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Web Buckling Analysis of Cold Formed Built-Up I Section

Azeem M
Department of Civil Engineering
MACE Kothamangalam

Prof. Dileep Kumar PG
Department of Civil Engineering
Calicut University

Prof. Merin Mathews
Department of Civil Engineering
KTU

Abstract

Modern construction industry is aiming at incorporating cost effective, economic, durable and light weight sections in their construction practice. Cold formed steel sections due to its high post buckling strength and the above mentioned qualities have a become a favorite building material among engineers. Hence it is necessary to make an in depth study about the buckling behavior of cold formed steel sections to understand about the most economical design of light gauge sections. Even though studies on individual flexural members like channel sections, lipped channel sections, zed sections have been done there are a very few researches on built-up I sections which is a very important flexural member. In this study, cold formed sections under considerations are built-up I sections. Finite element analyses are used to investigate the web buckling behavior of various cold formed built-up I sections with and without web holes, under interior two flange and interior one flange loading conditions. Sections are made with similar cross sectional areas for comparison. The web holes are located at the mid-depth of the sections with a horizontal clear distance of the web holes to the near edge of the bearing plate. This becomes of great importance to study the effect of web holes on the strength of the sections so that a better precise design and economy can be maintained.
Keywords- Cold Formed Steel, Built Up I Section, Buckling Analysis, Web Holes

I. Introduction

There are many cold formed steel sections which are used in the building industry. Although web buckling occurs in the web of the members, the interaction of the web element with the flange element plays an important role in determining the web buckling strength. The rotation of the web is directly proportional to the degree of restrain provided by the flange elements to the web elements. This is because the web flange interaction region is one the main region that influences the web buckling of the section and there by influence the web buckling strength of the section. Different cross-sections show different modes of behavior under web buckling failure. Thus the major parameters that influence the web buckling strength calculation of a section are:

- Thickness of the web
- Yield strength of the material
- Inside bend ratio to thickness ratio
- Bearing length to thickness ratio

II. Objectives

1) To compare the behaviour of cold formed back to back channel sections and I sections of same area with various loads and support conditions.
2) To predict the changes in structural behaviour with alteration in geometry (i.e. Holes in the web) using the model.
3) To compare the ultimate load carrying capacities obtained with various standards

III. Literature survey

From the literature reviews it was evident that various studies were conducted on light gauge steel section by considering various parameters like slenderness ratio, aspect ratios, bearing strengths, different boundary conditions etc. These studies were later concentrated mostly on web buckling behaviour of cold formed channels sections with larger inside bend to thickness ratio. Later the studies were extended to I sections, lipped sections which has considerable resistance to torsional buckling. It was found that distortional and shear buckling are common modes of failure in light gauge steel sections. Cold formed steel sections with different cross sections, loading conditions, different bearing lengths, fastened and unfastened conditions were tested. Numerical studies of shear buckling behaviour and shear flow distribution of LSBs with torsionally rigid, hollow flanges were carried out. Experimental validation was conducted for the same.

Later it was seen that shape of the web openings will depend upon the designer's choice and the purpose of the opening. There are no hard and fast rules to dictate the shapes of the openings. But, for designer's convenience, openings of regular shapes (such as circular or rectangular) are usually chosen. Introduction of openings in the web decreases stiffness of the beams resulting in larger deflections than the corresponding beams with solid webs. The strength of the beams with openings may be governed by the plastic deformations that occur due to both moment and shear at the openings.

In practical application of cold formed steel sections, back to back C section can be used in place of I section in floor joists, cladding panels, decking systems etc. While fixing electrical and plumbing conduits in these sections, holes are to be provided in the web of these sections in order to facilitate these conduits through them. These holes result in reduction of web areas of the sections. So this reduction in the web area affects the shear capacity and there by ultimate load carrying capacity of the section. The presence of web holes plays an important role in determining the vertical deflections of these sections. Therefore, the influence in of web holes in rolled sections and built up sections need further investigation.

IV. MODELLING AND ANALYSIS

In this study, I sections are built-up in four different ways with comparable areas using the cold formed sections and each one is given particular names for easy identification. Sections available in BS 2994:1976 is used for building up I sections. Designation (D x B x t) is used for channel section and Zed section whereas (A x B x t) is used for angles.

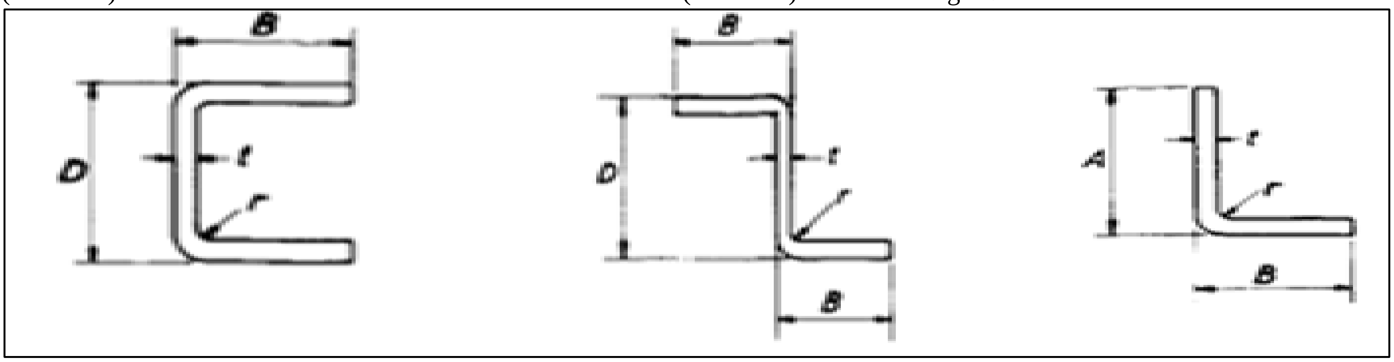

Fig. 1: Modeling and analysis

Holes are given as shown in the diagram of loading cases. A indicates the diameter of the hole. Values of A are chosen 20mm, 40mm, 60mm, 80mm and 100mm. X indicates the distance between the center of the hole and edge of the bearing plate. Values of X are chosen as 20mm, 40mm, 60mm, 80mm and 100mm. Rigid bearing plate of 25mm thickness and width 100mm was used The length of the specimen is calculated as 750mm. Tests were conducted with all combinations of these. Also a case with no holes was considered in each case.

Different I sections made are:

A. Back to Back Channel

An I section was made by placing two channels back to back and the name 'Channel I' was given. Channel section 150x50x3 is taken from BS 2994:1976.

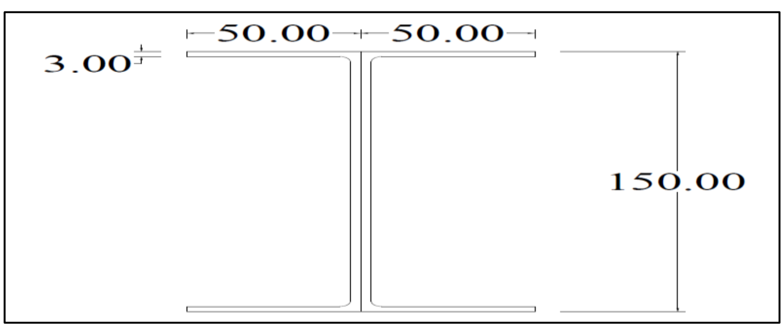

Fig. 2: Back to back channel (Area=1430mm^2)

B. Zed with unequal Angles (Case 1)

I section was built-up using a zed section and two angle sections. Zed section used was 150x40x3 and the angles used were 80x50x3 both taken from BS 2994:1976.

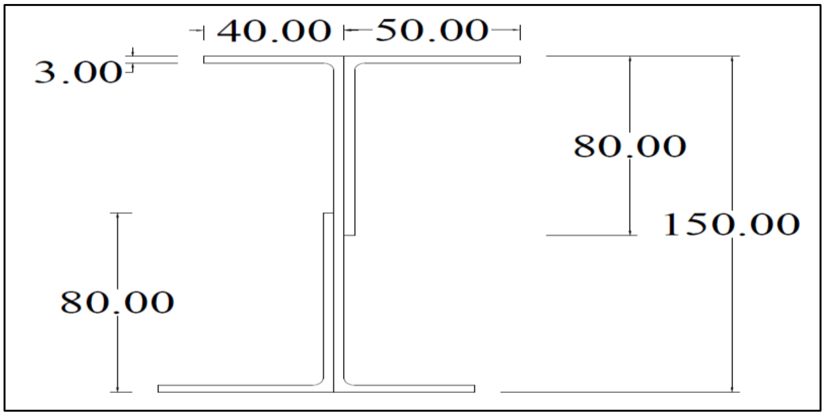

Fig. 3: Zed with unequal angles (case 1) (Area=1400mm^2)

C. Channel with unequal Angles

I section was built-up using a channel section and two angle sections .Channel section used was 150x50x3 and the angles used were 50x25x2.5 both taken from BS 2994:1976.

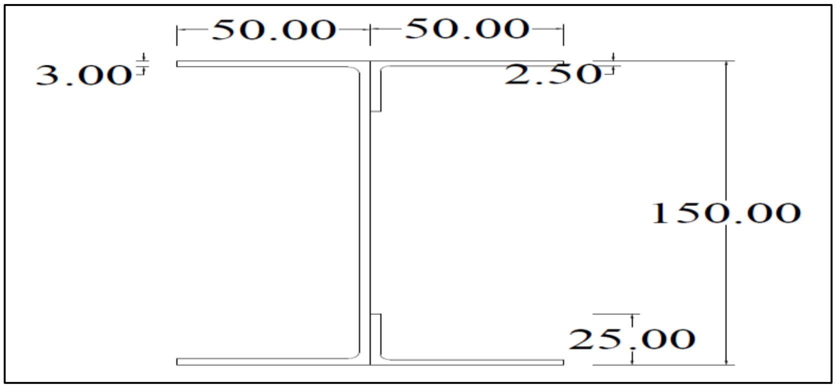

Fig. 4: Channel with unequal angles (Area=1064mm^2)

D. Zed with unequal Angles (Case 2)

I section was built-up using a zed section and two angle sections. Zed section used was 150x40x3 and the angles used were 50x25x2.5 both taken from BS 2994:1976.

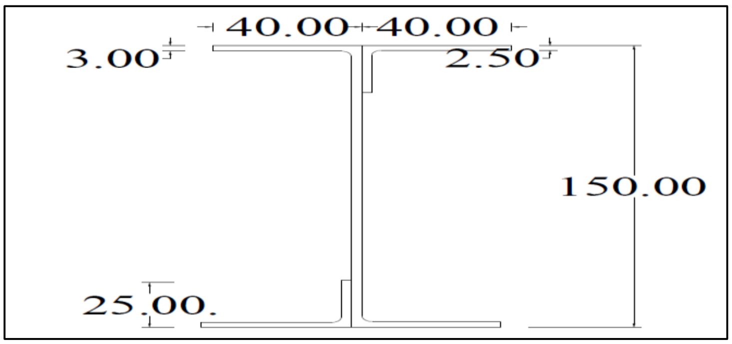

Fig. 5: Zed + small angles (Area=955mm^2)

V. LOADING AND BOUNDARY CONDITIONS

The nodes of the built-up I sections were restrained to represent the vertical and horizontal symmetry condition. The interface between the bearing plate and cold formed steel section and between the individual sections used to make I sections were modeled using the surface to surface contact option. The bearing plates were the target surface and the cold formed steel sections were the contact surface. Loading was done on the top bearing plate. In the analysis of these sections, Young's modulus adopted was 2E+ 05 MPa and the Poisson's ratio was 0.3. Yield strength was 250 MPa and tangent modulus was 1450 MPa. The material non-linearity was incorporated in the elements by specifying the true values of stresses and strains. The plasticity of the materials was determined. The true stress and plastic true strain were as per the specified methods in the ANSYS manual.

VI. BUCKLING ANALYSIS OF BUILT-UP I SECTIONS

Analysis of the built-up I sections were done using ANSYS which was capable of undertaking material and geometric nonlinearities. Finite element model was developed for both elastic and inelastic buckling analysis. Elastic buckling analysis was performed to study the effect of post buckling strength.

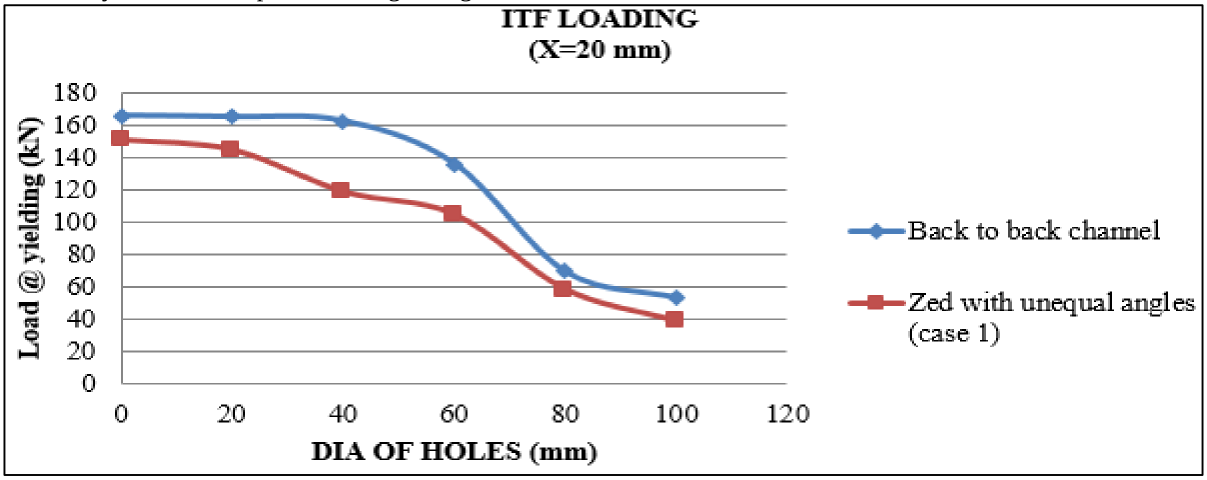

Fig. 6: Load vs. dia of holes of back to back channel and zed with unequal angles (case 1) X20 ITF

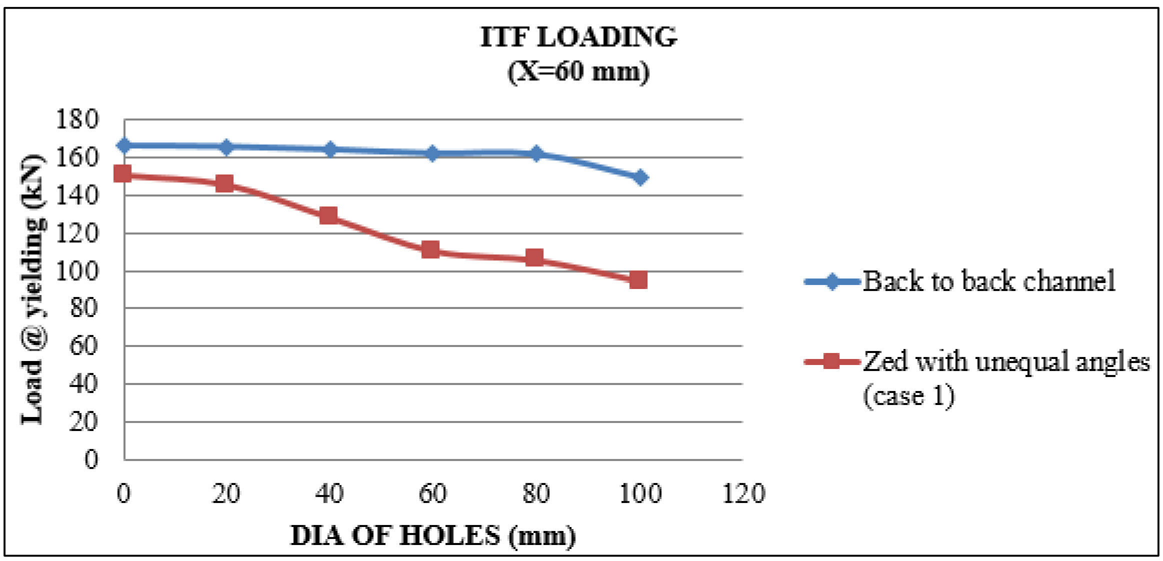

Fig. 7: Load vs. dia of holes of back to back channel and zed with unequal angles (case 1) X60 ITF

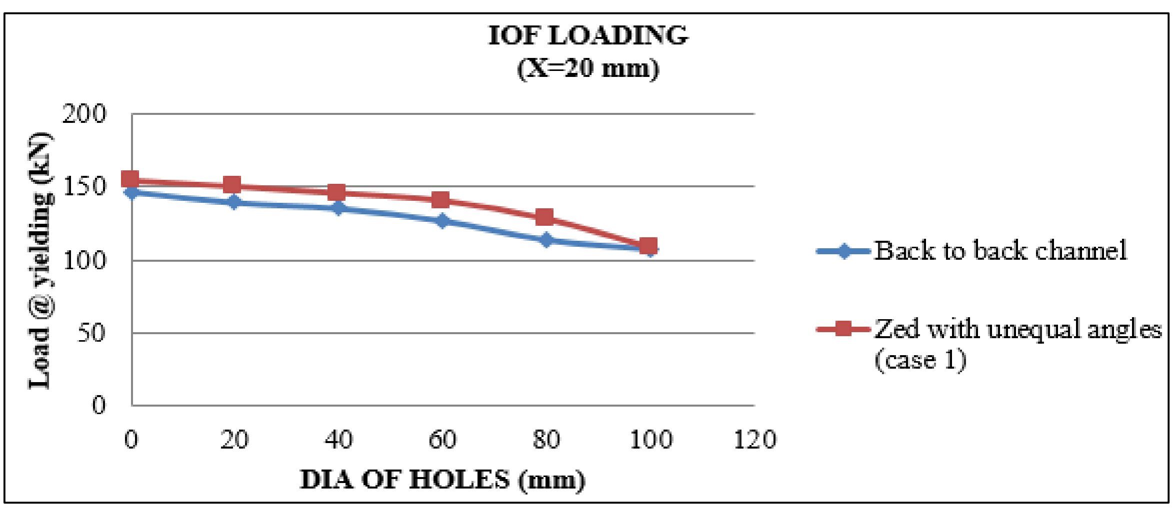

Fig. 8: Load vs. dia of holes of back to back channel and zed with unequal angles (case 1) X20 IOF

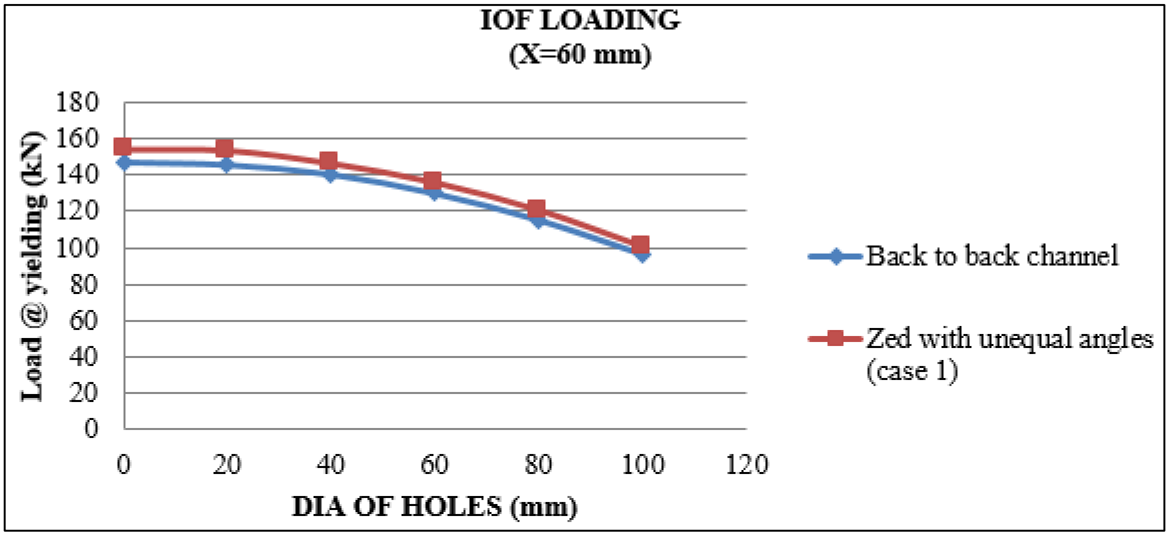

Fig. 9: Load vs. dia of holes of back to back channel and zed with unequal angles (case 1) X60 IOF

VII. RESULTS AND DISCUSSIONS

Sections taken into account were of same cross sectional areas. The ultimate load carrying capacities of the sections were found out using ANSYS and various codes like AISI Code and IS codes. Interior Two Flange (ITF) loading conditions and Interior One Flange (IOF) loading conditions were adopted.

Under the specified loading conditions, both the sections have undergone different behavioral patterns. Local buckling was the major type of failure which was seen in both of the sections. It is seen that the yielding initiated at the top flange and progressed to the web regions. It was noticed that for ITF loading of back to back channel and zed with unequal angles, back to back channel shows greater strength. For all other conditions I sections with zed element showed higher strength. This can be due to the asymmetric nature of Z section which gave more fixity at the web flange junction.

Web holes were positioned along the neutral axis of the sections and also various cases of X 20mm, X 40mm, X 60mm, X 80mm, X 100mm was evaluated. It was observed that in ITF loading the strength decreased drastically with increase in size of the hole. But as the distance of the hole from loaded bearing plate increased this rate of decrease in strength decreased. The same pattern was observed in IOF loading also but the gradient was lesser. This is because in ITF loading maximum load is taken by web portion. Ultimate load at yielding was evaluated and tabulated.. The buckling failure load was many times higher than load at yielding due to the post buckling strength of cold formed steel. This value cannot be estimated using standard code as there is no provision for considering post buckling strength in codes. Also a table of reduction factors was also prepared to quantitatively evaluate the influence of web holes.

VIII. CONCLUSION

For interior two flange loading, back to back channel has higher strength than zed with unequal angles. For all other conditions zed with unequal angles have higher strength which is due to the improved post buckling strength and asymmetric nature of zed element. Web crippling is less in zed with unequal angles. Ultimate buckling strength of cold formed sections is many times more than its critical stress due to the post buckling strength. With increase in diameter of web holes, shear capacity of the sections decreased. With increase in distance of the web holes from bearing plate, shear capacity of the section increased. AISI specification provided the ultimate load carrying capacity of the section whereas IS code provided the average maximum load. Thus IS code is more conservative than AISI specification. Codes under estimated the post buckling strength of cold formed steel sections.

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