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Analytical investigation of longitudinally stiffened cold-formed steel lipped channel purlins

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***Abstract**-- The maximum deflection of a cold-formed steel purlin can be minimized by introducing longitudinal stiffeners in both web and flange of the section and locating them in appropriate positions along the compression and tension zones.In this paper, a cold-formed steel lipped channel section is modeled in Finite Element Analysis using Abaqus.CAE software and V-stiffeners are located at different positions in the flange and the web individually. The models are subjected to pure bending and the maximum deflection of the tension zone is extracted and comparison is made. An appropriate positioning of V-stiffener in cold-formed lipped channel section is proposed.*

***Keywords**--Abaqus.CAE software, longitudinal stiffening, V-stiffeners,Finite element analysis, Cold-formed lipped channel section,location of stiffeners.*

I.INTRODUCTION

Cold-formed steel sections are more commonly used in industrial structures. CFS sections are manufactured by bending flat sheets at room temperature into complex shapes including stiffeners. Cold-formed steel sections are either press braked or cold-rolled.Major advantage of using a cold-formed steel section is its reduced thickness even upto 1mm. This reduced thickness allows us to manufacture the cold-formed steel into different complex shapes such as sigma, hat, etc., At the same time, because of its very low thickness, cold-formed steel sections are subjected to local, distortional and torsional buckling modes. Buckling plays a major role in the design of a cold-formed section.

Since CFS sections can be manufactured with very low tolerance values, comparatively higher length-thickness ratio leads to different buckling modes. This becomes the major drawback of CFS sections. Hence longitudinal stiffening of the cold-formed steel sections becomes essential. V-stiffeners are located at different points on the flanges of a standard cold-formed lipped channel section using Abaqus.CAE 6.14-1 software and finite element analysis is carried out. The maximum deflection of the tension flange is extractedfor each case and the results are compared. Similarly, the V-stiffeners are located on the web at different positions and the maximum deflection of the tension flange is extracted for each case and comparison is carried out.

II. STIFFENING OF THE SECTION

A. Geometric specimens

A standard cold-formed steel lipped channel section – rectangular is chosen from IS 811:1987 and is shown in the figure 1.

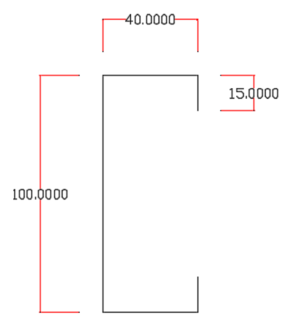

Fig 1. Dimensions of the plain specimen

TABLE 1
DIMENSIONS OF THE SPECIMEN(mm)

Sl.No.	Cross Section Type	Length (mm)	Thickness (mm)	Designation
1	C1	2000	2	C1L2000T2

B. Flange stiffening

The V-stiffener is introduced in the flanges of the CFS lipped channel section at seven different positions and the corresponding deflection values are obtained. The longitudinally flange-stiffened lipped channel sections are shown in the figure 2.

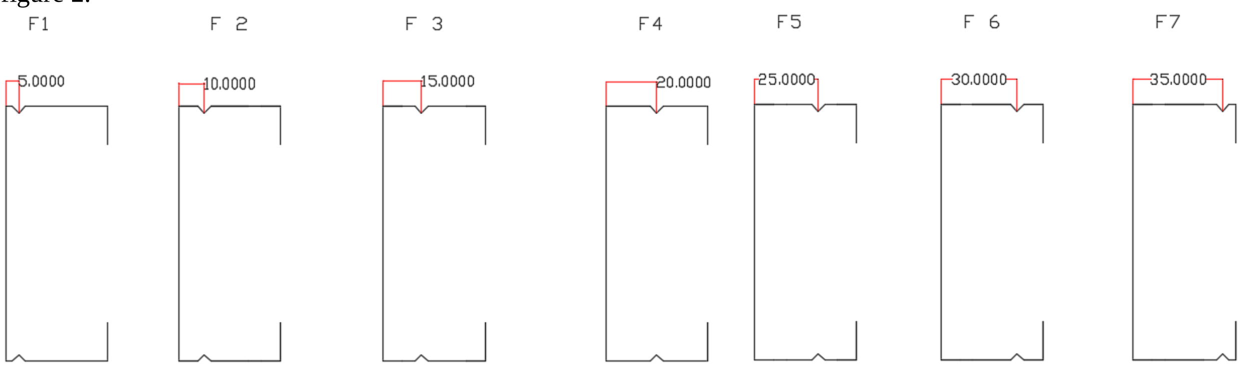

Fig.2 Location of stiffeners at different positions on the flanges.

C. Web stiffening

The V-stiffener is introduced in the web of the CFS lipped channel section at four different positions and the corresponding deflection values are obtained. The longitudinally web-stiffened lipped channel sections are shown in the figure 3.

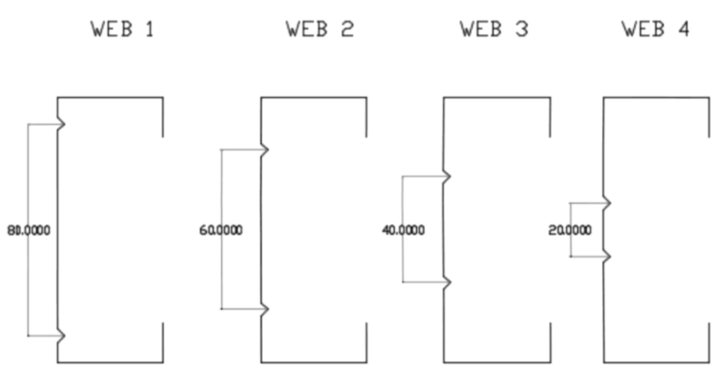

Fig.3 Location of stiffeners at different positions on the web.

D. Material properties

The material properties of the cold-formed lipped channel sections for analyzing in ABAQUS are listed below

Young’s modulus - 2.06×10^5 N/mm^2

Poisson’s ratio - 0.3

Yield stress - 240 N/mm^2

The plastic strain values are obtained from coupon test and are used to perform non-linear analysis of the sections in Abaqus software.

III. FINITE ELEMENT ANALYSIS

A. Modeling and meshing

The cold-formed steellipped channel section is modeled in Abaqus.CAE 6.14-1 software by creating a three dimensional, deformable, Shell element. The section is extruded for a depth of 2000 mm. The material properties of the section obtained from coupon tests are assigned to the section. The shell element (S4R) is used in all the finite element models.

Finite element models simulating the boundary conditions similar to experimental boundary conditions (i.e. One end is hinged and other end is free to translate in axial direction).

Free meshing of the model is carried out. Each part of the assembly is made independent and are meshed together in the assembly. The figure 4and 5 shows the Assembly view and Meshingof the section in primary and deformed shape respectively.

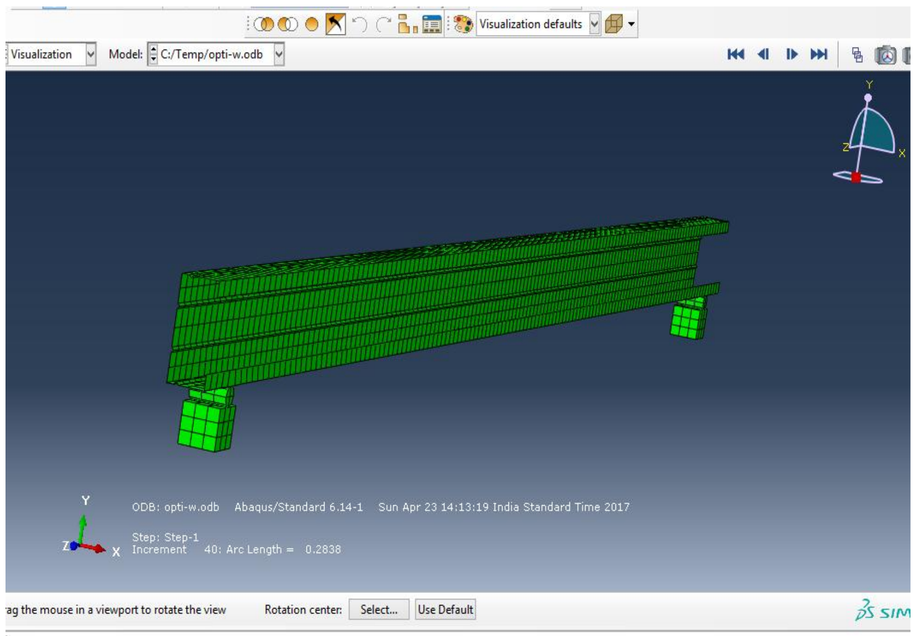

Fig 4. Meshed view of a web stiffened lipped channel section.

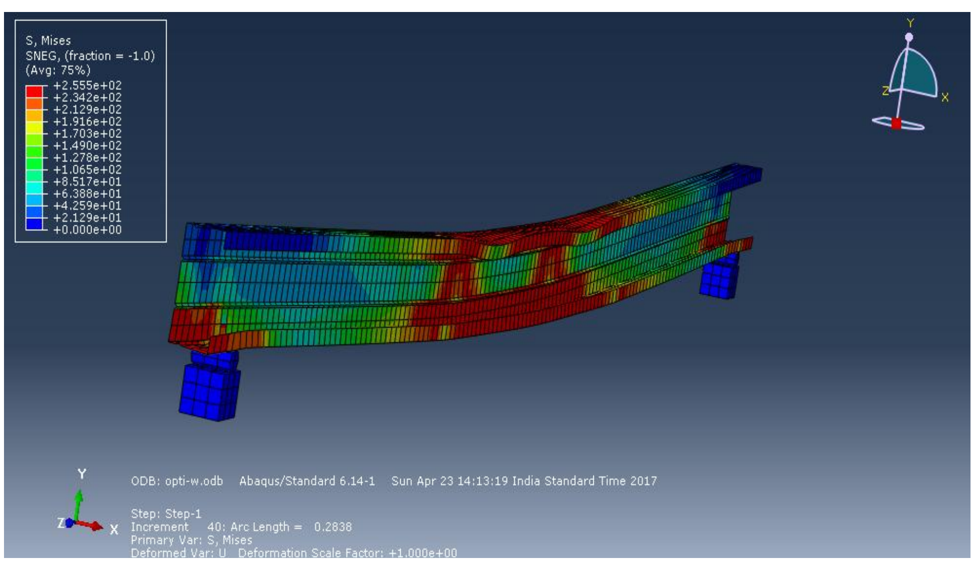

Fig 5. Deflected view of the web stiffened lipped channel section.

In order to achieve boundary conditions perfectly matching with the experimental set up, supports are created similar to the real supports and constraints are added to the supports. To apply load at shear centre, reference points are created at shear centre and connected to the section by MPC constraints. Loads are applied at the shear centre to restrict torsional buckling of the member.

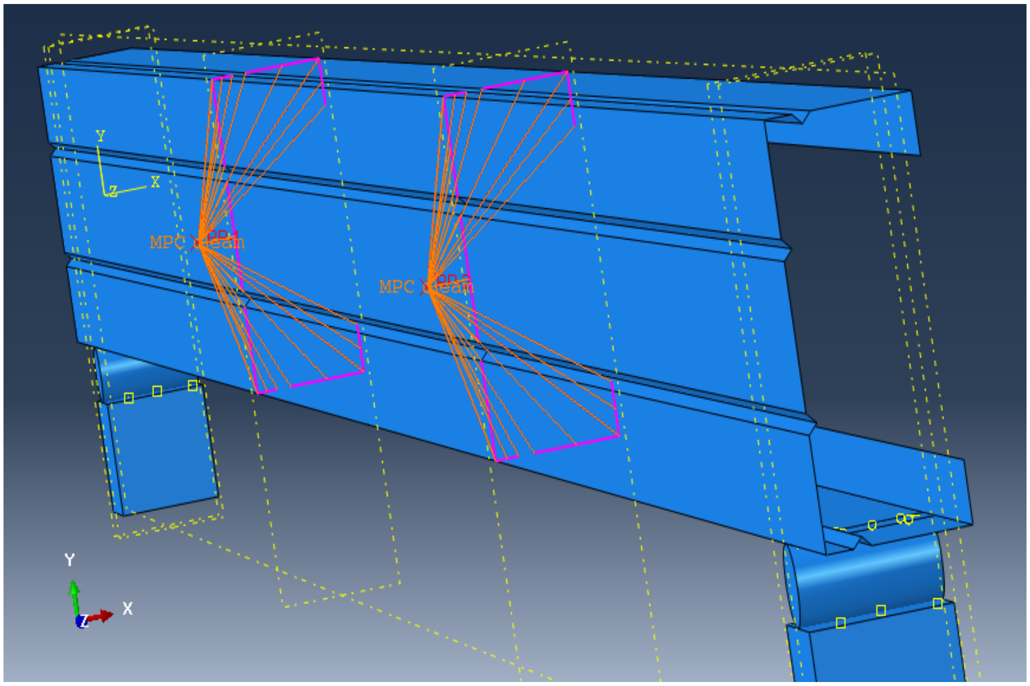

Fig 6. MPC constraints connecting ref.points to the beam

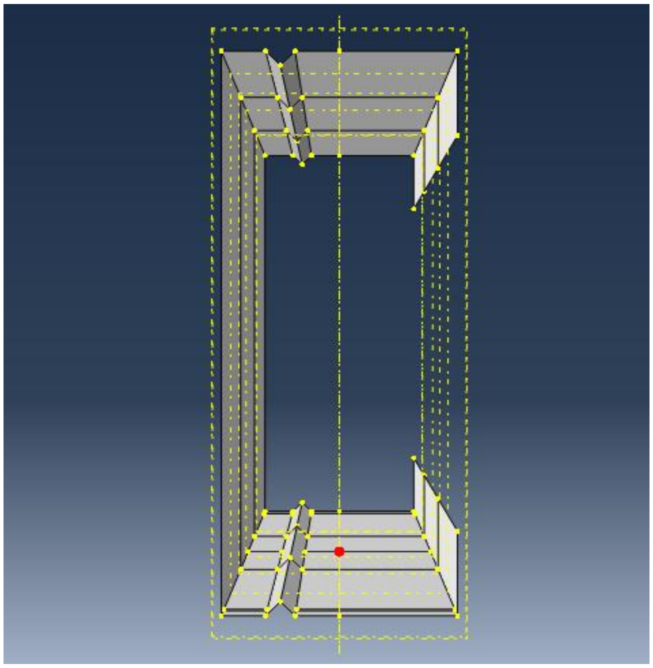

Fig 7. Node of the tension flange subjected to displacement U_2.

B. Loading and analysis

Two point loading is applied to achieve pure bending along the mid span. Shear centre of the section has been identified and two point loading is applied from the shear centre. The load is applied in 40 increments. The initial increment size was kept as 0.1. The maximum increment size was kept as 1.0 and minimum increment size was kept as 10^{-7}. A Static Riks analysis is carried out to analyze the member. The Nlgeom (Nonlinear geometry) is switched on during analysis.

IV. RESULTS AND DISCUSSION

The V-stiffener is located individually at seven different points along the width of the flange and the corresponding U_2 values are plotted and compared in the graph below.

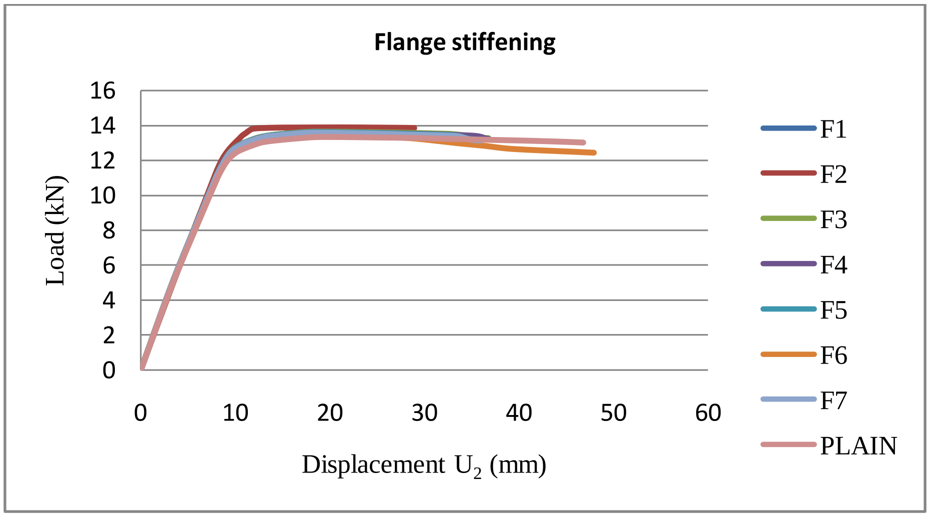

Fig 8. Load vs Displacement curve for flange stiffening

The V-stiffener is located individually at four different positions in the web and the corresponding U_2 values are plotted and compared in the graph below.

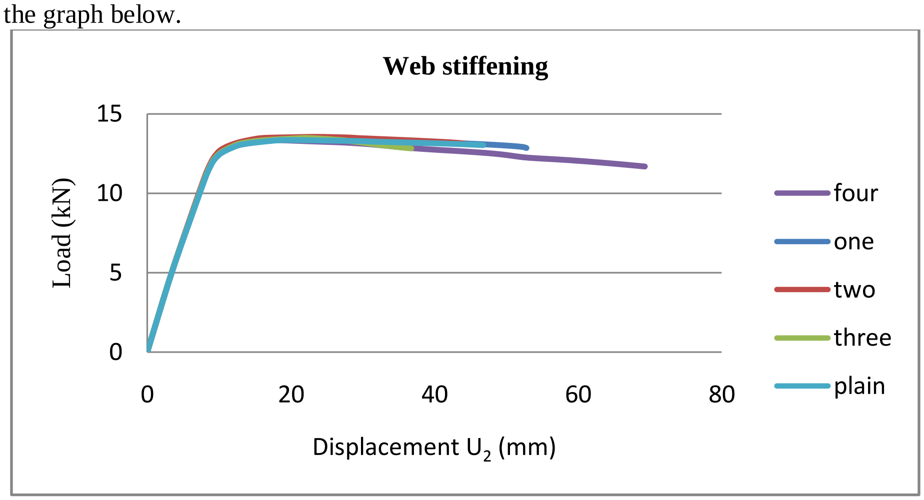

Fig 9. Load vs Displacement curve web stiffening

The optimum positioning of the stiffener for both web and flange is plotted in the following graph and compared with the result of plain section.

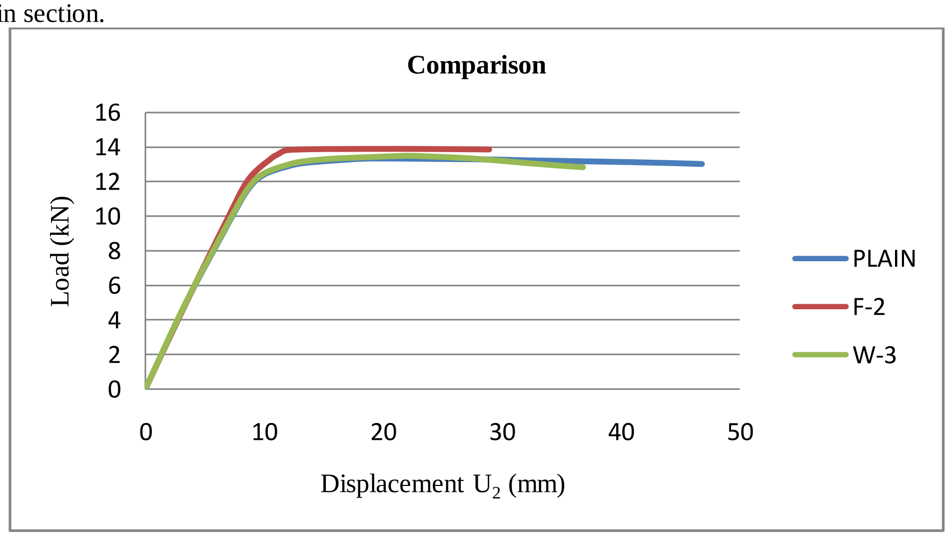

Fig 10. Load vs Displacement curves for optimum location of stiffeners.

From the graphs plotted above, it is evident that, in web stiffening, upto a certain limit, the displacement U_2 decreases as we approach from compression zone towards the neutral zone of the section. At position three, displacement is minimum and becomes maximum for the fourth position. The displacement for the fourth position is even greater than the displacement corresponding to plain section. Hence, the position three becomes optimum for the location of V-stiffeners along the web of the section for minimum displacement.

For flange stiffening, it can be clearly observed that, for F2, the displacement values are lowest and load taken for those displacement is the highest and so F2 becomes the optimum location of stiffener in the flange of the section.

V. CONCLUSION

Results of the analytical and numerical investigation of the CFS purlins subjected to two point loading at shear centres of the secitons are plotted in the form of graphs and discussed above. Since the geometric imperfections, residual stresses at the corners of the purlins are not considered for the investigation, the obtained results may not be accurate. However, the results can provide a basic understanding on the effect of longitudinal V-stiffeners along the web and the flanges of a cold-formed steel lipped channel sections subjected to two point loading. At the same time, loads are applied at the shear centre of the lipped channel section by creating MPC constraints between reference points and the purlin. This makes the study unique. The major problem faced in the analytical investigation is providing the increment size values for the static riks step for analysis. Trial and error method is adopted to provide increment sizes to perform the analysis. The study analyses the effect of longitudinal V-stiffeners in the flange and the web separately. Since Finite Element Analysis is the main sbject of the work, the modelling and meshing of the sections are carried out as accurate as possible. Sections and the support conditions are modelled almost similar to the experimental setup for the steel beam testing. Proper interaction values, boundary conditions, property assignments are achieved to get accurate results. The buckling behavior of the channel section is not taken into account. This study only aims to control the maximum deflection of the tension flange of a cold-formed lipped channel purlin subjected to two point loading at shear centre of the section.

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