IJISET - International Journal of Innovative Science, Engineering & Technology, Vol.4 Issue 5, April 2018
ISSN (Online) 2348 – 7968
www.ijiset.com

Evaluation of Torsional Buckling for Beam Structures

Archana Maria Thankachan[1], Anna M Thomas[2]

[1]Civil Engineering Department, APJ Abdul Kalam Technological University, Mar Baselios Institute of Technology and Science, Nellimattom, Ernakulam, Kerala, India

[2]Civil Engineering Department, APJ Abdul Kalam Technological University, Mar Baselios Institute of Technology and Science, Nellimattom, Ernakulam, Kerala, India

Abstract

This paper deals with the parametric study of castellated I beam with corrugated web and beam having web holes subjected to torsional buckling. Torsional buckling occurs in an unrestrained beam. Castellated beam with corrugated web are light weight sections with high strength compared to simply corrugated web. The use of castellated beam reduces cost. The corrugated beam is castellated with varying shapes. Main aim of this research is to compare simply corrugated beam and castellated beam with web corrugation and also to study the effect of number of web holes. Analysis is done with the help of finite element software Ansys. The maximum total deformation is less in the case of beam with castellation. In case of web holes, providing medium number of web hole shows better result.

Keywords: *Buckling, Castellated beam, Corrugated beam, I beam, Finite element, Total deformation*

1. Introduction

In this thesis, the study of buckling of castellated I beam with trapezoidally corrugated web will be investigated. Castellated steel beam with corrugated web are lightweight sections with high strength. While, 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 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.

In this study the effect of castellation shape in buckling is analyzed. Four models were taken for analysis. Each having trapezoidal corrugation and varying castellation. One model is simply corrugated and other models are having circular, hexagonal and octagonal castellation respectively. Only the shape of castellation changes but area remains constant. In case of effect of number of web holes, six models are analyzed by varying number of holes from 3-8.

2. Parametric Study

The main aim is to examine how ANSYS, the finite element software examines buckling of simply supported beam. And also to study the effect of castellation in I beam and effect of number of holes.

2.1 Description of Models

Four models are taken for analysis of effect of corrugation, each having trapezoidal web corrugation. One model is simply corrugated and other three models are with castellation. Circular, hexagonal and octagonal castellation are used. Each model was created in ANSYS. Six models are analyzed to study effect of number of web holes, by varying number of holes from 3-8.

2.2 Cross Section Geometry

The following labeling is used in this thesis. In case of web holes for each model the ratio of hole diameter to centre to centre distance between holes is taken as a constant 0.333.

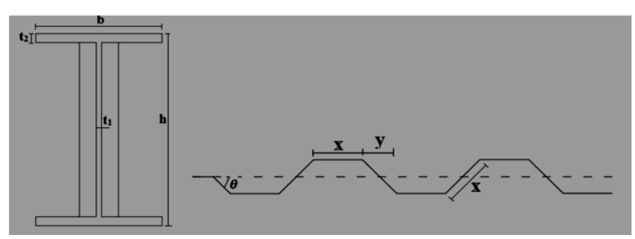

Fig. 1 Notations for the geometry of cross section and corrugation profile

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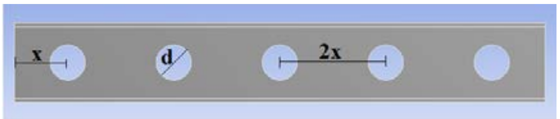

Fig. 2 Geometry for web holes

Table 1: Geometry of corrugated profile

NOTATION	***VALUE***
b (mm)	188
h (mm)	300
t_1 (mm)	8
t_2 (mm)	14
x (mm)	71
y (mm)	50.2
θ (^{o})	45

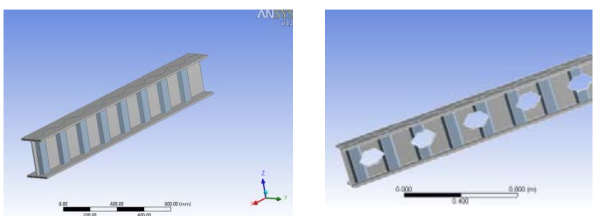

Fig. 3 Three dimensional model of simply corrugated beam and beam with castellation

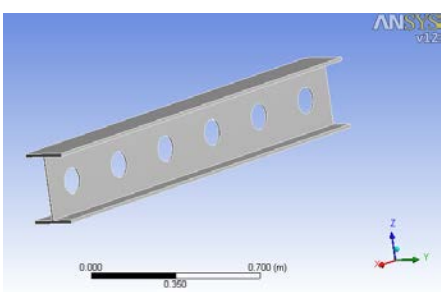

Fig. 4 Three dimensional model of beam with web holes

2.3 Meshing

The goal of meshing in ANSYS Workbench is to provide robust, easy to use meshing tools that will simplify the mesh generation process.

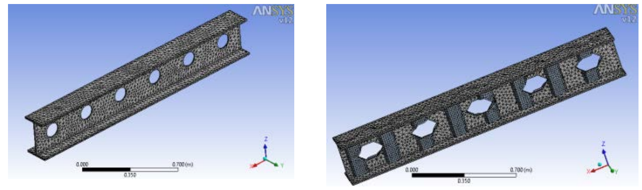

Fig. 5 Meshing of beam with web holes and beam with castellation

Various types of meshing are available in Workbench including assembly meshing, body level meshing and meshing by different element sizes. In this case fine meshing having 14mm size is used.

2.4 Boundary Conditions and Loading

All beams sections were simply supported and applied by compressive loads at ends. When compressive load is applied on a simply supported beam there occurs torsional buckling.

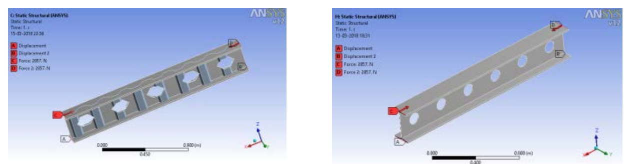

Fig. 6 Loading diagram

3. Finite Element Analysis

Depending on the type of physics involved provides several means to control the solution of the physics simulation. There may be several effects that can cause higher stiffness in the finite element models.

3.1 Static Structural Analysis

A static structural analysis determines the displacements, stresses, strains and forces in structures or components caused by loads that do not induce significant inertia and damping effects. The types of loading that can be applied in a static analysis include: externally applied forces and pressures, steady state inertial forces, imposed displacements and temperatures. A static structural analysis can be either linear or nonlinear.

Total Deformation

Deformation pattern is obtained as similar for all models. Maximum total deformations obtained for each model are as follows:-

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Table 2: Maximum deformations

MODELS		*MAX. TOATAL DEFORMATION (mm)*
Without Castellation		0.010064
With castellation	Circular	0.010092
	Hexagonal	0.010089
	Octagonal	0.010044
With Web Holes		
3		0.010148
4		0.010062
5		0.010042
6		0.010051
7		0.010058
8		0.010056

Table 3: Maximum equivalent stresses

MODELS		*MAX. EQUIVALENT STRESS (Pa)*
Without Castellation		3.9826×10^{6}
With castellation	Circular	3.1192×10^{6}
	Hexagonal	3.1567×10^{6}
	Octagonal	3.2352×10^{6}
With Web Holes		
3		2.1150×10^{6}
4		3.2175×10^{6}
5		3.2250×10^{6}
6		3.1919×10^{6}
7		3.2709×10^{6}
8		3.1932×10^{6}

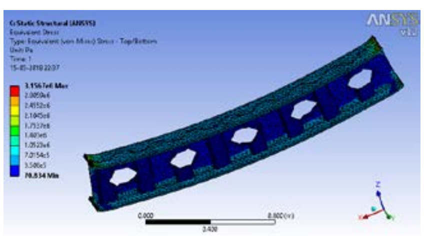

Fig. 7 Deflection pattern

Equivalent Stress

Equivalent stress pattern is similar for all models. Stress values for each model are as follows:-

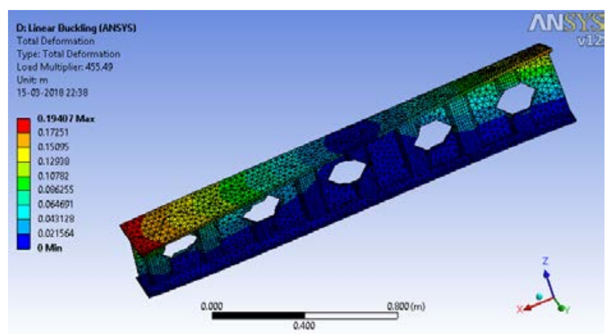

Fig. 8 Equivalent stress pattern

3.2 Buckling Analysis

Buckling analysis is a technique used to determine buckling loads or critical loads, at which a structure becomes unstable and buckled mode shapes, the characteristic shape associated with a structure's buckled response. Two techniques are available in ANSYS for predicting the buckling load and buckling mode shape of a structure: nonlinear buckling analysis and Eigen value or linear buckling analysis.

Table 4: Result of buckling analysis

MODELS		***TOTAL DEFORMATION (m)***
Without Castellation		0.18641
With castellation	Circular	0.18543
	Hexagonal	0.19407
	Octagonal	0.19156
With Web Holes		
3		1.0541
4		1.0541
5		1.0547
6		1.0550
7		1.0552
8		1.0552

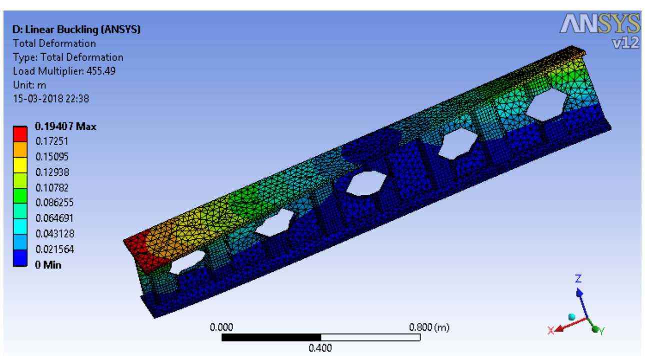

Fig. 9 Buckling mode shape

4. Conclusions

From the above results it is clear that, the maximum total deformation is less in the case of beam with octagonally shaped castellation compared to beam without castellation. The equivalent stress is more in case of web corrugated beam without castellation. Buckling result is better in case of beam with castellation. So we can conclude that beam with castellation is better compared to simply corrugated beam. In case of web holes, better result is obtained for five numbers of holes. So we can conclude that, providing a medium number of web holes will give better result.

Acknowledgments

I express my deepest sense of gratitude to Ms. Anna M Thomas, Asst. Professor, MBITS, Nellimattom, my guide, for her warm encouragement, thoughtful guidance, insightful decision, critical comments and correction of the thesis. I also express my sincere thanks to all the faculty members and students of the Civil Engineering Department of Mar Baselios Institute of Technology and Science for their cooperation and support.

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