

Effect of Web Opening on the Bending Behaviour of Cold Formed Steel Built-Up I Section

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ABSTRACT: Cold-formed steel members are widely employed in steel construction because they are lighter and more efficient than traditional hot-rolled ones. In cases where beams carry less moment it's uneconomical to use traditional hot rolled steel. Cold formed steel is an apt solution for this case. Lateral torsional buckling in Cold-formed Steel Built-up beam can be avoided by providing lacing between the web portions. In this thesis, the impact of variation in web opening on the flexural behaviour of Cold formed built-up I section under two point loading is investigated for the hinged-hinged condition. Numerical investigation has been carried out for 8 specimens by varying the thickness and depth of the built-up beam. The finite element package ANSYS13.0 has been used to carry out the numerical analysis for the built-up beams. The numerical method includes material and geometrical non-linearity. The geometric imperfections are also included in the model. Detailed procedure adopted for the analysis of latticed built-up I section beams using ANSYS13.0 are presented. Load vs. Deflection curve, failure modes and ultimate load carrying capacity of specimens are presented in this work.

KEYWORDS: Cold-formed steel, numerical method, I section beams.

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. These thin steel sections are cold-formed, i.e. their manufacturing process involves forming steel sections in a cold state (i.e. without application of heat) from steel sheets of uniform thickness. 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. Much thicker material up to 8 mm can be formed if pre-galvanised material is not required for the particular application. The method of manufacturing is important as it differentiates these products from hot rolled steel sections. Normally, the yield strength of steel sheets used in cold-formed sections is at least 280 N/mm², although there is a trend to use steels of higher strengths, and sometimes as low as 230 N/mm². Manufacturers of cold formed steel sections purchase steel coils of 1.0 to 1.25 m width, slit them longitudinally to the correct width appropriate to the section required and then feed them into a series of roll forms. These rolls, containing male and female dies, are arranged in pairs, moving in opposite direction so that as the sheet is fed through them its shape is gradually altered to the required profile. The number of pairs of rolls (called stages) depends on the complexity of the cross sectional shape and varies from 5 to 15. At the end of the rolling stage a flying shearing machine cuts the member into the desired lengths. An alternative method of forming is by press - braking which is limited to short lengths of around 6 m and for relatively simple shapes. In this process short lengths of strip are pressed between a male and a female die to fabricate one fold at a time and obtain the final required shape of the section.

II. ADVANTAGES OF COLD FORMED SECTIONS

Cold forming has the effect of increasing the yield strength of steel, the increase being the consequence of cold working well into the strain-hardening range. These increases are predominant in zones where the metal is bent by folding. The

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effect of cold working is thus to enhance the mean yield stress by 15% - 30%. For purposes of design, the yield stress may be regarded as having been enhanced by a minimum of 15%. Some of the main advantages of cold rolled sections, as compared with their hot-rolled counterparts are as follows: Cross sectional shapes are formed to close tolerances and these can be consistently repeated for as long as required. Cold rolling can be employed to produce almost any desired shape to any desired length. Pre-galvanised or pre-coated metals can be formed, so that high resistance to corrosion, besides an attractive surface finish, can be achieved.

III. APPLICATIONS OF COLD-FORMED STEEL

In building construction, cold-formed steel products are mainly used as structural members, diaphragms, and coverings for roofs, walls and floors. There are varieties of cold-formed shapes available as structural members, which include open sections, closed sections, and built-up sections. Cee-, zee-, double channel I-sections, hat, and angle sections are open sections while box sections and pipes are closed sections. The built-up members are formed by connecting two or more cold-formed steel members together, such as an I-section member built up by connecting two channel sections back-to-back. These structural shapes can be used in buildings as eave struts, purlins, girts, studs, headers, floor joists, braces, and other building components. Various shapes are also available for wall, floor, and roof diaphragms and coverings.

Metal Building Construction

In pre-engineered metal buildings, the entire building structure is made from steel products, and approximately 40-60% of the total steel used is cold-formed steel. A typical metal building system consists of primary rigid frames, secondary members, cladding, and bracing. The primary rigid frames are usually built up using welded plates with sizes optimized to satisfy the design requirements. The secondary members, such as purlins and girts, support the roof and wall coverings and provide lateral stability to the primary rigid frame members. The cold-formed metal roof and wall panels are often used as building claddings. They transfer the loads (such as wind and snow) to the secondary members and provide the integrity of the whole building. Straps or rods are often used as bracing members that maintain the building stability in the direction perpendicular to the primary rigid frames. They are also often used in end-walls for stability.

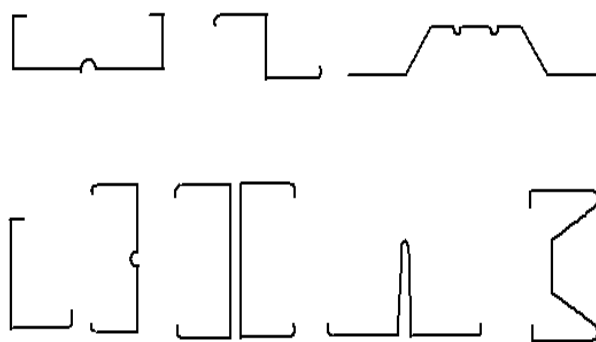


Figure-1: Typical cold formed steel profiles

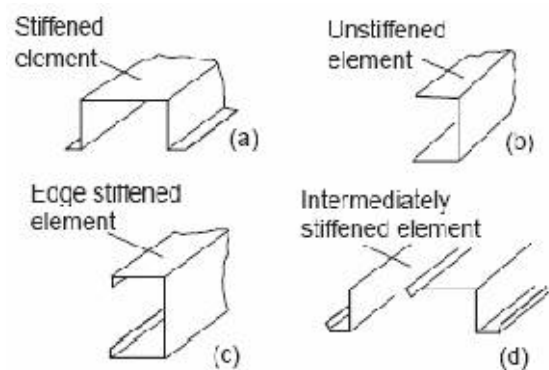


Figure-2: Types of CFS elements

IV. NUMERICAL INVESTIGATION

The finite element method is a numerical analysis technique for obtaining approximate solutions to wide variety of engineering problems. Most of the engineering problems today make it necessary to obtain approximate numerical solutions to problems rather than exact closed form solutions. The basic concept behind the finite element analysis is that structure is dividing into a finite number of elements having finite dimensions and reducing the structure having infinite degrees of freedom. The original body of structure is then considered as an assemblage of these elements

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connected at a finite number of joints called nodes or nodal points. This method of analysis has an advantage of that it can take care of any boundary and loading conditions. Solving Method of Engineering Problems

1. Pre processing
2. Solution
3. Post processing

Element Type: The type of element chosen for finite element model idealization plays an important role in the prediction of actual behavior of the structure. From the finite element that element SHELL 63 is used for angles and stiffeners, and Beam 188 for lacing bar.

Applying Displacement Constraints: Boundary conditions imposed on a finite element solid model is usually given in ANSYS by specifying the nodal point index and then restraining the necessary displacement. Here in our problem the beam is analyzed by simply supported end conditions. So that displacement components U_x, U_y, U_z are restrained at one end and displacement components U_y, U_z are restrained at another end. For the element shell 63 among the six degrees of freedom $U_x, U_y, U_z, ROT_x, ROT_y$ and ROT_z three degrees of freedom U_x, U_y and U_z are restrained.

Applying Loads: Loads can be applied to the finite element model in various forms such as applying loads to the key points, lines, areas, elements and at the nodes. For our problem the analysis is carried out for two points loading on beam by element.

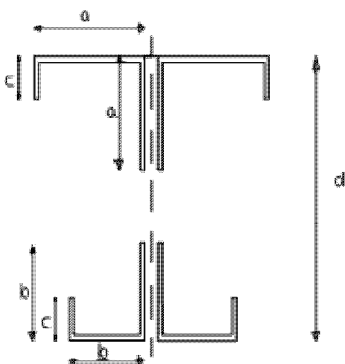
Solution: In this stage problem is subjected to static nonlinear analysis. The errors and warning are identified at this stage. After nullifying those errors the solution process gets completed.

Post Processing: Post processor helps us to view the results obtained from the analysis. The results obtained as nodal solution may be viewed in the tables from or contour plots. These plots are very much useful for us to identify the results such as displacement stresses and strains and also their maximum minimum values.

Finite Element Analysis: The results obtained from the ANSYS analysis of I section with web opening beam models are presented.

Specimen Details

- ⇒ The built-up I section is formed by using 4 lipped angles.
- ⇒ The bearing stiffeners of 3mm thick are provided at the supports and under the loading points.
- ⇒ 6mm diameter rod is used as lacing bar
- ⇒ All connections are made by spot welding



CROSS SECTIONAL VIEW OF THE SPECIMEN

Where,

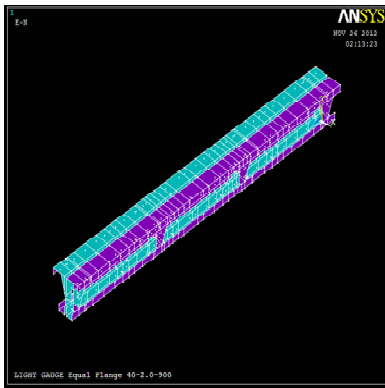
- a = Top flange width and depth
- b = Bottom flange width and depth
- c = Depth of lib
- d = Overall depth

The following steps were followed to analyze above specimen in ANSYS12.

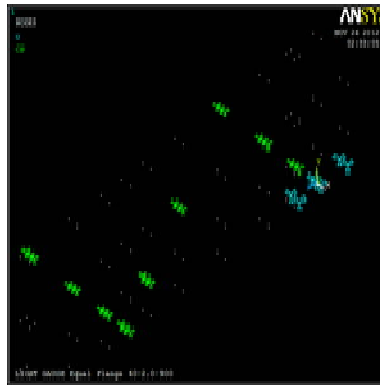
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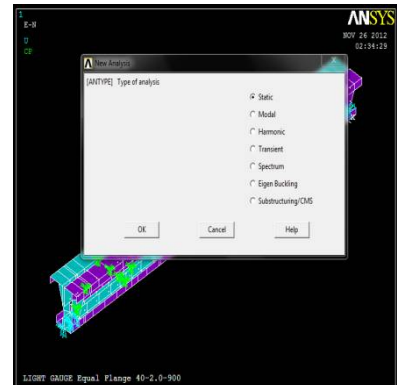
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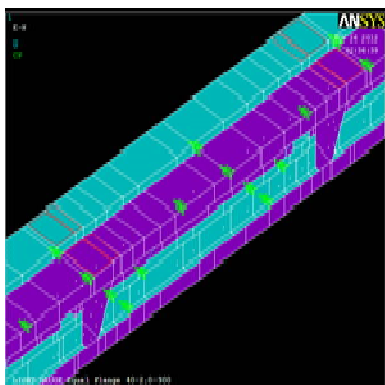
1. Modeling of specimen



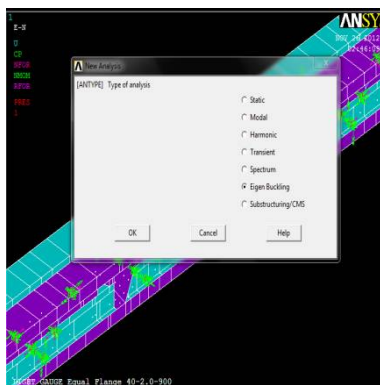
2. coupling of the specimen1 (900mm beam)



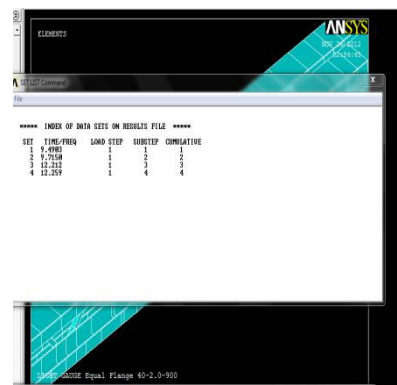
3. Static analysis of specimen 1



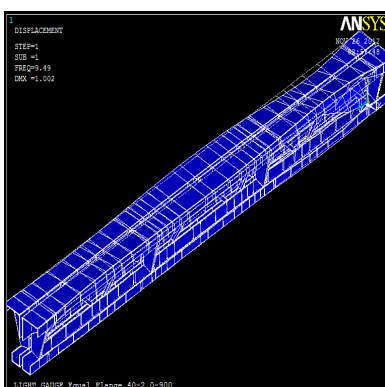
4. Applying pressure of specimen 1



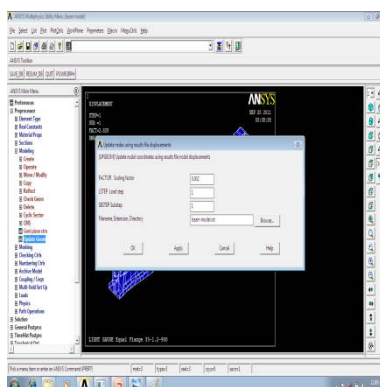
5. Eigen buckling of specimen



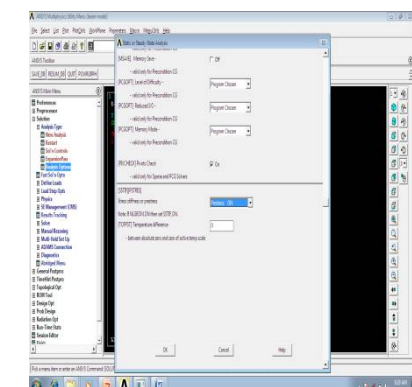
6. Time frequency of specimen 1



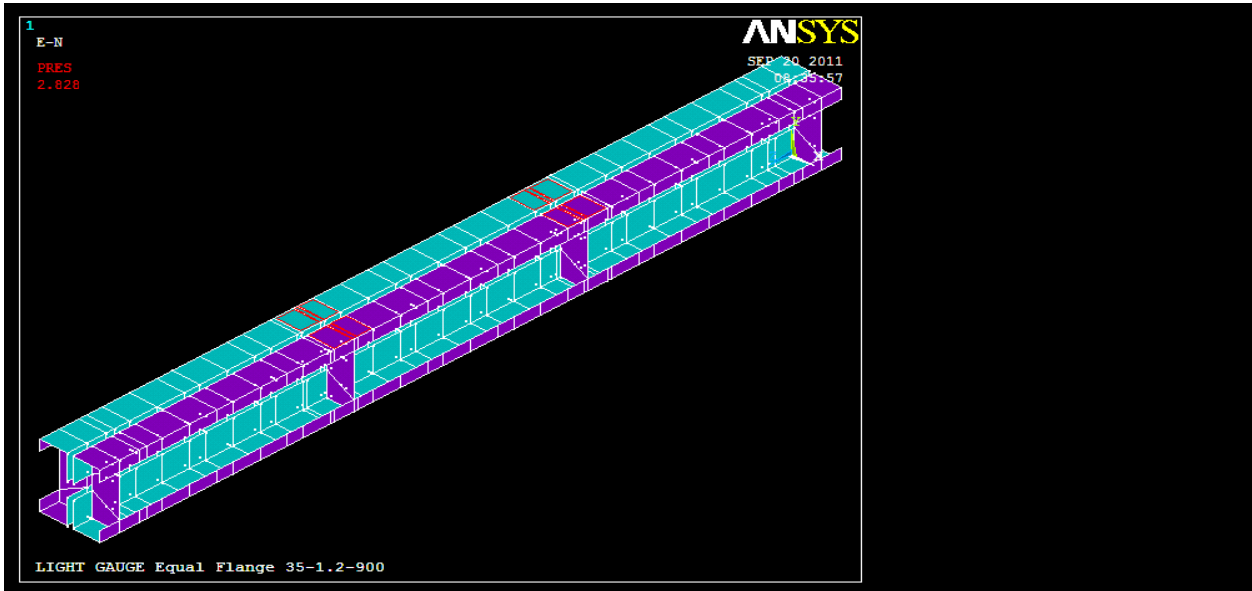
7. Deformed shape of specimen 1



8. Modeling



9. Unbridged menu



10. NEW PRESSURE (2.8280) APPLIED ON SPECIMEN 1

discussion

The load carrying capacities of specimens were estimated by using numerical analysis. Discussions were carried out with respect to the load carrying capacities and the failure mode occurred. The load carrying capacities of built up I section beams analyzed by Numerical analyses are discussed here. Numerical analysis is done by ANSYS.

Table-1: ANSYS results		
Specimen Dimension(mm)	Web Opening	Ultimate Load Carrying Capacity
50-50-150-1.2-2400	50mm	13.87kN
50-50-200-1.2-2400	100mm	15.323kN
50-50-250-1.2-2400	150mm	11.265kN
50-50-300-1.2-2400	200mm	13.925kN
50-50-150-2.0-2400	50mm	22.741kN
50-50-200-2.0-2400	100mm	19.234kN
50-50-250-2.0-2400	150mm	14.824kN
50-50-300-2.0-2400	200mm	11.209kN

From the numerical investigation, the following observations are made:

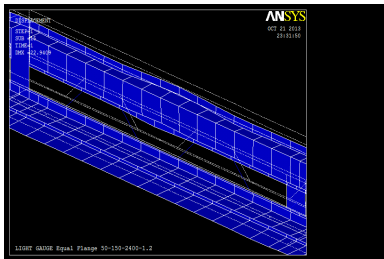
For the first two specimens, namely 50-50-150-1.2-2400 and 50-50-200-1.2-2400, the ultimate load carrying capacity is increasing. The mode failure observed was Distortional buckling. For the specimen 50-50-250-1.2-2400, the load carrying capacity is decreased due to the collapse of element on the whole. For the specimen 50-50-300-1.2-2400, load carrying capacity is affected by the shear buckling. Specimens of 2mm thickness fail by global buckling on top compression flange.

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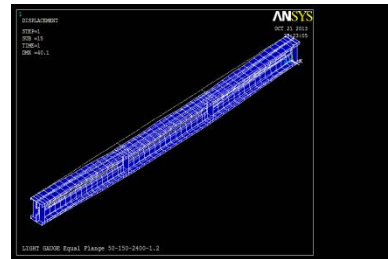
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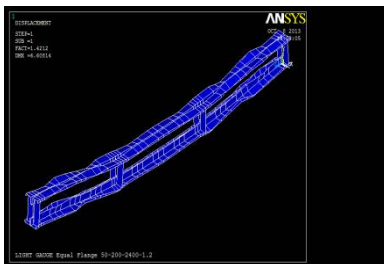
Failure modes



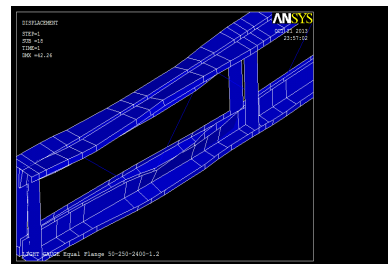
1. Distortional Buckling



2. Global Buckling



3. Wobbling of Angle



4. Shear Failure

V. CONCLUSION

Modelling using ANSYS and analysis procedure was studied. 8 models were chosen with depth 150mm, 200mm, 250mm and 300mm for thickness 1.2mm and 2mm. All the specimens has been created and analysed. Various modes of failure and ultimate load carrying capacity of I section beams are obtained. Shear failure may be improved by increasing the lacing size. So the lacing size shall be increased to 10mm. Wobbling of angle may be avoided by improving the quality of cold formed sheet used. For retrofitting the existing building, X bracing and Brick wall techniques are effective to reduce storey drift value.

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