Study on Stiffened Cold-Formed Steel Sections with and without Web Openings

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Abstract -*Cold formed steel sections are normally used in construction. These CFS elements can be used as compression members and beam element. Sometimes during construction holes are to be provided in these elements due to constructional needs. Making holes in these sections reduces its strength. Hence certain methods are adopted to strengthen or stiffen the steel section. The model is subjected to three-point loading. Then the best model is selected.*

Key Words: Cold-formed steels sections -Steel Beam-Stiffening -Stiffened steel section -Web stiffening -Flange stiffening -Strengthening methods -Web strengthening -Hole strengthening -Three-point loading.

1. INTRODUCTION

Cold-formed steel sections are normally used in construction. In large constructions these steel sections need to withstand large loads and undergo large amount of deflection. During construction sometimes, holes are to be provided in these steel sections due to constructional needs. Holes are mainly made for the passage of electrical wires, pipes, conduits etc. Creating these holes damages the structural integrity of the section. Steel sections must be stiffened before using it in large constructions. Stiffening is done to give certain amount buckling strength to the steel section. The stiffening procedure is done by proving crimps in the web and flange. The models with stiffening elements (WSE) and without stiffening elements (WOSE) are analyzed. In this paper sections with crimps in both web and flange are tested. The crimps are provided at 45° angle. Then holes are provided on these sections and analyzed for loading conditions.

The use of cold-formed steel members in building structures has increased significantly. Stiffened compression elements have both edges of the element parallel to the direction of stress stiffened by a web, flange, or stiffening lip. Manufacturers have been using light-gauge high-strength steels together with innovative technologies to strengthen the demand for cold-formed steel construction. Cold formed steel sections are easy to produce and efficient in cost. The various methods are providing crimps on the flanges, web and providing lips on flanges. In CFS structures web openings are to be provided to facilitate ease of services, electrical supply lines, cables, water pipes. Creating such holes in the web can cause reduction in the web crippling strength. To overcome this problem several methods are adopted to strengthen the steel section. The methods used are web stiffening and hole stiffening. There are two types stiffening methods- web stiffening and hole stiffening methods. In web stiffening method external steel elements are provided on the web by two methods namely web stiffener and truss stiffener. In web stiffener vertical and horizontal CFS plates are provided throughout the web. In truss stiffener inclined CFS plates are provided in the form of a steel truss. In hole stiffening method CFS plates are provided as a support to the hexagonal openings provided at the web. There are basically two methods- Plate stiffener and ring stiffener. In plate stiffener CFS plates with corresponding openings are placed at the web openings throughout the beam on both sides along the entire span. In ring stiffener CFS rings are provided at the web openings throughout the entire span of the beam. Hence the crippling strength of CFS sections with holes are improved. This project investigates the structural behavior of CFS sections with stiffened and unstiffened elements under flexural bending test. We choose a better section and make holes in the web and study the structural behavior of that sections. Certain strengthening methods are done on the sections. The best model with highest load carrying capacity is found.

2. FINITE ELEMENT MODELLING

2.1 General

To investigate structural performance of cold formed steel sections, modeling of structure was done using SOLID186 element of ANSYS 16.1

2.2 Scope

Scope of the work is limited to find the load carrying capacity of cold formed steel structures (CFS) with stiffeners, hexagonal web openings and strengthening methods, using nonlinear finite element approach.

2.3 Objectives

To investigate the structural behavior of cold formed steel structures with stiffened elements under flexural bending. To study the behavior of steel sections with hexagonal web openings after stiffening. Strengthening elements by web stiffening and hole stiffening method. Web stiffening can be done providing truss type CFS plates on web and by vertical and horizontal plates on the web. Hole stiffening can be done by providing ring stiffener and plate stiffener.

2.4 Geometry and Material properties

Cold formed steel beam models have a span of 1837.5mm, depth of web 175mm and width of flange 60mm. The thickness of the entire steel sections and all other elements is 1.2mm. The beam was made up of steel with yield strength of 200GPa, Poisson's ratio of 0.3 and ultimate strength of 630MPa. The diameter of the hexagonal openings is 87.5mm.

Table -1: Material properties of steel beam models

Properties	Description
Density (kg/m^3)	7850
Young's modulus (MPa)	210000
Poisson's ratio	0.3

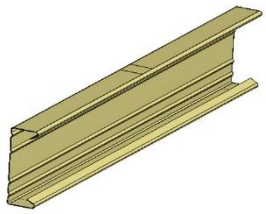

Fig -1: WSE- on web without web openings

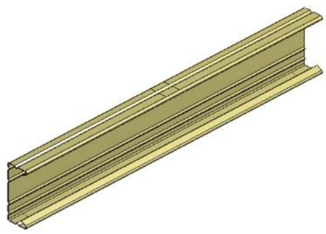

Fig -2: WSE- on web & flanges without web openings

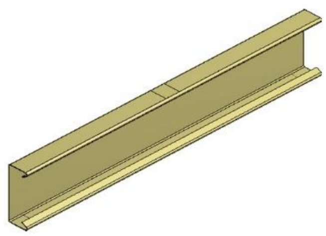

Fig -3: WOSE- without web openings

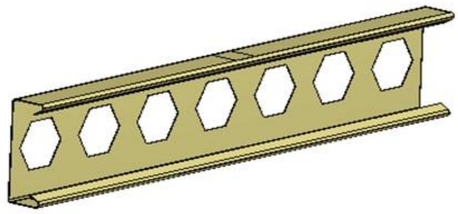

Fig -4: WOSE- with web openings

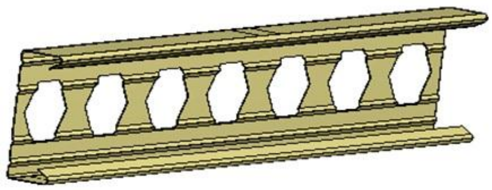

Fig -5: WSE- on web with web openings

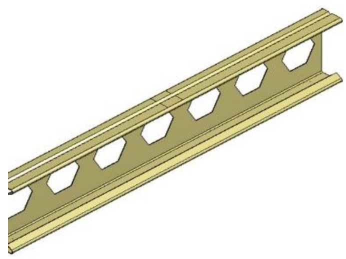

Fig -6: WSE- on flange with web openings

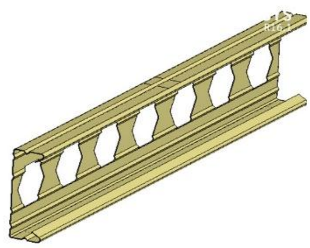

Fig -7: WSE- on web & flange with web openings

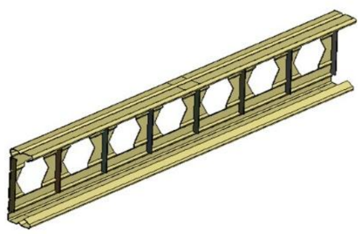

Fig -8: CFS model with Web stiffener

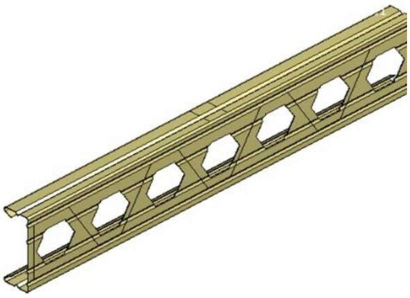

Fig -9: CFS Model with truss stiffener

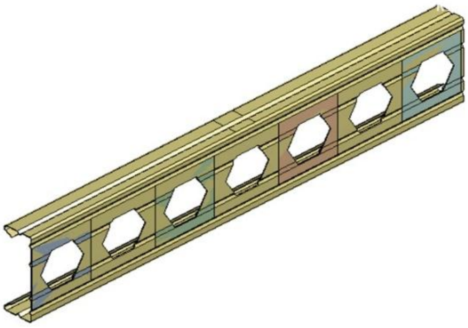

Fig -10: CFS model with plate stiffener

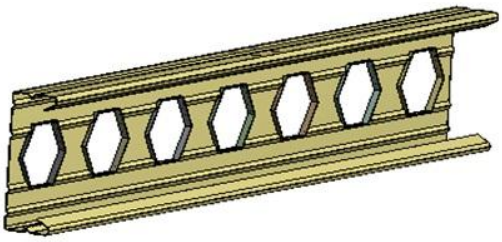

Fig -11: CFS model with ring stiffener

2.5 Meshing

To understand structural behavior properly solid models were subjected to meshing. Meshing divided whole model into finite elements. After meshing solid models were converted into finite element models.

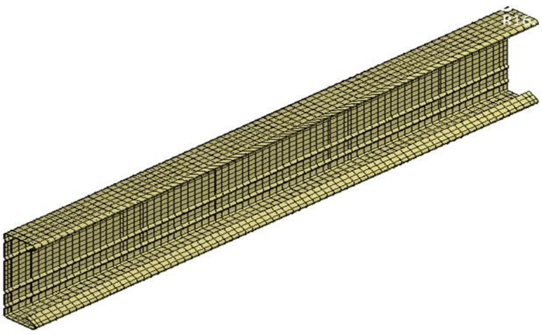

Fig -12: Meshing of 3D model in ANSYS 16.1

2.6 Loading and Boundary conditions

To stimulate real conditions, cold formed steel beams were analyzed with a simply supported system at both ends and load was applied at midspan in one direction. The load was placed at 918.75mm from the ends. The bilinear isotropic hardening rule was used for finite element analysis.

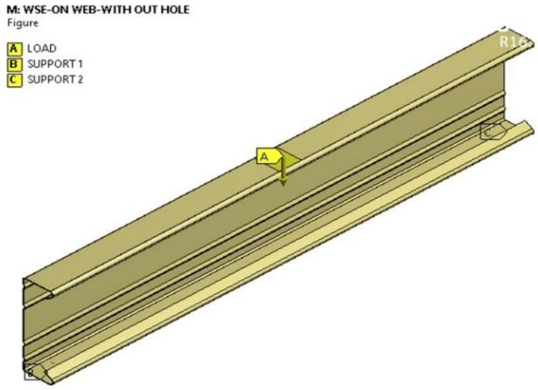

Fig -13: 3-point loading

3. RESULTS AND DISCUSSIONS

3.1 Three-point loading test

CFS beams were subjected to three-point loading. The models were simply supported at the ends and load was applied at the midspan of the model. From the load deflection graph, ultimate load carrying capacity and total deformation of the models were obtained and compared.

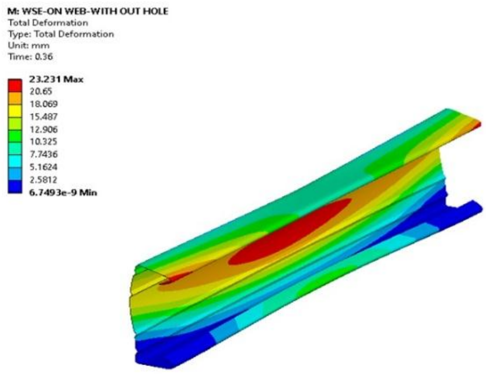

Fig -14: Total deformation of WSE- on web without web openings

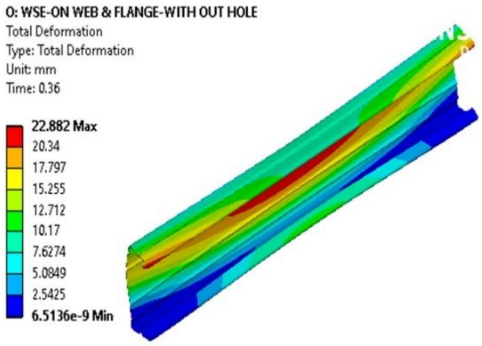

Fig -15: Total deformation of WSE- on web & flanges without web openings

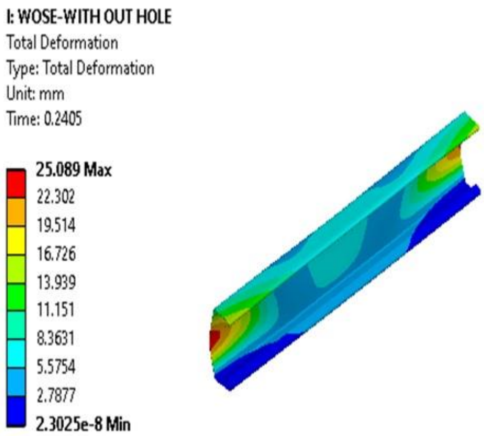

Fig -16: Total deformation of WOSE- without web openings

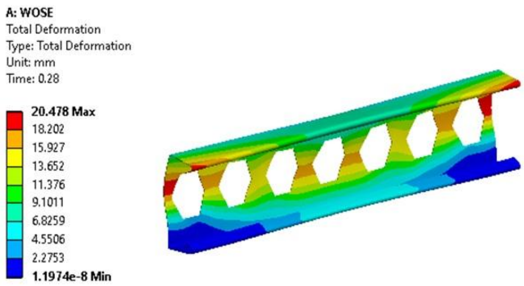

Fig -17: Total deformation of WOSE- with web openings

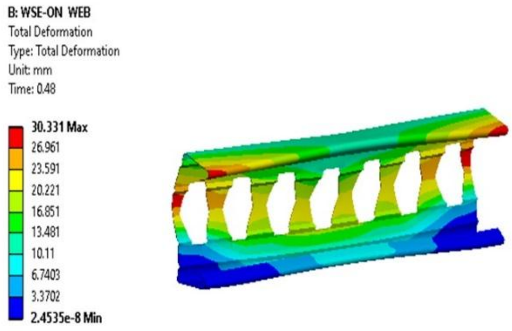

Fig -18: Total deformation of WSE- on web with web openings

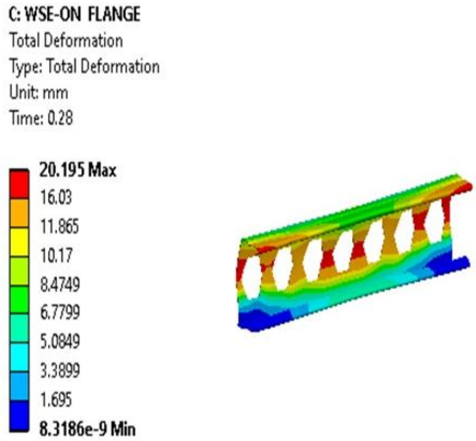

Fig -19: Total deformation of WSE- on web & flange with web openings

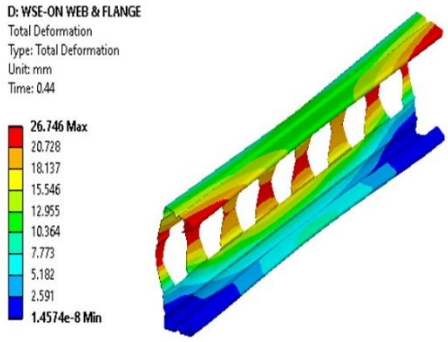

Fig -20: Total deformation of WSE- on web & flange with web openings

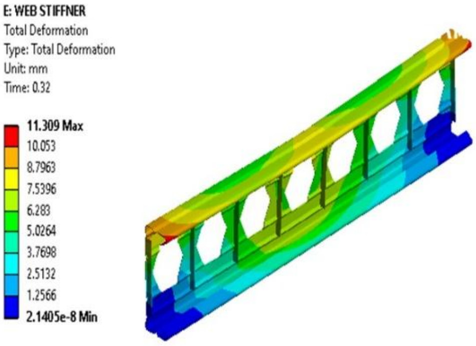

Fig -21: Total deformation of CFS model with Web stiffener

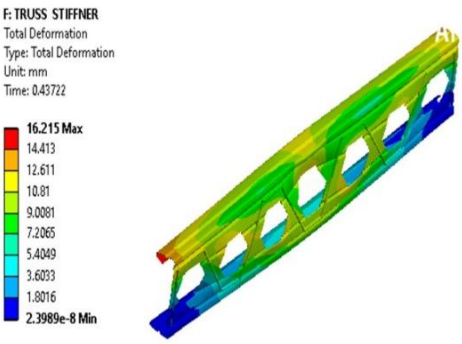

Fig -22: Total deformation of CFS Model with truss stiffener

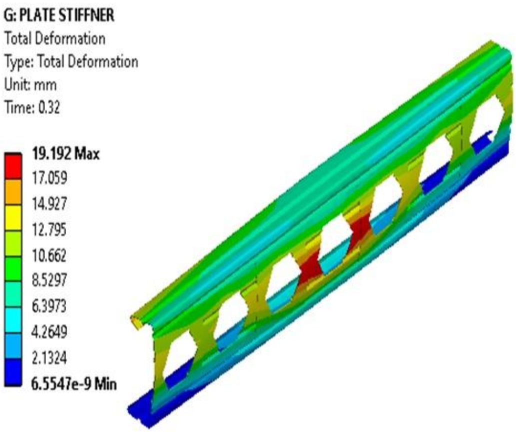

Fig -23: Total deformation of CFS model with plate stiffener

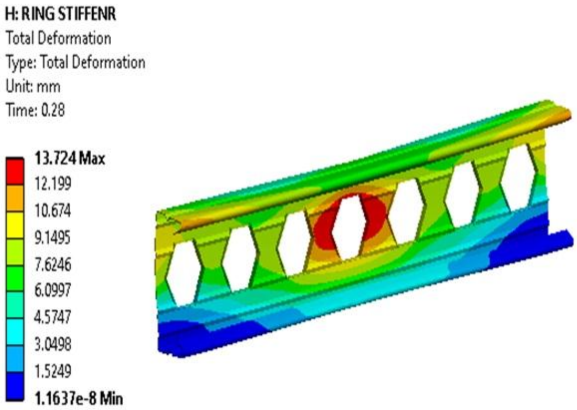

Fig -24: Total deformation of CFS model with ring stiffener

Table -1: Ultimate load and Total deformation of models without web openings

No.	Name	Ultimate load (kN)	Total deformation (mm)
1	WSE- on web without web openings	18.96	23.23
2	WSE- on web & flanges without web openings	19.44	24.49
3	WOSE- without web openings	13.968	25.089

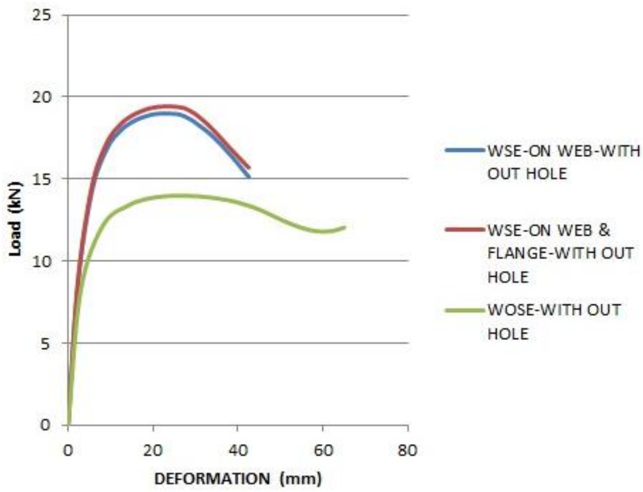

Chart -1: Load deflection graph of models without web openings

Table -2: Ultimate load and Total deformation of models with web openings

No.	Name	Ultimate load (kN)	Total deformation (mm)
1	WOSE- with web openings	12.82	22.92
2	WSE- on web with web openings	14.65	30.33
3	WSE- on flange with web openings	12.40	20.20
4	WSE- on web & flange with web openings	14.05	26.75

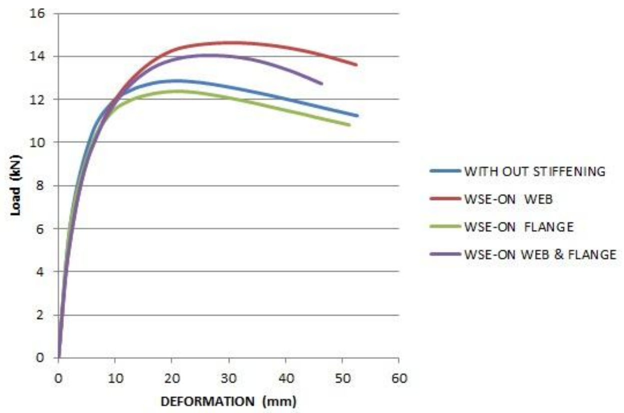

Chart -2: Load deflection graph of models with web openings

Table -3: Ultimate load and Total deformation of models with web openings and stiffeners

No.	Name	Ultimate load (kN)	Total deformation (mm)
1	CFS model with Web stiffener	27.03	11.31
2	CFS Model with truss stiffener	24.93	16.22
3	CFS model with plate stiffener	19.62	19.19
4	CFS model with ring stiffener	22.96	13.72

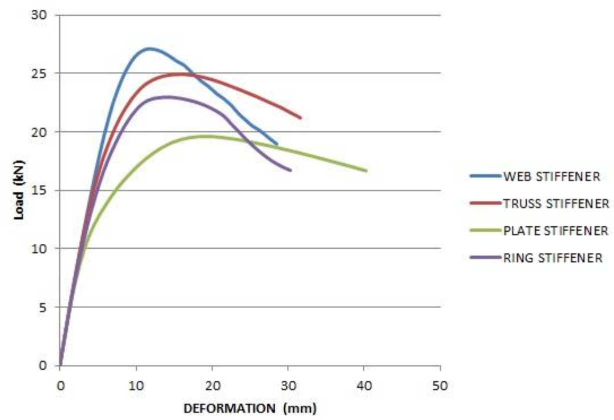

Chart -3: Load deflection graph of models with web openings and stiffeners

By comparing results obtained from the first three models it is found that the model WSE- on web & flange without web openings is having a greater load carrying capacity.

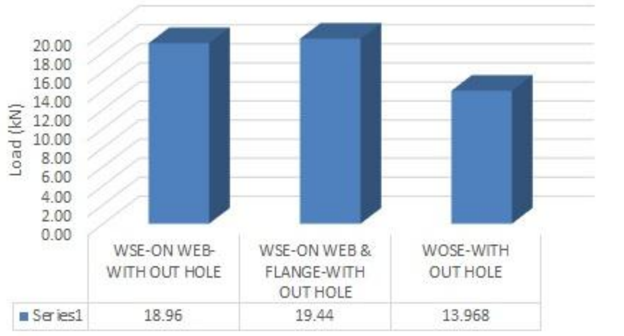

Chart -4: Load comparison graph of models without web openings

By comparing the results obtained from the models with web openings it is found that the model with WSE- on web with openings is having a greater load carrying capacity.

Chart -5: Load comparison graph of models with web openings

By comparing the results obtained from the four models with web openings & stiffeners with the best model obtained from chart 4 it is found that the model with web stiffener is a having a greater load carrying capacity.

Chart -6: Load comparison graph of models with stiffener & web openings

4. CONCLUSIONS

From the study, following conclusions were arrived at

- Model WSE- on web & flanges without web openings is having a higher load carrying capacity than WSE- on web without web openings and WOSE- without web openings.
- Model WSE- on web without web openings has greater strength than WOSE- without web openings.
- Model WSE- on web with web openings is a higher load carrying capacity than WOSE- with web openings, WSE- on flange with Web openings and WSE- on web & flange with web openings.
- Beam models with web openings is having lower strength than beam models without web openings.
- By providing web openings the structural integrity of the CFS beams are compromised.
- To improve the load carrying capacity additional external steel stiffening elements are provided.
- There are two types stiffening methods- web stiffening and hole stiffening methods.
- Out the various stiffening methods discussed web stiffener method is more efficient.
- Model with web stiffener is having a higher load carrying capacity with low deformation than all other models with and without stiffener.

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