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Buckling Study Of Sigma Shaped Cold-Formed Steel Built Up Sections

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Abstract- Cold-formed steel (CFS) members have been extensively employed in light gauge steel constructions because of their inherent benefits. The increasing demand for CFS sections with higher capacities has necessitated the creation of "built-up" cross-sections by joining multiple single cross-sections. The sigma section, with its shear center's proximity to the web, is reported to possess various structural advantages over ordinary C and Z sections, including better specific strength, stronger torsional rigidity, and higher cross-sectional resistance. The optimization of these CFS members will result in more cost-effective and efficient building solutions by gaining increased load-bearing capacities. Hence, this study aims to determine the sigma sections are back to back in this thesis. The analysis has been done under two-point loading with simply supported condition with both laterally restrained and unrestrained conditions. Finite Element Analysis has been carried out using ABAQUS software. The section selected for analyzing are 150 x 80 x 15 mm and 200 x 100 x 15 mm, 225 x 120 x 15 mm with 1.6 mm thickness having span of 1.5 m. The investigation has thus presented the load carrying capacity and mode shape of sigma section with respect to varying heights and widths both laterally restrained and unrestrained conditions.

Index Terms— Cold Formed section, Abaqus, flexural strength

I. INTRODUCTION

In steel construction, two primary types of structural members are employed hot-rolled steel shapes and cold-formed steel forms. The term "cold-formed steel" pertains to steel that manufacturers produce at room temperature, in contrast to hot-rolled steel, which is manufactured at elevated temperatures. Structural components constructed from Cold-Formed Steel (CFS) are less prevalent but are gaining increasing importance. Cold-formed steel elements are often employed for decking, sheets, wall studs, floor joists, cladding rails, and purlins, among other applications. When compared to bulkier hot-rolled counterparts, they provide a significant improvement in the strength-to-weight ratio. There are numerous shapes on the market, with C and Z sections being the most commonly utilized options in situations involving light loads and medium spans, such as roof systems.

The method known as "cold forming" involves changing the shape and structure of steel by drawing, extruding, hammering, pressing, spinning, or stretching it at temperatures lower than its recrystallization temperature. These processes modify the metal's composition, enhancing surface quality while increasing hardness and tensile strength.

In general, these sections are termed Cold Formed Steel sections. Occasionally, they are also referred to as cold-rolled steel sections or light gauge steel sections. Cold formed construction typically employs steel sheets ranging from 1 to 3 mm in thickness. The production process is pivotal as it distinguishes these components from hot-rolled steel sections.

II. NUMERICAL INVESTIGATION

A. A. General

The project is carried out in two cases. The first case deals with variation in height and width with the unrestrained. The second case deals with variation in thickness and width and height with restrained conditions. With the advance of computational mechanics and computer software, numerical methods have become increasingly popular in research into the behaviour of CFS structures, as they offer advantages in parametric studies and in solving complex problems over experimental and analytical methods.

B. Material properties

For the numerical analysis, the ABAQUS Software requires input of the material stress-strain curves in the form of true stress (σtrue) versus true plastic strain (εtrue). The true stress (σtrue) and true plastic strain (εtrue) are calculated from the engineering stresses (σ) and engineering strains (ε) as follows. The engineering stresses and engineering strains are found out by using formulas in reference journal paper.

$\sigma true = \sigma (1 + \varepsilon)$
$\sigma true = \ln (1 + \varepsilon) – (\sigma true / E)$

The young’s modulus of 2.01 x 105 N/mm2 and the yield stress of 345 N/mm^2.
The true stress and plastic strain values are obtained by using reference journal paper formula and values are used to non linear analysis in abaqus software.

TABLE 1 STRESS AND STRAIN VALUE

True stress(N/mm^2)	Plastic strain
338	0.1007
350	0.124
365	0.153

III. GEOMETRIC DETAILS OF SPECIMENS

The thickness of the sections were fixed and the height and width are varied accordingly. Other geometric parameters such as lip, span were kept constant. height and width increased to aspect ratios of 3.75,4 and 3.75. In the first case specimen kept as the unrestrained condition with yield stress 345 N/mm2 and the second case specimen kept as the unrestrained condition with yield stress 345 N/ mm2.

TABLE 2 SPECIMEN DETAILS

Specimen	Size(mm)	Type	Aspect Ratio	Length (mm)
S1	150X40X 15X1.6	unrestrained	3.75	1500
S2	200X50X 15X1.6	unrestrained	4	1500
S3	225X60X 15X1.6	unrestrained	3.75	1500
S4	150X40X 15X1.6	restrained	3.75	1500
S5	200X50X 15X1.6	restrained	4	1500
S6	225X60X 15X1.6	restrained	3.75	1500

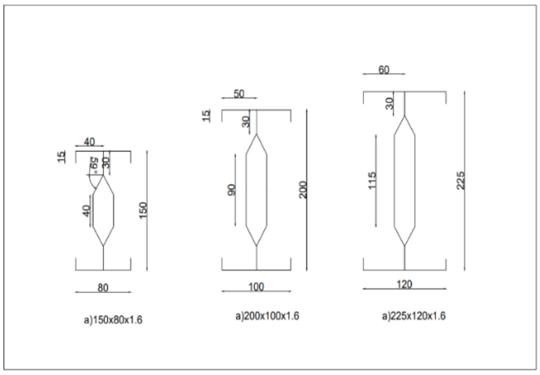

Fig. 1. Cross section details.

III. RESULTS AND ANALYSIS

The load proportionality factors and the deflection plots are obtained from the analysis in ABAQUS. load vs deflection curves are obtained from analysis. The values are then interpreted and the maximum load carrying capacity is obtained for all the sections.

A. Finite Element Analysis

The modelling of sigma section purlins was done by creating 3-dimensional, deformable shell part in ABAQUS. The shell element was used in all the finite element models. Young’s modulus, Poisson’s ratio, Yield stress, Density of the material, True stress and Plastic strain were assigned for material property.

The simply supported boundary conditions and Two-point loading were provided. The size of the mesh was given as 16 mm. Surface-to-surface interactions & tie constrains were given at both ends of the section and at the loading points.

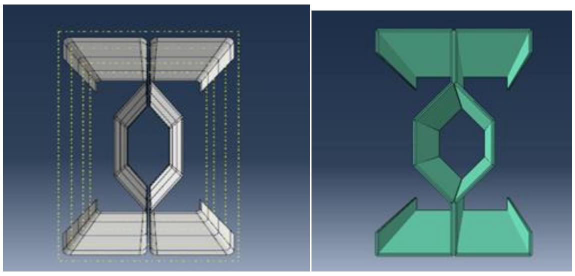

Fig. 2. Modelling of specimen.

The Static Riks method was adopted for analysis in all the three cases. The load proportionality factors and deflection curves are obtained from the analysis. The values are then interpreted and the maximum load is obtained for all the sections. The deflection corresponding to the service load calculated.

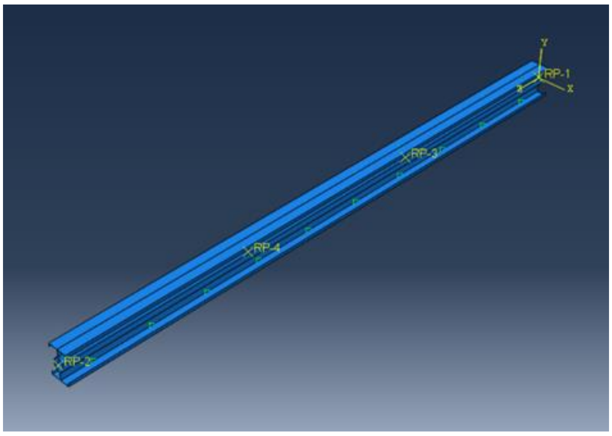

Fig.3. Reference point fixing.

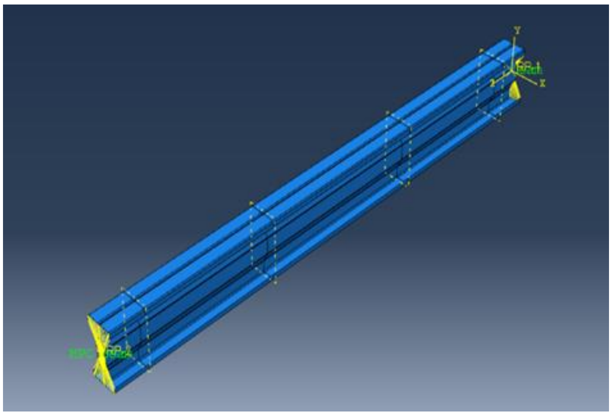

Fig.4. Constrain for unrestrained Specimen.

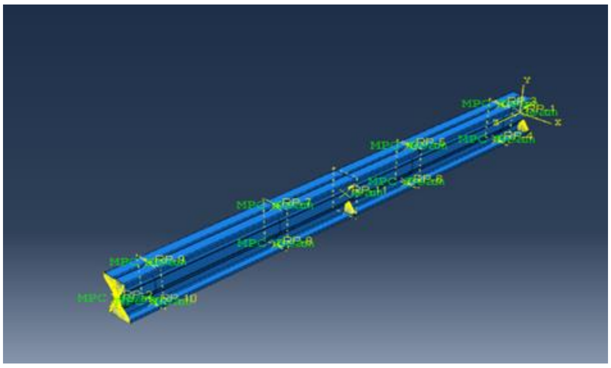

Fig.5. Constrain for restrained Specimen.

B ANALYSIS RESULTS FROM ABAQUS

The values are then interpreted and the maximum load is obtained for all the sections. The load vs deflection curves are plotted and comparisons are done for ultimate load and deflection for all the sections.

TABLE 3 ANALYSIS RESULTS FROM ABAQUS

Specimens	Type	Ultimate Load(kN)	Deflection(mm)
150X80X15X1.6	Unrestrained	28.3	35
200X100X15X1.6	Unrestrained	31.6	31
225X120X15X1.6	Unrestrained	39.8	28
150X80X15X1.6	Restrained	33.4	27
200X100X15X1.6	Restrained	40.2	22
225X120X15X1.6	Restrained	45.3	19

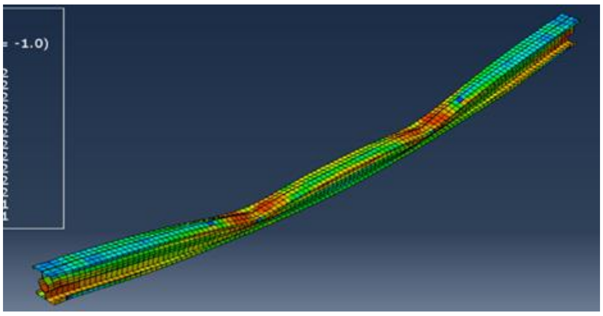

Fig.6. Von Mises Stress Distribution For Specimen 1

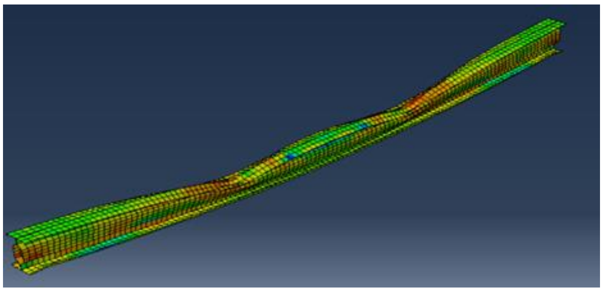

Fig.7. Von Mises Stress Distribution For Specimen 2

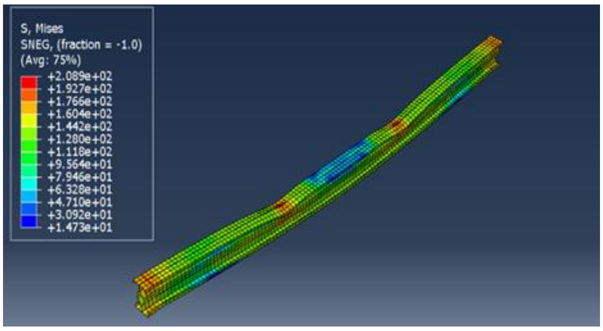

Fig.8. Von Mises Stress Distribution For Specimen 3

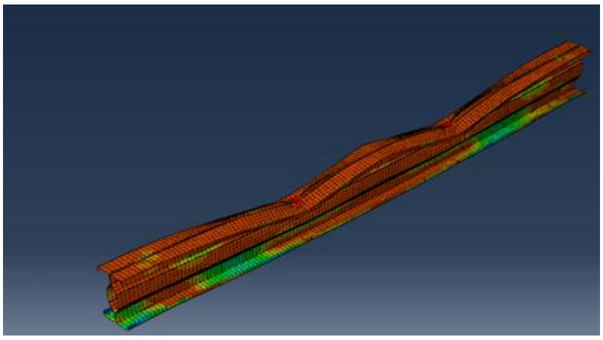

Fig.9. Von Mises Stress Distribution For Specimen 4

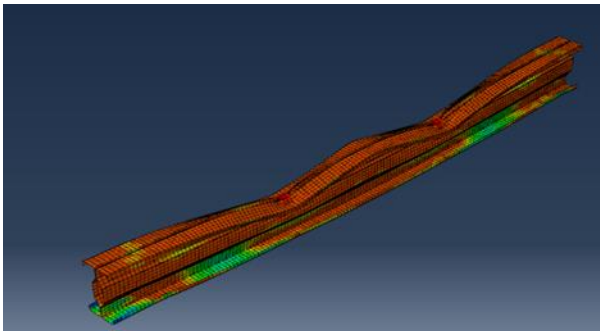

Fig.10. Von Mises Stress Distribution For Specimen 5

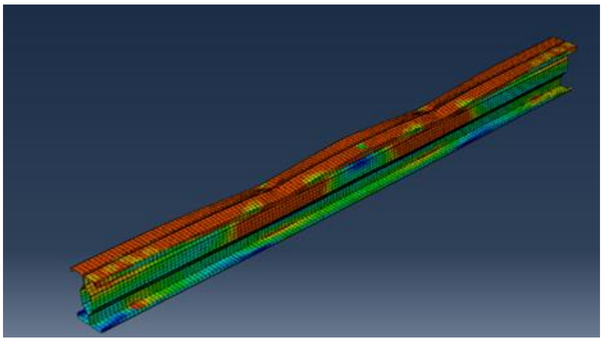

Fig.11. Von Mises Stress Distribution For Specimen 6

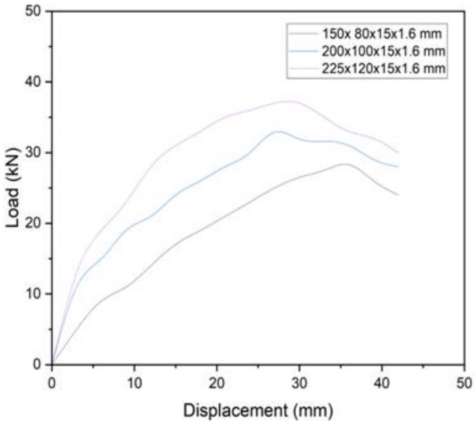

Fig.12. Comparison graph for Unrestrained specimen

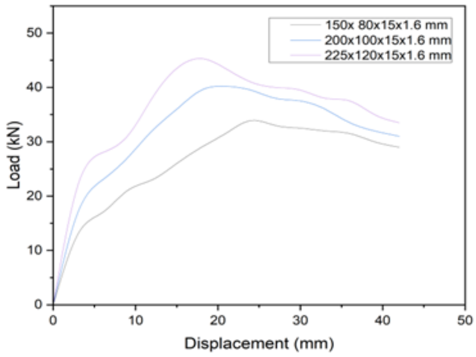

Fig.13. Comparison graph for restrained specimen

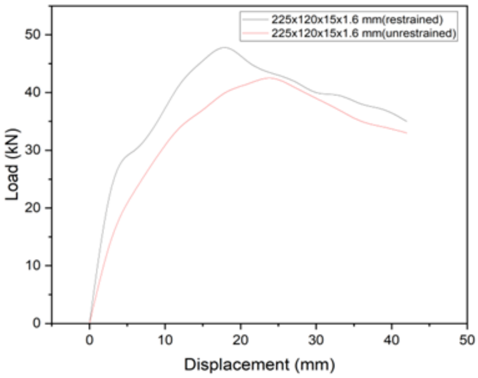

Fig.14. Comparison graph for both Unrestrained and restrained specimen

CONCLUSION

Thus, the numerical investigation is performed in two cases and analysed using Abaqus software. The following conclusions are made for each case respectively.

A. *Case 1 - Variation In Height and Width With Laterally Unrestrained Conditions*

The load carrying capacity of the specimen 3(225x120x15x1.6) is 39.8KN which is higher than the other specimens of laterally unrestrained conditions having 1.6mm Thickness.

The load carrying capacity increases by 11%, 29% by increasing the Height and width of the specimen having 1.6 mm thickness for specimens S2(200x100x15x1.6) and S3(225x120x15x1.6) respectively from S1(150x80x15x1.6).

B. *Case 2 - Variation In Height and Width With Laterally Restrained Conditions*

The load carrying capacity of the specimen 6(225x120x15x1.6) is 39.8KN which is higher than the other specimens of laterally restrained conditions having 1.6mm Thickness.

The load carrying capacity increases by 20%, 36% by increasing the Height and width of the specimen having 1.6 mm thickness for specimens S4 and S5 respectively from S6.

The deflection at the ultimate load decreases with the increase in the height of the specimen.

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