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Web Buckling Analysis of Lipped and Hollow Flanged Light Gauge Sections with Web Hole

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Abstract- Cold formed steel (CFS) beams are produced by cold rolling of mild steel sheets. These members are used as roof purlins and floor joists. Low wall thickness to height ratio causes cold formed steel members to undergo local buckling. However improved post buckling behaviour of cold formed sections increases its efficiency and is widely used now a days. CFS channel sections are commonly used in floor joists with web openings in industrial, commercial and residential buildings. These openings provided for facilitating building services, causes reduction in shear strength. IS 811-1983 provides specifications for lipped channel sections and is widely used. Hollow flanged sections are special type of cold formed steel produced by a special process which includes simultaneous cold rolling and dual electric resistance welding. In this paper, both IS and hollow flanged sections are analysed with and without web holes with the numerical models created in ANSYS. Comparison is made on the basis of reduction in strength with increase in web hole diameter of two members with same clear depth and aspect ratio

Index Terms- Cold formed steel, Web openings, Lipped channel, Hollow flanged, Shear strength, Web buckling

1. INTRODUCTION

Cold-formed steel and hot-rolled steel are the two main steel material types that are used in the steel industry. The use and importance of cold-formed steel is growing in building construction. Starting from the 1950's cold-formed steel was used as cladding for walls and as decking for floors and roofs. Advances in manufacturing technology made the production of heavier gauge cold-formed steel sections possible. Subsequently, cold formed steel started to be used as an alternative to hot-rolled steel and timber structural members due to its versatility, high strength-to-weight ratio and economic considerations. Unlike hot-rolled steel sections, cold-formed steel sections are produced by cold forming operations: "press braking" and "roll forming." Sections with inclined webs and different types of intermediate or edge stiffeners can be formed with these production methods. Curved transition between the webs, flanges and stiffeners are the results of the cold forming operations. Width-to-thickness ratios of cold-formed steel sections are relatively high compared to hot-rolled steel sections. This property of the cold-formed steel sections causes local buckling at stress levels lower than the actual yield stress of the steel. However, it is the redistribution of the stresses that allows the member to continue to carry loads after local buckling. The ability of the section to carry loads after local buckling is called post-buckling behavior. Web crippling is one of the failure modes that must be taken into consideration in cold-formed steel design. Cold-formed steel members may experience web-crippling failure due to the high local intensity of loads and/or Reactions. Various tests were conducted on light gauge sections considering parameters like wall slenderness, inside bend to thickness ratio bearing strength etc. These studies were later concentrated on web crippling behaviour of cold formed channel and Z and C sections with large inside bend to thickness ratio. Later the studies were extended to lipped sections and hollow flange sections with considerable resistance to torsional buckling. These sections were later modified using web stiffeners.

Distortional and shear buckling are common modes of failure in light gauge sections. Cold formed channel sections having different strain strain curves were analysed in literature. Later this test was extended to various cross sections. Post buckling behaviour was also studied. Numerical Study of shear buckling behaviour and shear flow distribution of LSBs with torsionally rigid, Hollow flanges were carried out. Experimental validations were carried out for the same. Later these studies were extended to Hollow flanged channel sections with web holes. In Indian standards, lipped and unlipped channel sections were studied for distortional and overall lateral buckling. Geometric modifications like web holes reduce web stiffness. Studies were concentrated on square and circular web holes, punched away from bearing plates and strength reduction factors were formulated. Later the test was modified with holes punched beneath the bearing plates. Rectangular fillet holes were used in End one flange and interior one flange conditions

2. MATERIAL PROPERTIES

Young's modulus (E) and Poisson's ratio (μ) were defined as: E = 2.1X10[5] MPa and μ = 0.3. Beam section is subjected to large deformations beyond

yield and hence it was necessary to create a material model with nonlinear properties. The essential ingredients of elastic-plastic, rate independent plasticity theory are yield criteria, a flow rule, and a hardening rule. Here the yield criteria used is von Misses yield theory, which relates the state of stress to the onset of yielding. Nonlinear characteristics is defined by specifying yield stress as 370MPa.

Fig. 1 Applications of web holes in Floor systems

3. NUMERICAL MODELLING

Numerical modelling is carried out in ANSYS. ANSYS element library is capable of providing required elements for this work. Elements SHELL181, MPC184, MASS21 etc. are used for numerical modelling. SHELL 181 is used for meshing channel sections due to its capability of undergoing large deflections, large strains and non-linear behaviour. MPC184 comprises a general class of multipoint constraint elements that apply kinematic constraints between nodes. The elements are loosely classified here as constraint elements and joint elements. The constraint may be as simple as that of identical displacements between nodes. Rigid regions are modelled using MPC 184.

MASS21 is used for defining reference nodes. It's a unit mass capable of acting as a master node which can be connected to slaves by means of coupling equations. MASS21 is assigned with 6 degrees of freedom by default and thus reference nodes can move in all directions with applied loads and boundary conditions. in this study, finite element models of single LSBs with shear centre loading and simply supported boundary conditions were used to simulate the shear tests. Actual experimental setup in literature includes two channel sections are placed back to back and connected by 75mm wide rigid plates as shown in figure 2.

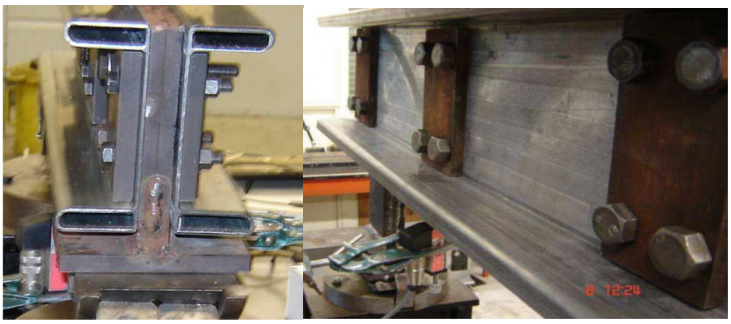

Fig. 2 Experimental setup for shear loading [21]

In practical case Rigid plates are bolted to channel sections for loading and for applying boundary conditions. In numerical model rigid plates are avoided and the areas in contact with plates are modelled as rigid regions. These regions are capable of undergoing rigid body displacement

For this, web plate is divided into three intermediate regions 75mm width and is meshed using MPC184 element. No real constants are required for MPC184.In experimental set up, loads and boundary conditions are applied to rigid plates. In numerical model these are applied to the shear centre. For this purpose, a reference node is defined. Motion of the rigid regions are controlled by corresponding reference nodes. Reference nodes are meshed using MASS21 element. Reference nodes are linked with rigid region by means of constraint equations. All degrees of freedom are arrested between master (Reference node) and slave nodes. Slave nodes are nodes included in rigid region. Boundary conditions are applied to reference nodes at supports and displacement is applied to centre reference node. And reaction is listed out after analysis. Thus Displacements or loads applied to reference node will be transferred to the entire rigid region and will

Edges	U	V	W	Rx	Ry	Rz
Left and right	0	1	1	1	0	0
Middle	1	0	1	1	0	0

Table 1. The planning and control components undergo rigid body displacement.

4. VALIDATION OF NUMERICAL MODEL

Numerical model is validated with literature. In [18], hollow flange channel sections 250x75x2.5 and 300x75x2.5 were analysed. Aspect ratio (a/d1) of 1.5 is adopted for the sections. ABAQUS is used for analysis in literature. Similar conditions are stimulated in ANSYS. Similar model with same aspect ratio is modelled and nonlinear analysis is carried out. Load deflection curves plotted and was similar to that from literature

5. BUCKLING ANALYSIS OF LIPPED CHANNEL SECTIONS

These members are now being used as load bearing components in residential commercial and industrial structures. Behaviour of lipped channel sections are different from that of hollow flange sections. Web openings are introduced for facilitating building services without affecting clear height. Circular holes are most commonly used. Web openings cause a significant reduction in shear capacity due to reduced web area. This reduction in primary shearing area will cause reduction in overall shear capacity of beams. Many parameters affecting the shear capacity of members including specification of members, size shape and location of hole. Etc. Typical section available in market is chosen from IS 811-1987, 200X50X20X3.15 for the study. From [21] aspect ratio a/d1 is fixed as 1.5 for the section. For lipped channel sections d1 and d are similar. Neglecting the corner radius d is taken as 200. From aspect ration the clear span (a) is taken as 300. 75mm rigid plates are placed at supports and mid-span. Thus total length of specimen is taken as 825mm. from the dimensions obtained, modelling is completed in ANSYS. Initial analysis is carried out without introducing web holes. Displacement is applied at Middle reference node and

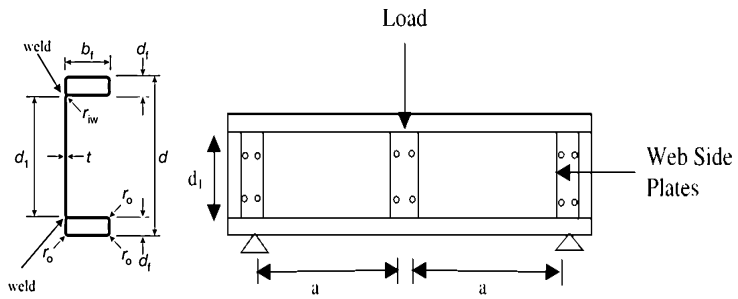

Fig. 3 Experimental setup for shear loading [18]

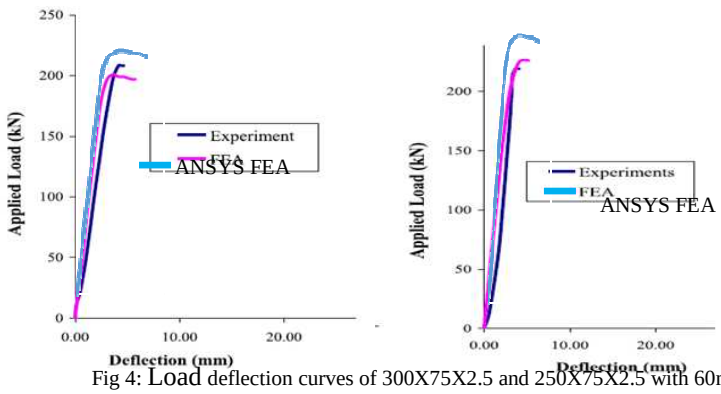

Fig 4: Load deflection curves of 300X75X2.5 and 250X75X2.5 with 60mm dia holes

reaction forces are calculated. When analysed without holes, Yielding occurs near loading region. Peak load is obtained. However stress concentration is slightly increased near the holes. With 40mm holes, yielding is observed near the mid span near the rigid plates. Yielding is observed near webholes. Still more yielding occurs near the loading region. No considerable reduction in strength is observed. With 60mm holes more stress concentration is observed

near the holes. Only a slight reduction in strength is observed. With 80mm Holes considerable reduction

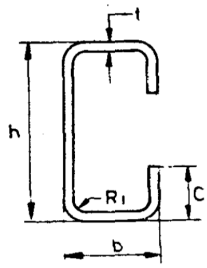

Fig 5: Lipped channel sections

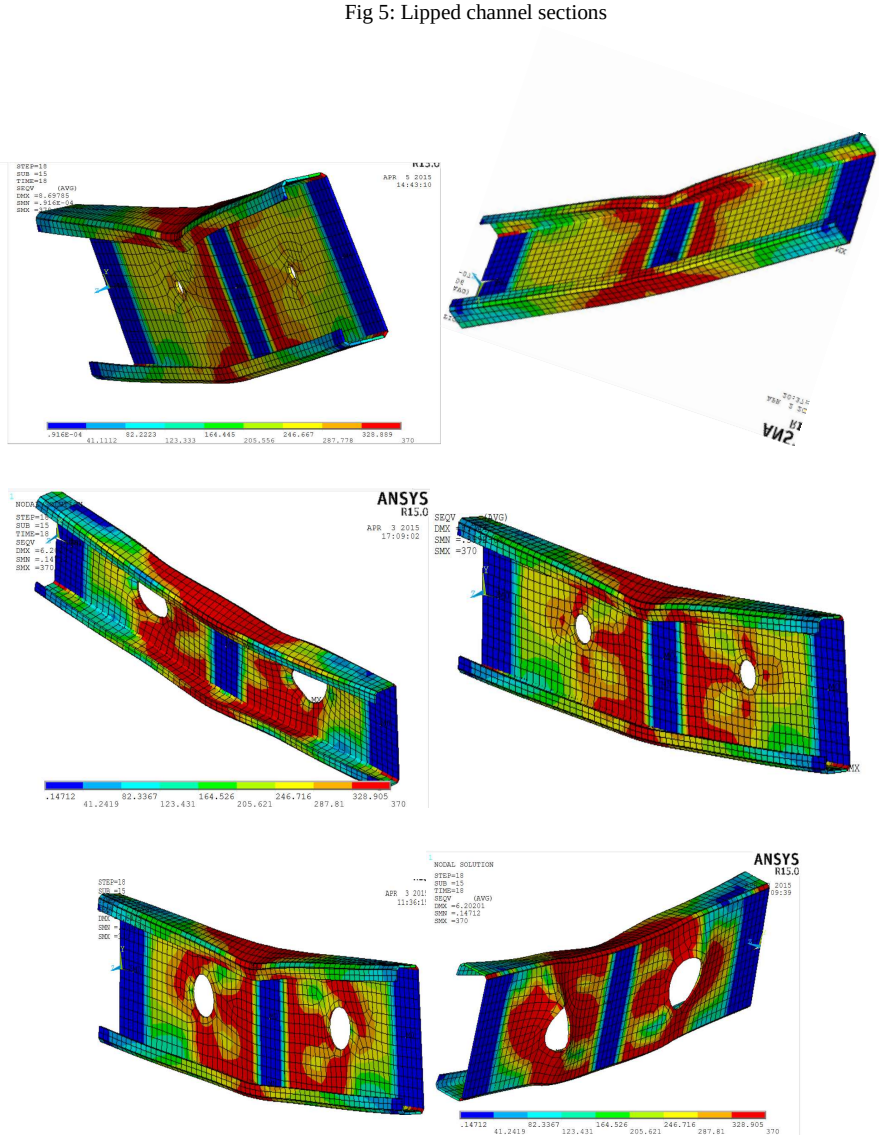

Fig 6: Stress contour plot of sections with no hole, 20mm, 40mm, 60mm and 80mm hole

in strength is observed and major yielding occurs near the holes. Web buckling also occurs near the holes. Considerable reduction in strength occurs when the hole diameter reaches 80mm. Peak deflection and force values are reduced. Load deflection curve is shown in Fig 7

6. BUCKLING ANALYSIS OF HOLLOW FLANGE SECTIONS

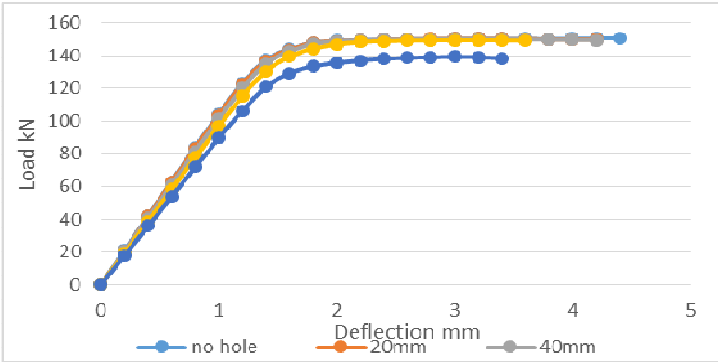

Fig 7: Variation in deflection characteristics with change in hole dia of lipped channel sections

A typical hollow flange section is chosen from the literature. Overall depth of the section is 250mm, which leaves a clear depth d_1 of 200 mm. Thus the web area is comparable to that of Indian sections. Hear aspect ratio (a/d_1) is taken as 1.5. Thus the clear span becomes 300mm and total specimen length is 825mm. Modelling is completed in ANSYS

In hollow flange models it is clear that web regions have much more influence in the shear strength. Yielding initiates at the web and then to flanges. Also considerable web buckling is observed near the holes. Web buckling initiates around 20mm holes. Load deflection curves of hollow flange section is shown in fig 10

7. RESULTS AND FUTURE STUDY

From the graphs obtained, it is clear that the performance of hollow flanged sections are highly affected by web holes. Strength reduction is high in case of hollow flange sections than in IS sections. This is because of the excess rigidity of flanges. IS sections flange buckling is predominant. Thus web holes have only a little effect. Further investigations are to be made on the basis of equations in various standard codes. Also experimental testing of IS

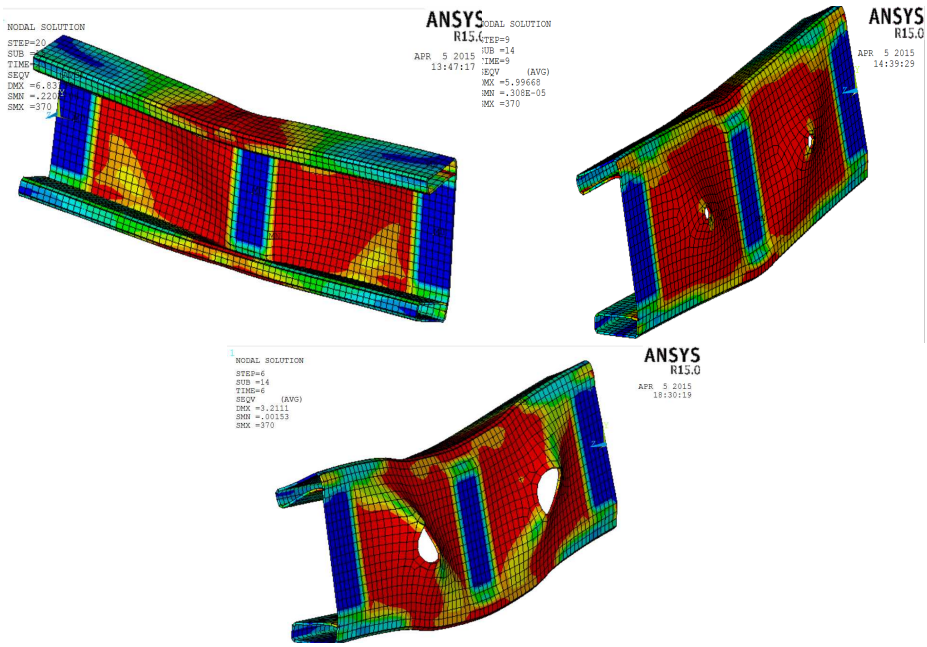

Fig 8: Stress contour of lipped sections w/o holes and 20mm 40mm holes

sections are still under the scope of further study.

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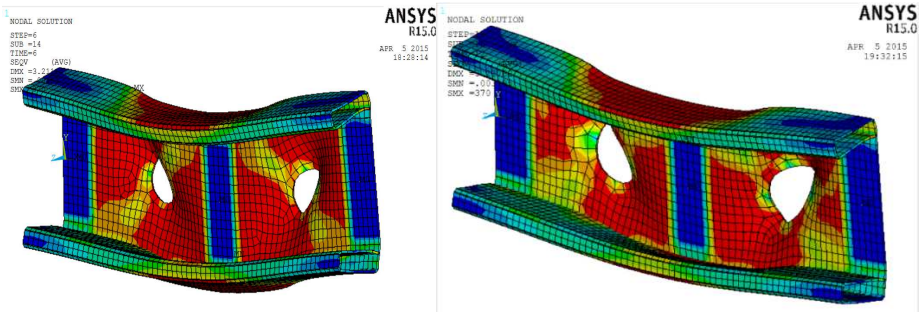

Fig: 9 Sress contour of lipped channel sections with 60 and 80 mm holes

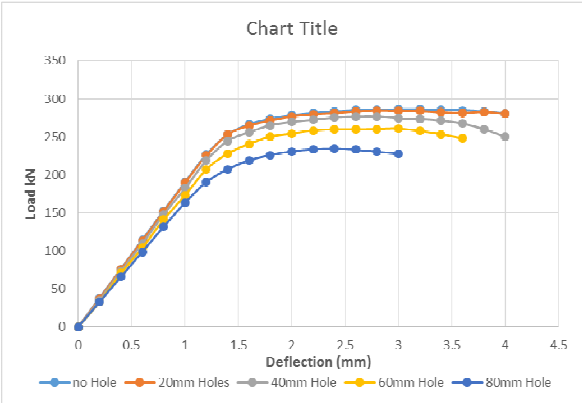

Fig 10: Variation of load deflection curve with change in hole diameter

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