Numerical Analysis on Cold Formed Steel Latticed Built-Up I Beam Under Single Point Loading Condition

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Abstract— This paper presents the numerical investigation on combined bending and shear behaviour of cold-formed (CF) steel built-up I section using the software package ABAQUS/Standard (6.10).Eight models are created in two groups, first group of four specimens with 1.2mm thickness and second group of four specimens with 2mm thickness, analyzed under single point loading conditions. The results show the modes of buckling and their influence on the bending strength and behaviour of CF built-up I sections. Finally, a parametric study was undertaken in order to investigate the influence of the height, thickness and span of the beams on its structural behaviour.

Key words: Cold-formed Steel build-up section, ABAQUS/Standard, single point loading, modes of buckling, shear behaviour

I. INTRODUCTION

Thin sheet steel products are extensively used in building industry, and range from purlins to roof sheeting and floor decking. Generally these are available for use as basic building elements for assembly at site or as prefabricated frames or panels.

Cold forming is the term used to describe the manufacture of products by forming material in the cold state from a strip or sheet of uniform thickness. There is a variety of different methods of forming used for cold-formed products in general, but in the case of structural sections, the main methods used are folding, press-braking, and rolling. This process helps getting the specimen to desired size. These are given the generic title Cold Formed Steel Sections. Sometimes they are also called Light Gauge Steel Sections or Cold Rolled Steel Sections. The thickness of steel sheet used in cold formed construction is usually 1 to 3 mm. if pre-galvanized material is not required for the particular application. The method of manufacturing is important as it differentiates these products from hot rolled steel sections.

Experiments and research works say that it has more advantage than hot rolled steel. It provides economic structure. Cold-Formed Steel members have been widely used in building constructions, bridge constructions , storage racks, grain bins ,car bodies , railway coaches ,transmission towers, transmission poles and drainage facilities. cold-formed steel products can be classified into three categories, members, panels, prefabricated assemblies. Typical Cold-Formed Steel members such as studs, track, purlins, and grits are mainly used for carrying loads while panels and decks constitute a useful surface such as floor, roof and walls.

Instability Phenomena, such as local buckling, distortional buckling and lateral buckling and their interactions, are the most interesting and complex subjects within this research field. Understanding and dealing with these phenomena has been a central focus of research efforts. Studies on the structural behaviour of cold-formed steel (CFS) beams are increasingly popular in now a days. These buckling modes are mostly responsible for the ultimate strength of the members as they may occur even before parts of the cross-section yield.

ABAQUS/Standard [6] software is used for numerical analysis. First, all elastic instability modes for the gross cross-section are determined (distortion and lateral torsional buckling mode). Most of the studies in the literature only take into account the structural behavior of CFS members with just one profile and the majority of them is by series of flexural tests focused on cold-formed steel beams consisting of a compound cross-section. Which are often used in roofs of industrial buildings. The object of the paper is to evaluate the ultimate buckling resistance of cold-formed steel section subjected to flexural and there by evaluating their performance.

Thin walled built-up I section beams are economical with same flexural rigidity when compared to thin walled solid web sections. Though this type of sections results in economic type of construction, presently the usage of such members are limited because of the complexity involved in the analysis and prediction of their behaviour become tedious. As this type of sections with open cross section are susceptible to multiple modes of buckling when they are connected together by a system of continuous bent bar with circular cross sections, the behaviour of the beam elements may be governed by local buckling in the component plates, distortional buckling of the outstanding legs and the local buckling of web element. This paper provides the study the behaviour of the latticed cold-formed steel beams.

II. SECTIONS DETAILS

Schematic views of the analytically modeled specimen with single-point loading condition is shown in Figureure.1,

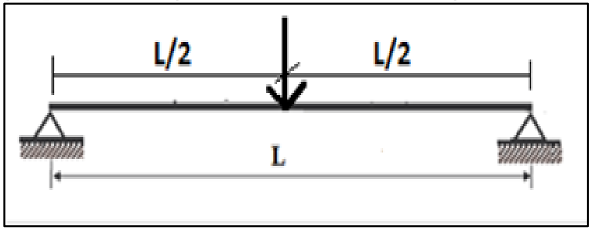

Fig. 1: Schematic view of the loading specimen

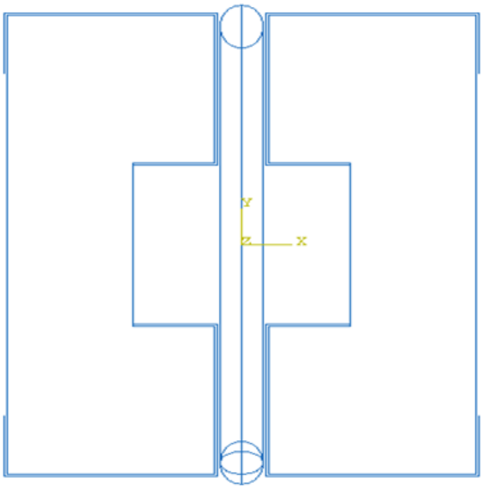

Fig. 2: Cross-section of beam

Four angles of 50mm size were used to create each built-up I beam. Totally eight models were created by varying thickness of angle, depth and length of the beam.Four models with 1.2 mm thikness and four with 2mm thickness were created.

Specimen	Overall Depth, D (mm)	Web Opening, O (mm)	Thickness t (mm)	Span L (mm)
B-1	150	50	1.2	1500
B-2	200	100	1.2	1600
B-3	250	150	1.2	1500
B-4	150	50	2.0	1500
B-5	200	100	2.0	1600
B-6	250	150	2.0	1500
B-7	150	50	1.2	1800
B-8	150	50	1.2	1800

Table 1: Specimen Details

III. NUMERICAL ANALYSIS

The numerical analysis was carried out using the finite element program ABAQUS with geometrical nonlinearity. It was used to simulate the model and find buckling mode and strength of cold-formed steel beams under single point loading condition.

A. *Elements*

The model is a combination of 3 parts which are Cold formed angle (50x50x1.2 mm CFS angle),3mm thick Stiffener plate to connect the compression and tension flanges and 10mm diameter lacing bar inclined at 450 along the length of the beam

B. *Material Properties*

The elastic properties of the material were assigned to the created model of built-up beam. The value of Young’s modulus ‘E’ from the Coupon test is 2x105 N/mm2. The Poisson’s ratio is = 0.3. The yield stress of the cold formed angle from the Coupon test is 235 MPa and that of lacing bar is 415MPa. Density of the material is 7.850x10-9N/mm3.

C. *Meshing*

For meshing approximate global size is given as 5

- For angle sections, S4R (Shell-Four node elements) element type is used.
- For stiffeners, S4R (Shell-Four node elements) element type is used.
- For lacing rod C3D4 (Continuum-3D-Four node elements) element type is used.

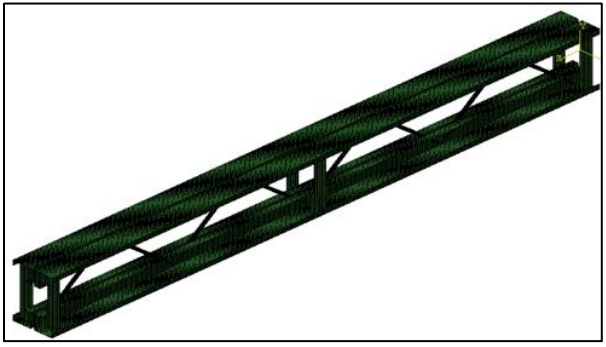

Fig. 3: Meshing of built-up I beam

D. *Boundary Condition*

One end of the specimen was constrained in X, Y and Z directions and the other end of the specimen was constrained X and Y direction.

Here in our problem the built-up beam is analyzed with simply supported end conditions. So that displacement components U1, U2, and U3 are restrained at one end and displacement components U1 and U2 are restrained at another end.

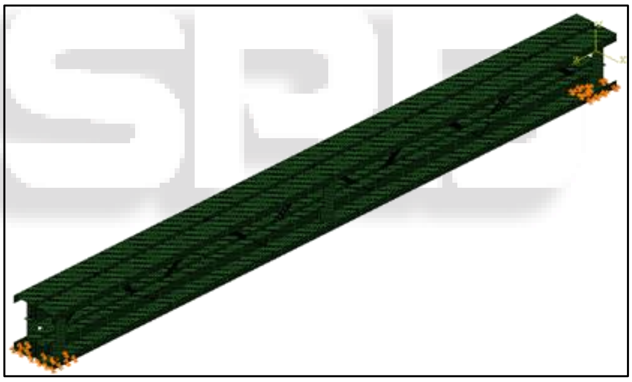

Fig. 4: Applying boundary conditions

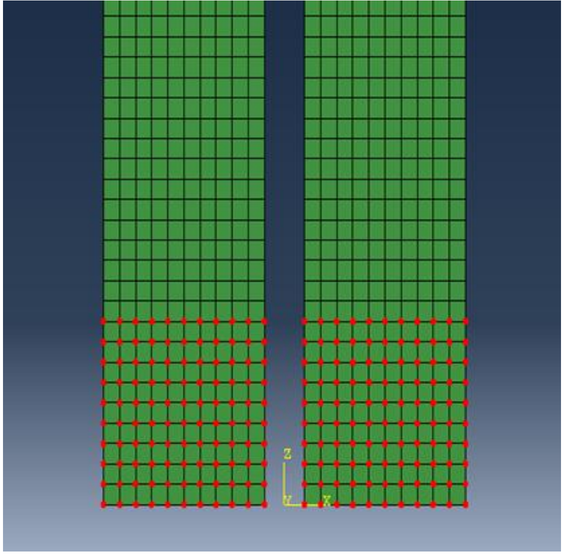

Fig. 4: Applying boundary conditions

E. Load

The analysis is carried out for concentrated mid span load. The pressure for a width of 50mm was applied along transverse lines of the upper surface of the top flange above the stiffener.

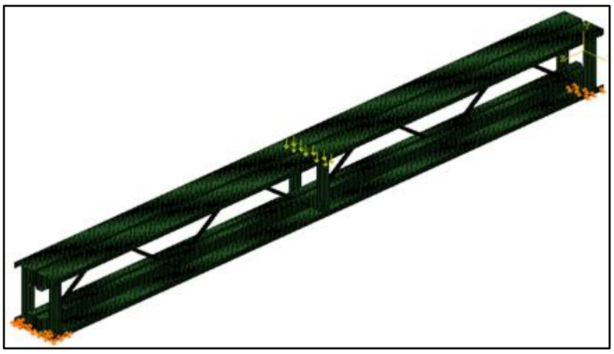

Fig. 5: Applying load

IV. ANALYSIS

Then, the nonlinear static analysis with geometrical and material imperfections (GMNIA) was undertaken under bending. A non-linear geometric parameter (*NLGEOM=ON) [11] was set to deal with the geometric nonlinear analysis, namely, with the large displacement analysis, and Vertical displacements were also monitored .The parameters used in the nonlinear static analyses were;

- Maximum number of load increments = 100.
- Initial increment size = 0.1.
- -Minimum increment size = 0.000001.
- -Automatic increment reduction enabled, and large
- Displacements enabled [13]

V. ANALYTICAL RESULTS &DISCUSSION

A. Load-Carrying Capacity

Comparison of the load–vertical displacement curves of CFS beam obtained from finite element analysis (FEA) are shown in Figure.6,7,8,9,10,11,12,13and14. In the numerical Simulations, it can be seen that the maximum moment carrying capacity of the built-up I beam for the different sections that was Changed in Depth, thickness and span respectively.

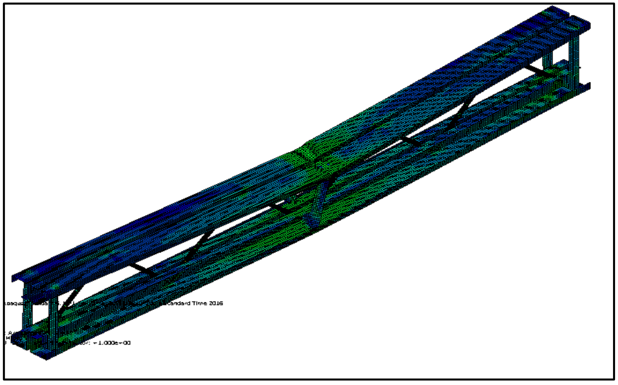

Fig. 7: Failure mode of 50-50-200-1.2-1600

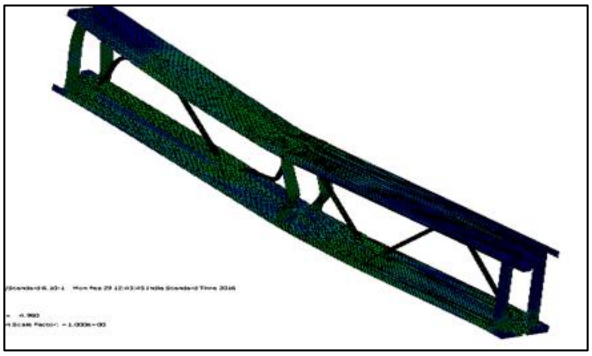

Fig. 8: Failure mode of 50-50-250-1.2-1500

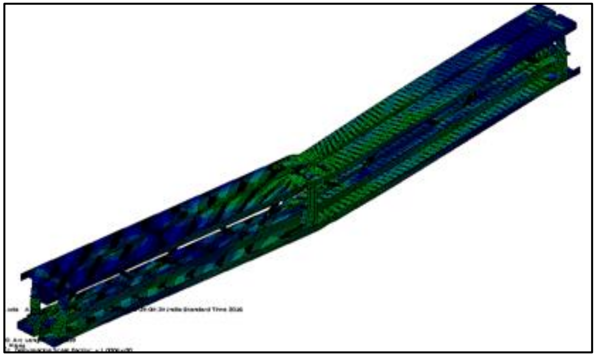

Fig. 10: Failure mode of 50-50-150-2-1500

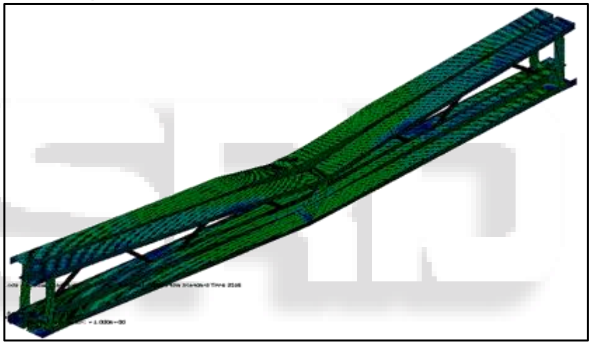

Fig. 11: Failure mode of 50-50-200-2-1500

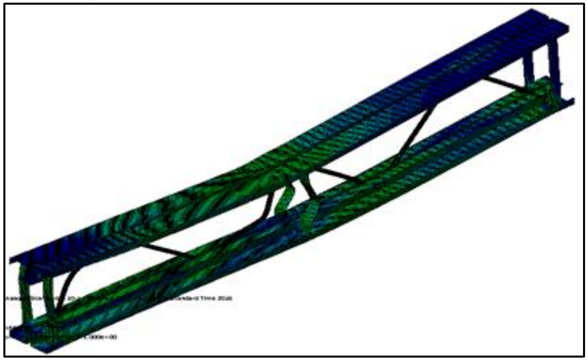

Fig. 12: Failure mode of 50-50-250-2-1500

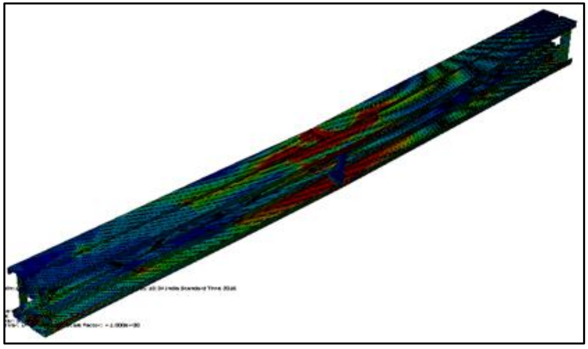

Fig. 13: Failure mode of 50-50-150-1.2-1800

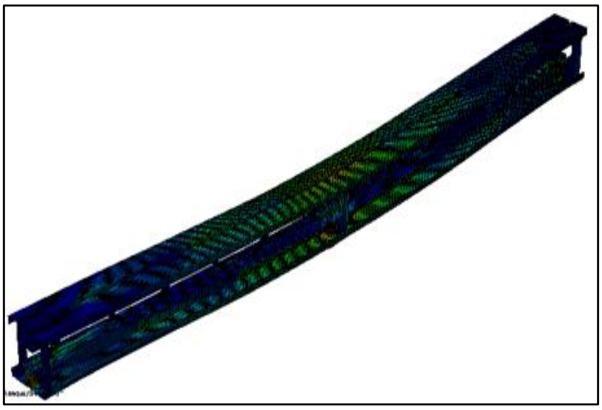

Fig. 14: Failure mode of 50-50-150-2-1800

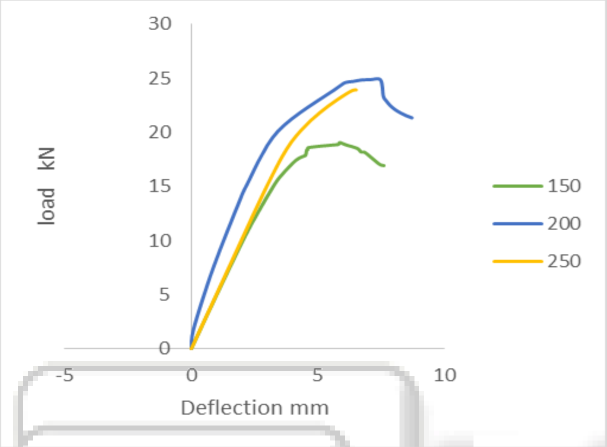

Fig. 15: Load-Deflection curve for 1.2mm thickness

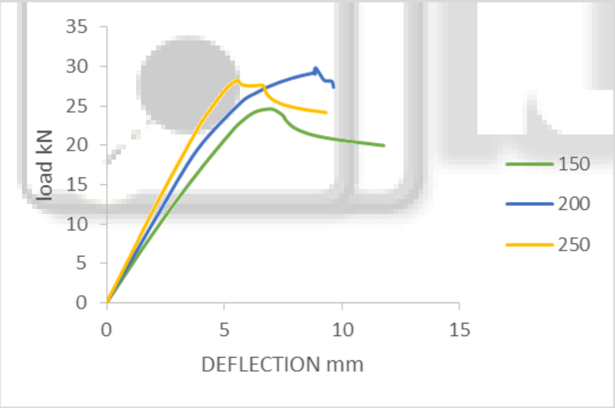

Fig. 16: Load-Deflection curve for 2mm thickness

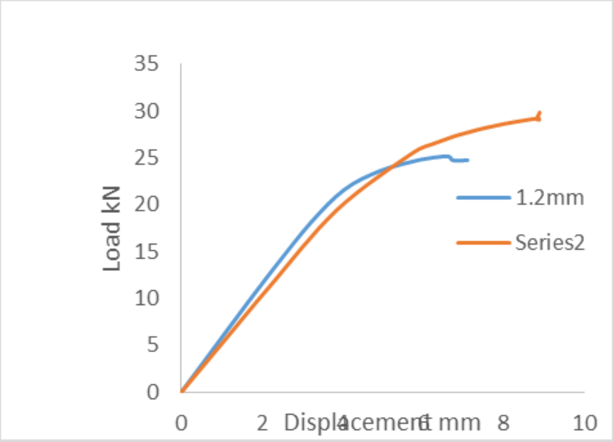

Fig. 17: Failure mode of 50-50-150-1.2-1800

The lacing failure was took place in the beam with 150mm opening depth. Stiffeners were failed in 200mm and 250mm depth beams. So that, the opening depth plays an important role in buckling and moment carrying capacity of beam.

Specimen (mm)	Ultimate Load (kN)	Ultimate Moment (kNm)	Type of Buckling
50-50-150-1.2-1500	19.18	7.192	L
50-50-200-1.2-1600	24.82	9.928	DT SF
50-50-250-1.2-1500	23.73	8.898	DT SF
50-50-150-2.0-1500	24.88	9.33	L D
50-50-200-2.0-1600	29.74	11.88	DT SF
50-50-250-2.0-1500	28.98	10.867	SF LF
50-50-150-1.2-1800	24.25	10.912	L
50-50-150-2-1800	29.31	13.189	L

L-Local buckling DT-Distortional buckling SF- Stiffener LF-Lacing failure

Table 2: shows the ultimate load and moment carrying capacity of the built-up beams. From comparison of moment carrying capacity, it is observed that the 200mm depth beams are carrying more load than 150mm and 250mm depth beam.

B. Failure Modes of Built-Up Beams

Various failure modes of CFS beam obtained from finite element analysis (FEA) is shown in Figure.6,7,8,9,10,11,12,13and14. The beams were failed by various buckling modes such as local buckling, Distortional buckling and stiffener failure. The beams having opening to depth (o/d) ratio 0.33 failed due to local buckling of compression flange. Stiffener failure followed by Distortional buckling were occurred in beams having o/d ratio 0.5. Lacing and stiffener failure along with Distortional took place in beams having o/d ratio 0.75. The beams having span of 1800mm exhibits high bending strength.

VI. CONCLUSION

[1] Ultimate moment carrying capacity and modes of failure were studied. From this investigation it is concluded that the built-up beams with 100mm web opening has carried more load.
[2] The bearing stiffener were failed when the opening to depth ratio of web is increased to 0.75. To avoid this, thickness of the stiffener can be increased or some other types of bearing stiffeners can be used.
[3] The lacing bar was failed followed by stiffener failure when the depth of the opening increased to 150mm.
[4] To avoid this failure diameter of the lacing rod can be increased or square shaped bar can be used.
[5] The members failed by distortional buckling exhibited very low post buckling reserve strength, whereas those failed by local buckling showed high post buckling reserve strength.

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