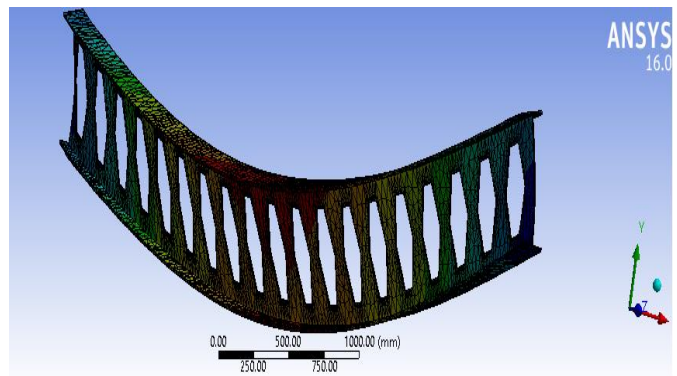**Fig -3** Position and Orientation

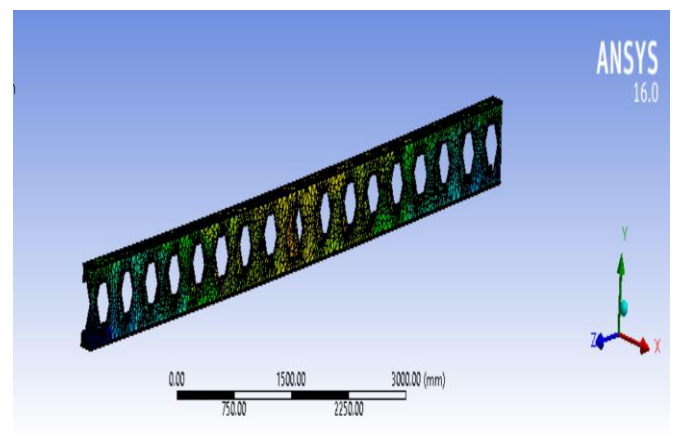**Fig -4:** Total deflection of IC 450 for Single Web Castellated beam

Fig -5: Total deflections of IC 450 for Double Web Castellated beam

3. FABRICATION AND EXPERIMENTAL TESTING OF SPECIMENS

Fabrication of Castellated beams is a comparatively simple series of operations when adequate handling and controlling equipment is used. Structural Steel by burning two or more at. A time, depending upon their depth. Splitting is performed by using a component of the oxy-acetylene gas cutter equipment shown in fig.7 this is an electrically propelled buggy which runs on a fixed track. The buggy has building burning patterns. That can be adjusted to any one of live standard longitudinal "module" dimensions and to any hall-opening height.

However, the castellation of the beams results in distinctive failure modes depending on geometry of the beams, size of web openings, web slenderness, type of loading, quality of welding and lateral restraint conditions. The failure modes comprise shear, flexural, lateral torsional buckling, rupture of welded joints and web post buckling failure modes.

The experimental investigations carried out on the test specimen to study the Lateral torsional buckling behavior of castellated beam sections. Test specimen's span (l) = 1.5m. The beams were simply supported at the ends and subjected to a concentrated load applied at the mid-span. The deflection at center of beam and various failure patterns are studied.

ISMB150 section of depth 150 mm is selected for the fabrication of solid as well as castellated beam. Markings for which cutting should be done was made and then gas cutting machine is used to cut the specimen along its markings. After cutting, the two pieces were welded together to form a castellated beam

Fig -7: Single and Double Web Castellated beam

Fig -8: Showing Load carrying Capacity for ICSW 225

Fig -6: Fabrication of IC 225 for Single and Double web of Castellated beam

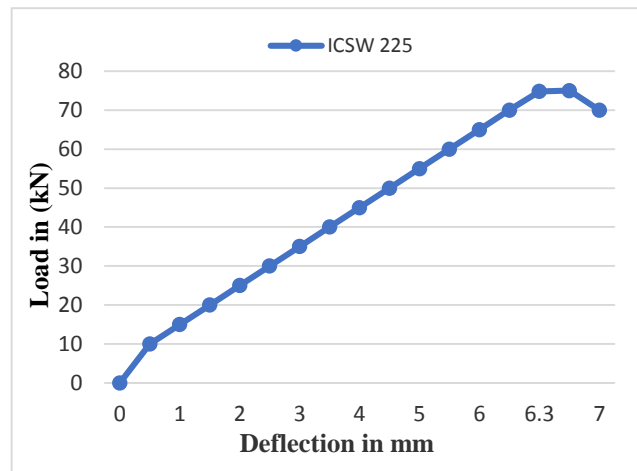**Fig -9**: Showing Load carrying Capacity for ICDW 225

Fig -10: Showing Lateral torsional buckling of Web for ICSW 225

Fig -11: Showing Failure of compression flange for ICDW 225

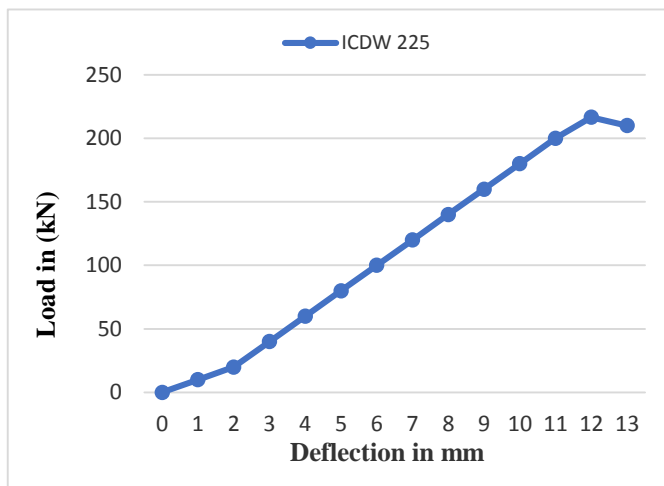## 4. TABLES AND GRAPHS FOR DEFLECTION

Experimental testing Tables and Graphs are plotted deflection for span of 1.5m with section of ICSW 225 and ICDW 225

TABLE -1: Load v/s Deflection for ICSW 225

Sr. No.	Load (kN)	Deflection (mm)
1	0	0
2	10	0.7
3	15	1.01
4	20	1.35
5	25	1.71
6	30	2.10
7	35	2.49
8	40	2.88
9	45	3.28
10	50	3.64
11	55	3.95
12	60	4.27
13	65	4.65
14	70	5.19
15	74.80	6.30
16	75	6.30
17	70	7.01

Graph - 1: Load v/s Deflection for ICSW 225

TABLE. -2: Load v/s Deflection for ICDW 225

Sr. No.	Load (kN)	Deflection (mm)
1	0	0
2	20	0.6
3	40	1.25
4	60	1.81
5	80	2.37
6	100	3.03
7	120	3.80
8	140	4.71
9	160	6.02
10	180	8.80
11	200	12.49
12	216.54	12.80
13	210	13.14

Graph - 2: Load v/s Deflection for ICDW 225

5. CONCLUSION

The analysis of steel beams with web openings for deflection and stresses is done by ANSYS software. Area of opening and load are constant and the results are observed from tables and graphs. The results obtained from experimental testing and ANSYS 16.0, it was observed that the double web castellated beam with hexagonal opening having more load carrying capacity and lesser deflection than in the single web castellated beam. Hence double web castellated beam can provide in large industries for longer spans. And also, strength and economy of castellated beam is improved and modes of failures are also minimised by using such types of beams.

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