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# LATERAL TORSIONAL BUCKLING OF CASTELLATED I BEAM WITH CORRUGATED WEB

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**Abstract -** *The paper work dealt with a parametric study of castellated I beam with corrugated web at varying depth and opening size. One aim of this research is to study the developed shell finite element models to investigate and understand the lateral torsional buckling behavioral characteristics of simply supported beam. By utilizing the non linear analysis and FE models to characterize the load- deflection and moment-rotation responses of castellated I beam in lateral torsional buckling state with the help of finite element software ANSYS. 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. That also causes smooth stress distribution.*

***Key Words*: Lateral-torsional buckling, castellated beam, trapezoidally corrugated web, non linear analysis, ANSYS, parametric study...**

## 1. INTRODUCTION

In this thesis, the study of lateral torsional buckling of sinusoidal shape castellated I beam with trapezoidally corrugated web will be investigated. Castellated steel beam with corrugated web are lightweight sections with high strength. While, lateral torsional buckling is one of the failure modes at the section of castellated slender beam. For beams under predominant bending moments, the failure mode tends to be lateral-torsional buckling, in which the member buckles laterally out of loading plane and twists. An unrestrained beam is considered when its compression flange is free to displace laterally and rotate. When an applied load causes both lateral deflection and twisting of a member lateral torsional buckling has occurred. Mainly the lateral-torsional buckling strength is influenced by several major variables such as unbraced length, load type and location of applied load, boundary conditions, section type and initial imperfections of geometry and loading. This study is carried out to proven the software result about the deflection and rotation of the corrugated web influence by the opening in the middle of the beam.

The 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. Sinusoidal opening used in corrugated web which's increased area for stress distribution in addition to curved edges that causes smooth stress distribution and also provides better performance in strength.

### 1.1 Objectives

- Develop and verify shell finite element models for simply supported I beam with corrugation on web and also provide sinusoidal openings to the corrugated web
- Use the developed shell finite element models to investigate and understand the lateral torsional buckling behavioral characteristics of simply supported beam.
- By utilizing the non linear analysis and FE models to characterize the load- deflection and moment-rotation responses of castellated I beam in lateral torsional buckling state with the help of finite element software ANSYS.

### 1.2 Scope and Limitations

- To study the behavior of lateral torsional buckling of I beam
- Factors affecting lateral torsional buckling

The parametric study was limited to 9.5 meter single spanned steel beams, using software ANSYS.

- Members subjected to a uniform bending moment about the strong axis of the member, when considering lateral-torsional buckling.
- Elastic, homogeneous isotropic material.
- Beams with the same material properties for flanges and web.
- Thin-walled I-shaped beams with equal angles.
- Webs with varying height over the length of the beam considered for parametric study.

## 2. 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.

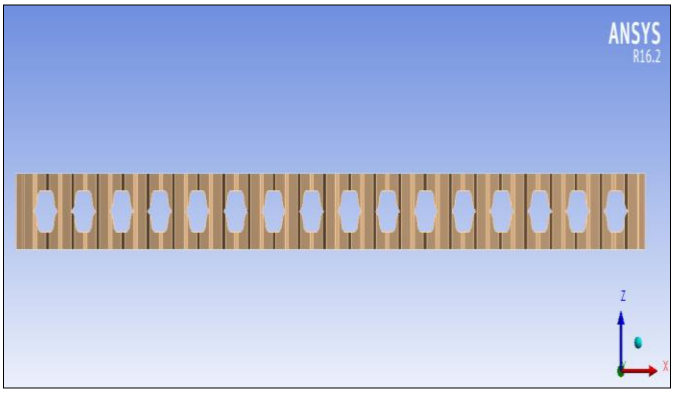



**Fig -1:** Model of Castellated I beam with trapezoidal corrugation – 2D view

## 2.1 Cross Section Geometry

If nothing else stated, the following labeling of cross-section dimensions are used in the thesis.

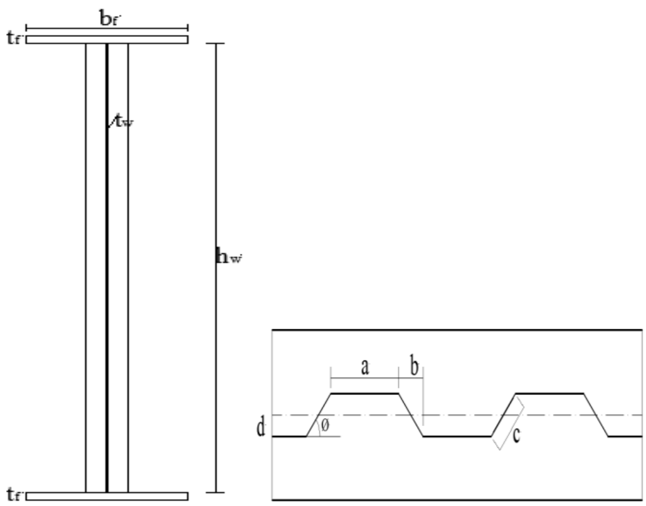



**Fig -2**: Notations for the geometry of the cross-section and corrugation profile

**Table -1:** Geometry of corrugated profile

| Length L(m) | bf (mm) | tf (mm) | hw (mm) | tw (mm) | a (mm) | b (mm) | c (mm) | d (mm) | θ (°) |
|---|---|---|---|---|---|---|---|---|---|
| 9.5 | 200 | 12 | 700 | 2 | 140 | 50 | 71 | 25 | 45 |

The basic terms involved in the analysis and design of castellated beams are illustrated in Fig- 3 [2].

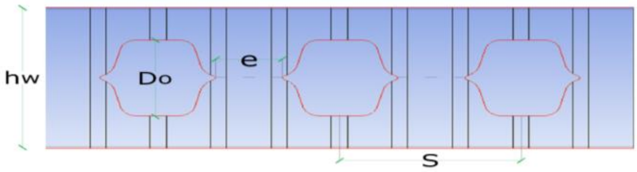



**Fig -3:** Typical cross section of the castellated beam

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 -2.

**Table -2:** Parameters considered for sinusoidal opening

| Model No | hw (mm) | Do (mm) | hw/Do | S/Do | S (mm) | e (mm) |
|---|---|---|---|---|---|---|
| M 1 | 700 | 410 | 1.707 | 1.4 | 574 | 123 |
| M 2 | 710 | 440 | 1.651 | 1.4 | 616 | 132 |
| M 3 | 720 | 470 | 1.531 | 1.4 | 658 | 141 |
| M 4 | 730 | 500 | 1.46 | 1.4 | 700 | 150 |
| M 5 | 740 | 530 | 1.39 | 1.4 | 742 | 159 |
| M 6 | 700 | 410 | 1.707 | 1.3 | 533 | 123 |
| M 7 | 710 | 440 | 1.651 | 1.3 | 572 | 132 |
| M 8 | 720 | 470 | 1.531 | 1.3 | 611 | 141 |
| M 9 | 730 | 500 | 1.46 | 1.3 | 650 | 150 |
| M10 | 740 | 530 | 1.39 | 1.3 | 689 | 159 |
| M11 | 700 | 410 | 1.707 | 1.2 | 492 | 123 |
| M12 | 710 | 440 | 1.651 | 1.2 | 528 | 132 |
| M13 | 720 | 470 | 1.531 | 1.2 | 564 | 141 |
| M14 | 730 | 500 | 1.46 | 1.2 | 600 | 150 |
| M15 | 740 | 530 | 1.39 | 1.2 | 636 | 159 |

## 2.2 Boundary Conditions and Loading

In order to have equilibrium some degrees of freedom must always be restrained at the boundary. An important and often mentioned support condition is the fork support.

A fork support is defined to have the following boundary conditions (Fig -4).

- Displacement in *x*, *y* and *z* (Fixed)
- Rotation about *x*-axis (Fixed)
- Rotation about *y*-axis (Free)
- Rotation about *z*-axis (Free)

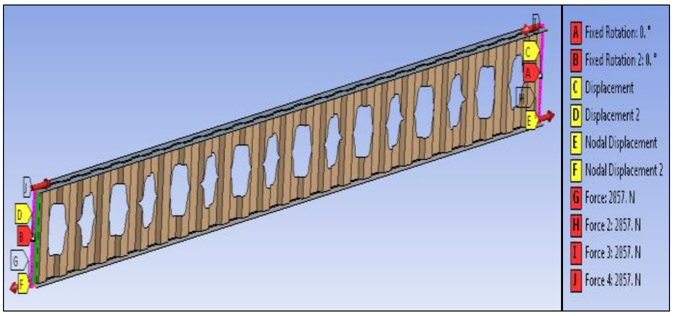



**Fig -4:** Boundary Condition Application in Software

**3. 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. 5 deformed shape of beam with un-deformed form and the region where the maximum and minimum deformations occurred at specified loading.

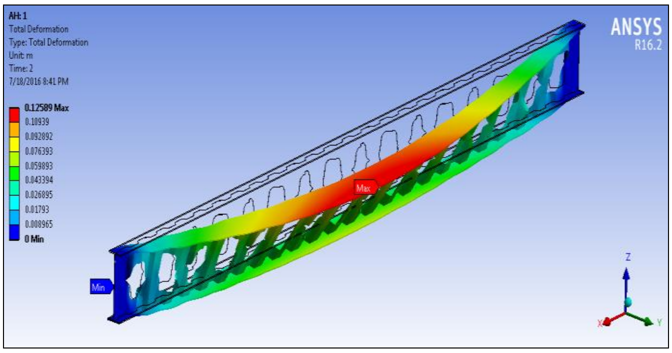



**Fig -5**: Total deformation of beam at maximum and minimum range

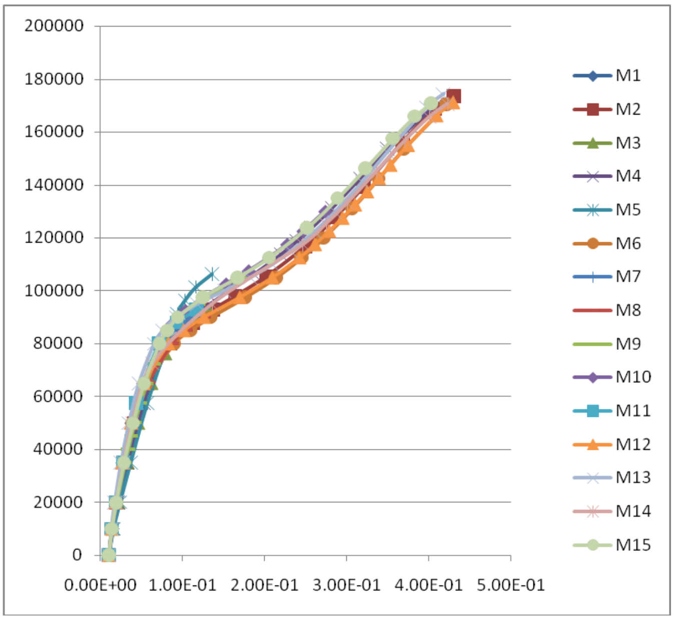
### 3.1 Comparative Study

A comparative study of each FE models from finite element analysis result are carried out for better conclusion of this study. The results from Finite Element Analyses presenting lateral-torsional buckling behavior of the castellated I beam with corrugated webs have been collected shown in Table- 3.

By analyzing the chart -1, 3 models -model M5 (S/Do=1.4), M10 (S/Do=1.3) and M15(S/Do=1.2) have equal web depth and opening size and also their c/c spacing is in increasing order shows comparatively satisfactory performance against loading. 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.

**Table -3:** FE Analysis result

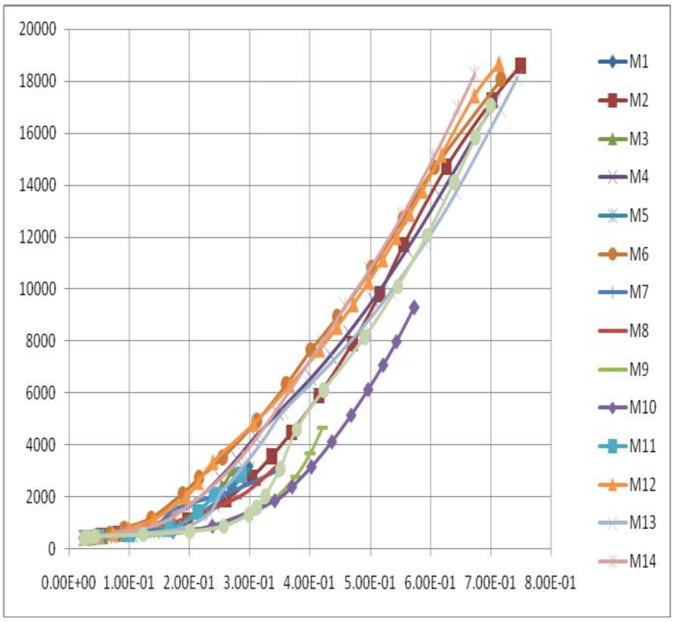
| Model No | Load at yield (KN) | Max. Deformation (mm) | Moment of reaction (KNm) | Rotation about x axis (°) |
|---|---|---|---|---|
| M 1 | 90 | 125.89 | 3.181 | 0.29691 |
| M 2 | 173.70 | 430.65 | 18.59 | 0.74906 |
| M 3 | 92.50 | 131.91 | 3.087 | 0.27204 |
| M 4 | 170.60 | 409.73 | 17.242 | 0.70695 |
| M 5 | 106.20 | 135.78 | 3.056 | 0.29955 |
| M 6 | 170.60 | 422.237 | 18.093 | 0.71696 |
| M 7 | 92.90 | 125.08 | 3.045 | 0.34833 |
| M 8 | 90 | 125.77 | 3.174 | 0.34296 |
| M 9 | 105 | 172.87 | 4.671 | 0.42015 |
| M10 | 130 | 274.02 | 9.282 | 0.57236 |
| M11 | 92.90 | 117.18 | 2.853 | 0.28669 |
| M12 | 171.20 | 429.25 | 18.668 | 0.71284 |
| M13 | 174.40 | 417.79 | 18.113 | 0.7437 |
| M14 | 170.70 | 422.91 | 18.29 | 0.67267 |
| M15 | 170.90 | 403.31 | 17.059 | 0.69956 |




X axis- Total deformation in m

Y axis- Applied load in N

**Chart-1:** Load -Deformation curve from FE Analysis




X axis- Rotation about x axis in (º)

Y axis- Moment in Nm

**Chart-2:** Moment- Rotation curve from FE Analysis

In general, the FE models capable to the prediction of the complete moment- rotation curve and also to estimate effectively the rotation capacity. The results obtained from the developed FE models show significant effect on the moment- rotation curve.

## 4. CONCLUSIONS

In this study, lateral-torsional buckling of the inelastic castellated I beam with corrugation profiles of the web has been considered.

- All the specimens failed due to lateral buckling on top compression flange.
- If the models has equal web depth and opening size and also their c/c spacing is in increasing order, model with lowest spacing able to carry maximum load at minimum rate of deformation
- The FE models appear capable in the prediction of the complete moment- rotation curve and to estimate effectively the rotation capacity
- Sinusoidal openings give less stress concentration at opening.

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