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Lateral Torsional Buckling of Corrugated I-Beam with Sinusoidal Openings

Krishnarani. K. K [1], Swathi Krishna [2]

[1]*P.G. Student,* [2]*Assistant Professor, Department of Civil Engineering,*
Vedavyasa Institute of Technology, Malappuram, Kerala, India

Abstract: In this thesis, the study of lateral torsional buckling of castellated I beam with trapezoidally corrugated web will be investigated. By utilizing the non linear analysis and FE models to characterize the load- deflection response of castellated I beam in lateral torsional buckling state The required three dimensional finite element models develop by using ANSYS v.16.2, FE software. Castellated steel beam with corrugated web are lightweight sections with high strength as compared to simply corrugated web. The use of castellated I beam suppress the cost of material by applying more efficient cross sectional shapes made from standard sinusoidal profile in combination with significant weight saving. That also causes smooth stress distribution.

Keywords— Lateral torsional buckling, corrugation on web, sinusoidal shape opening, FE analysis

I. INTRODUCTION

The structural purpose of steel in construction industry are becoming more popular and having greater importance due to their better durability, strength, uniform shapes and its ease and simplicity in construction. In steel structure, one of the issues raised are how to reduce the weight and cost of the component parts such as girder and beams. The investigation of web is usually considered for such requirements by comparing the thickness and the shape. Most of the compressive stress is usually carried by the web in the beam and transmits shear while flanges support the major external loads. It can decrease the cost and materials without weakening the load-carrying capacity of the beam. Thin web is efficient and economical for design of girders and beams. However, to carry the moments, the sections have to be slender and the extremely slender section will cause the web buckling. Hence we provide the corrugations to the web are used to avoid this buckling. The main purpose of using corrugated web is that it permits the use of thinner plates which require no stiffening; hence it considerably reduces the cost of beam fabrication with significant weight saving.

Main objectives of this study are,

Develop and verify shell finite element models a I beam with trapezoidal corrugation on web and also provide sinusoidal openings

To investigate and understand the lateral torsional buckling behavioral characteristics of simply supported beam using developed shell finite element models

To characterize the load- deflection responses of castellated I beam in lateral torsional buckling state with the help of finite element software ANSYS by utilizing the non- linear analysis and FE models.

II. PARAMETRIC STUDY

The main aim of this Master's thesis was to examine how ANSYS, finite element software calculate the max deflection and angle of twist and to explain potential differences in the results. In order to achieve this, a parametric study was carried out where mentioned above were calculated for selected situations in the programs. There are small differences in the sectional data implemented by the programs, see Table -1. It was therefore expected that the differences are computed. Since exact reference values are needed to make evaluations of the accuracy, the same beams and loading conditions have been suggested as in the research by Mattias Larsson *et al.* (2013) [4], as well as the various web perforations have been proposed by P.D Kumbhar *et al*. (2015) [5].

In all, a group of 15 tests models were performed. The specimens were designed 9500 mm lengths and different sizes of opening. The analysis of the corrugated beam with sinusoidal shaped openings is carried out for different sizes. In this investigation,the nonlinear FEA computations of castellated beam under consideration were performed by using the commercial finite element software package ANSYS 16.2.

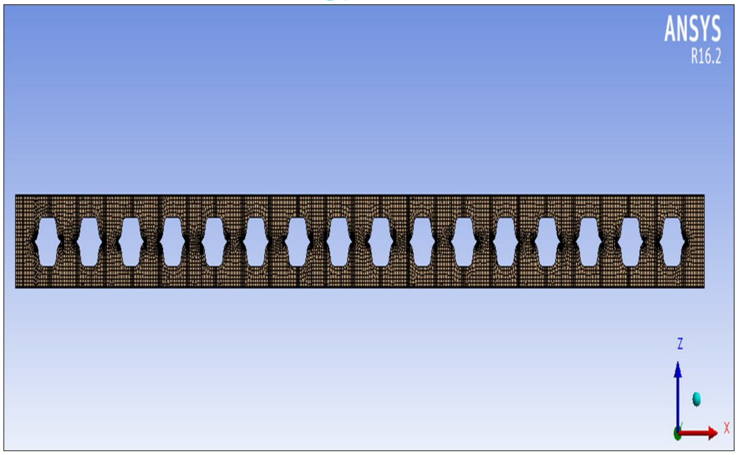


Fig-1 Meshing of model- 2D view

Simply supported castellated I beam with corrugated webs are chosen under pure bending conditions in order to evaluate the lateral torsional buckling for them. A typical configuration of the expanded beam and the notation adopted are shown in Fig 5.4. When modeling bending moment is about the strong axis, the boundary conditions represent fork supports and were modeled as shown in Fig 5.5. At point A, displacements in all directions (x,y and z) and rotation about the longitudinal axis (x) were restrained. Vertical (z) and lateral (y) displacements were restrained at point B, as well as rotation about the longitudinal axis (x).

Material properties which have been used in all models are,

Young's modulus, E = 198 Gpa

Poisson's ratio, $\upsilon = 0.3$

Shear modulus, $G = E / 2(1+ \upsilon) = 76.15$ Gpa

Density = 7850 Kg/m^3

The parameter considered for the study is h_w/Do ratios and S/Do of the opening. The variations in the parameters and corresponding cross sectional dimensions of the sinusoidal openings are given in Table -1.

Table -1
Parameters considered for sinusoidal opening

	Sl. No	Model	hw(mm)	Do(mm)	hw/Do	S(mm)	e (mm)
Case 1	1	M1	700	410	1.707	574	123
	2	M2	710	440	1.651	616	132
	3	M3	720	470	1.531	658	141
	4	M4	730	500	1.46	700	150
	5	M5	740	530	1.39	742	159
Case 2	6	M6	700	410	1.707	533	123
	7	M7	710	440	1.651	572	132
	8	M8	720	470	1.531	611	141
	9	M9	730	500	1.46	650	150
	10	M10	740	530	1.39	689	159
Case 3	11	M11	700	410	1.707	492	123
	12	M12	710	440	1.651	528	132
	13	M13	720	470	1.531	564	141
	14	M14	730	500	1.46	600	150
	15	M15	740	530	1.39	636	159

III. RESULT AND DISCUSSION

Comparisons were made between the different parameters changed models of results. Discussions were carried out with respect to the comparisons of load capacities and the mode of failure occurred. The figure Fig. 2 is the deformed shape of beam with un-deformed form and the region where the maximum and minimum deformations occurred at specified loading.

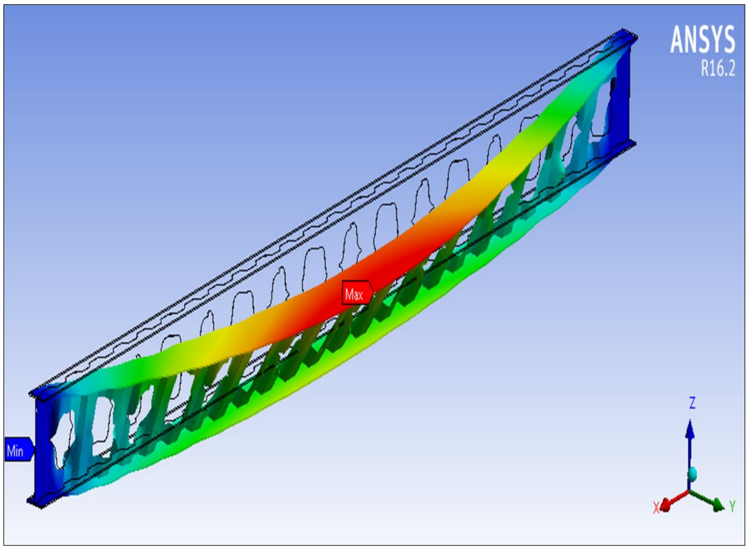
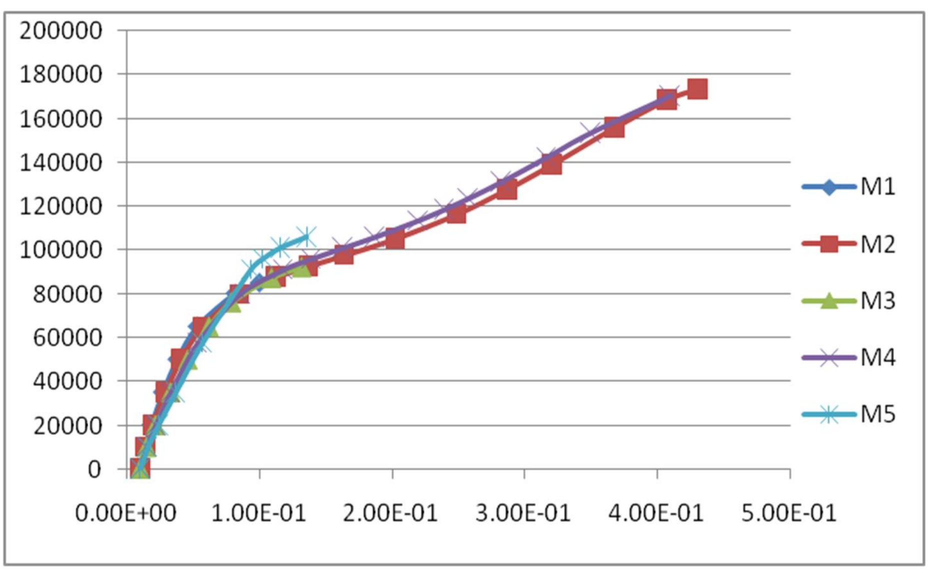


Fig -2: Total deformation of beam at maximum and minimum range

A comparative study of each FE models from finite element analysis result are carried out for better conclusion of this study.

A. Case -1

In this case, 5 models have been categorized on the basis of varying web height and opening size at constant S/Do ratio of 1.4. As can be observed from Fig. 6.5, the load- displacement curves for five models first has been linear, then it has bended and got asymptotic to the value of the critical load. Then the buckling has occurred and the analysis has finished. Model M5 show better performance as minimum deformation occurred at maximum rate of load compared to other 4 models.



X axis- Total deformation in m

Y axis- Applied load in N

Fig. 6.5 Load – Deflection plot for Case 1 FE models

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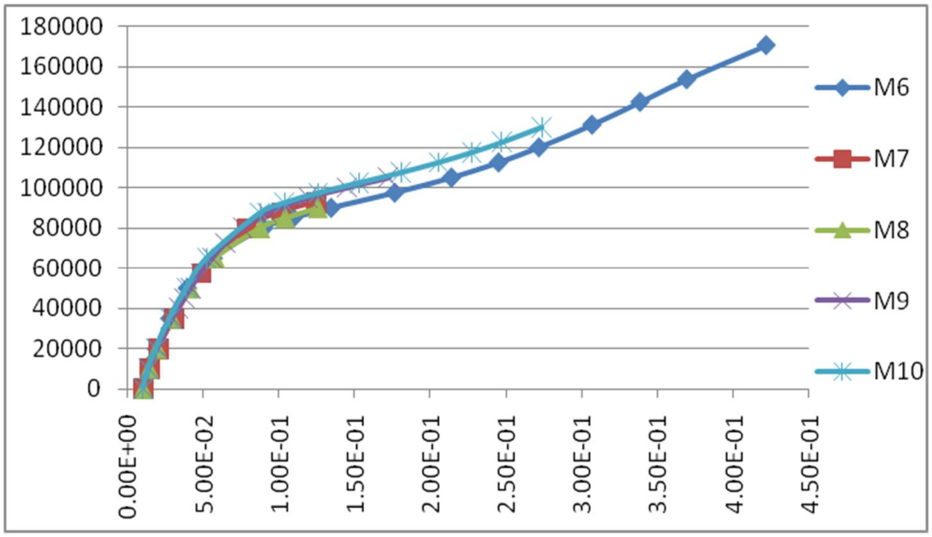
B. Case – 2

In this case, models have been categorized on the basis of varying web height and opening size at constant S/Do ratio of 1.3. As can



be observed from Fig. 6.6, the load- displacement curves for five models first has been linear, then it has bended and got asymptotic to the value of the critical load. Then the buckling has occurred and the analysis has finished. Model M10 shows slightly better performance as minimum deformation occurred at maximum rate of load compared to other 4 models.

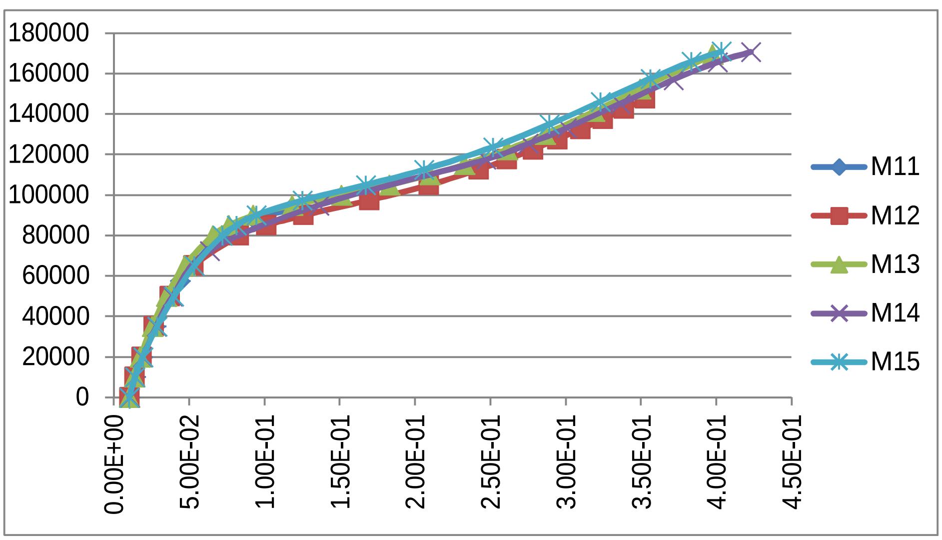
X axis- Total deformation in m

Y axis- Applied load in N

Fig. 6.6 Load – Deflection plot for Case 2 FE models

C. Case - 3

In this case, models have been categorized on the basis of varying web height and opening size at constant S/Do ratio of 1.2.



X axis- Total deformation in m

Y axis- Applied load in N

Fig. 6.7 Load – Deflection plot for Case 3 FE models

As can be observed from Fig. 6.7, the load- displacement curves for five models first has been linear at a particular level, then it has bended and got asymptotic to the value of the critical load. Then the buckling has occurred and the analysis has finished. Model

M15 shows slightly better performance as minimum deformation occurred at maximum rate of load compared to other 4 models.

IV. CONCLUSION

From the study, it is observed that the castellated I beam with corrugated web at varying corrugation height (h_w) and depth of opening (Do) with constant S/Do are considered for each case can withstand maximum load with minimum rate of deformation. In order to reach a final conclusion, it has been compared the load- deformation response of model M5 (S/Do=1.4), M10 (S/Do=1.3) and M15(S/Do=1.2). By analyzing the graph (Fig. 6.8), 3 models have equal web depth and opening size and also their c/c spacing is in increasing order. They show linear deformation at a particular level, but after that M5 able to carry maximum load at minimum rate of deformation than M10 & M15.

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